

# MACHINE THEORY

## Bachelor in Mechanical Engineering

### CAMS DESIGN

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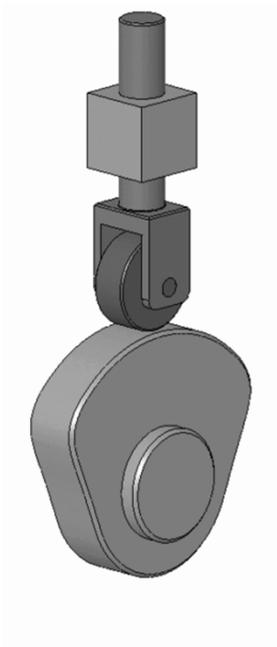
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# 1. Introduction

**Cam mechanism** – a very versatile mechanical element for transforming an input motion into another. It is mainly composed of two parts:



**Cam:** Input linkage. Motion is usually rotation.

**Follower:** Output linkage. Translation or oscillation.



# 1. Introduction

## ◉ *Advantages of cams*

- **Many possibilities of motion transformation. Very versatile.**
- Have few parts.
- Take small space.
- Widely used in industry. Known technology.



## ◉ *Limitations of cams*

- Suceptible to vibrations.
- Wear.
- Fatigue.
- Lubrication needed.

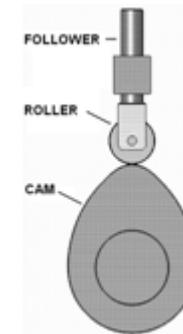


# 1. Introduction

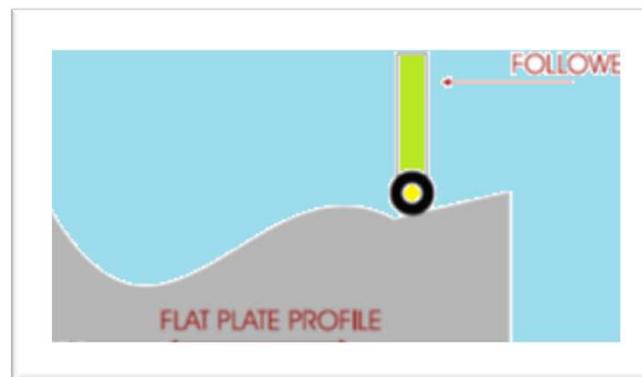
◉ Cams are usually classified according to the cam geometry:

▶ **Planar cams**

➤ **Disc or plate cams**



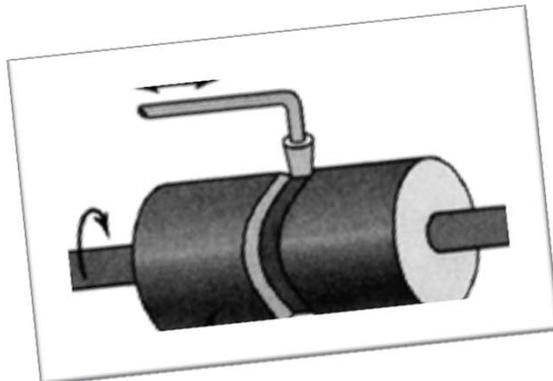
➤ **Linear cams:** Cam do not rotate. Backwards and forwards motion.



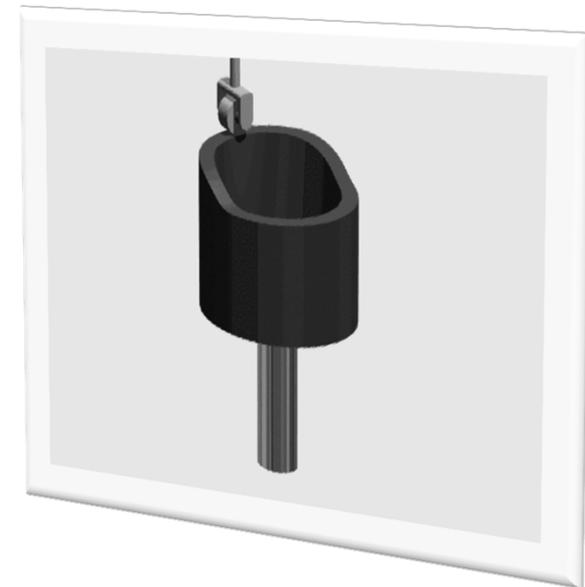
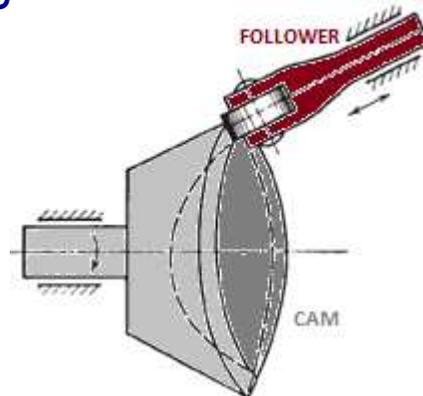
## 2. Cams clasification

### ▶ Spatial cams (three-dimensional)

- **Cylindrical** cams: The roller follower operates in a groove cut on the periphery of a cylinder. The follower may translate or oscillate



- **Conical** cams:



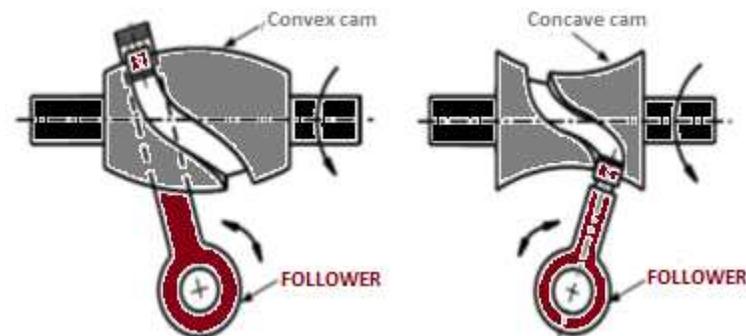


## 2. Cams clasification



## 2. Cams clasification

- **Globoidal cams:** compact structure, high load capacity, low noise and vibrations and high reliability. Widely used in industry.



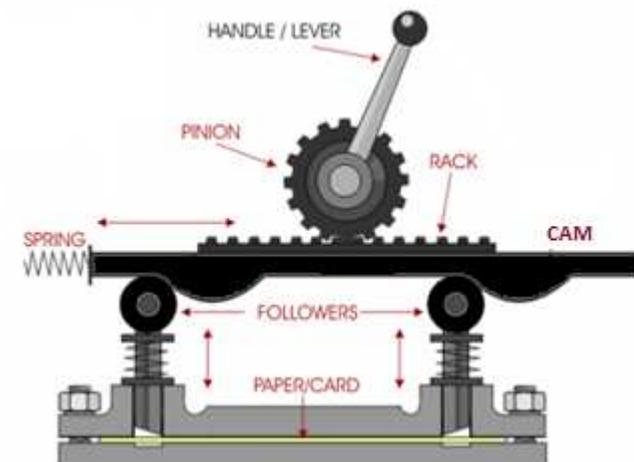
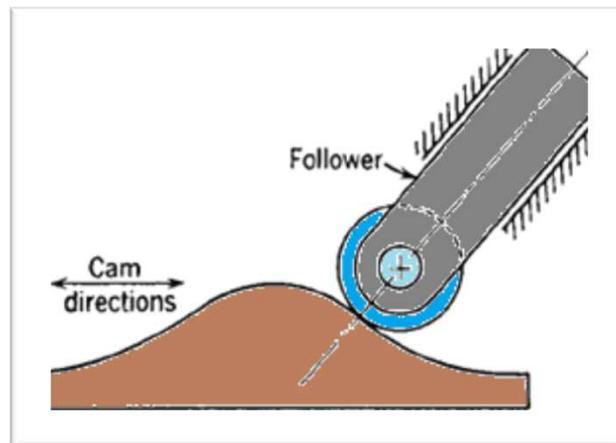
- **Spherical end cams**

## 2. Cams clasification

- Cams can be classified according to the follower motion respect the rotation axle of the cam

- ▶ **Radial Cams**

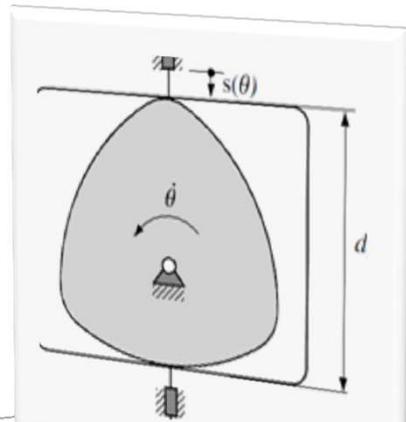
- ▶ **Translational or Axial Cams**



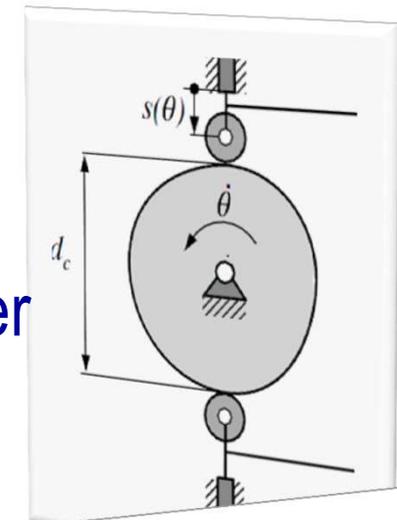
# 3. Desmodromic Cams

Desmodromic cams use two higher pairs (closed form) so that both impose the same kinematic restrictions.

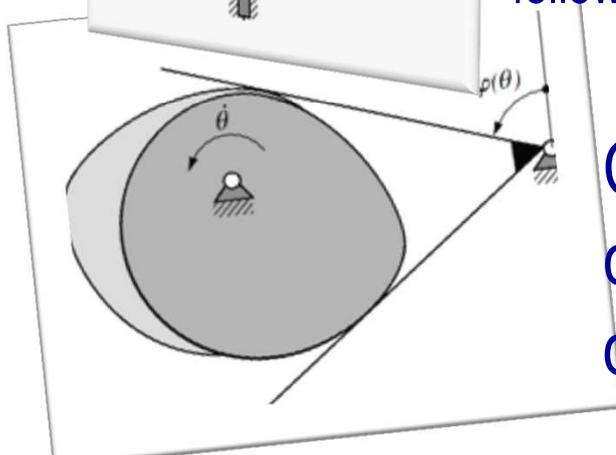
There are four types of planar desmodromic cams:



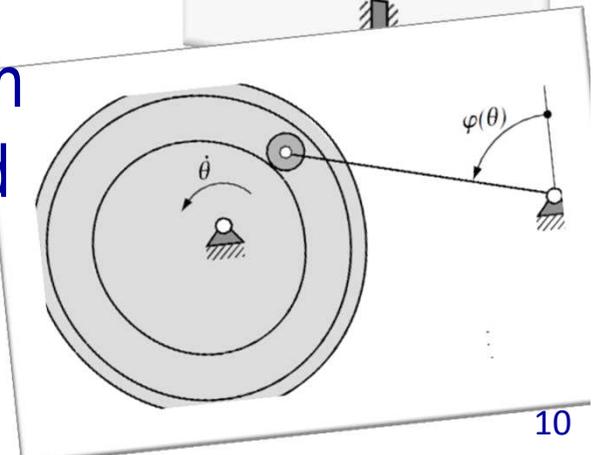
Cams with  
constant width  
(double flat faced  
follower)



Cams with  
constant diameter  
(double roller follower)



Conjugate  
cams with  
double follower

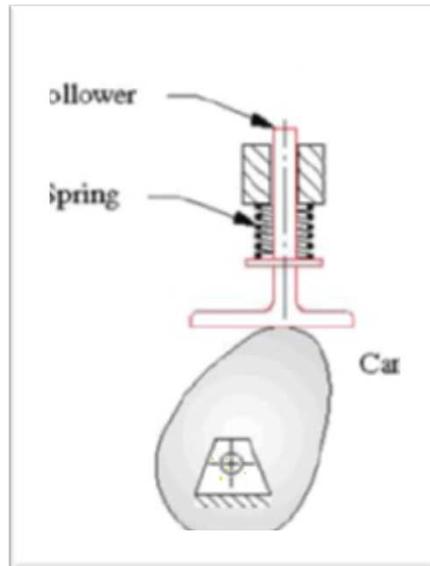


Cams with  
a grooved  
face

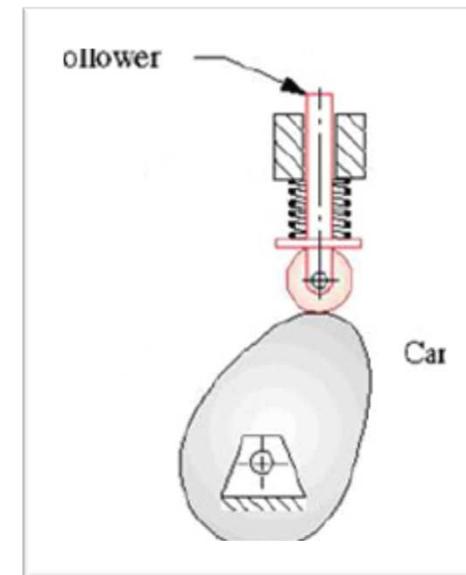
## 4. Followers clasification

- Followers can be classified by the geometry of the contact surface. E.g.

- ▶ **Flat-face:** More compact and less expensive than roller. Widely use in automotive industry



- ▶ **Roller:** Less susceptible to wear. Easy to replace the roller with a short delay. Widely used in production machinery

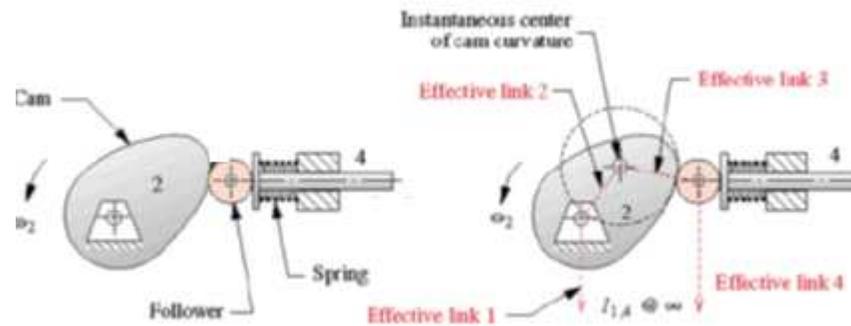


- ▶ **Knife edge follower and others**

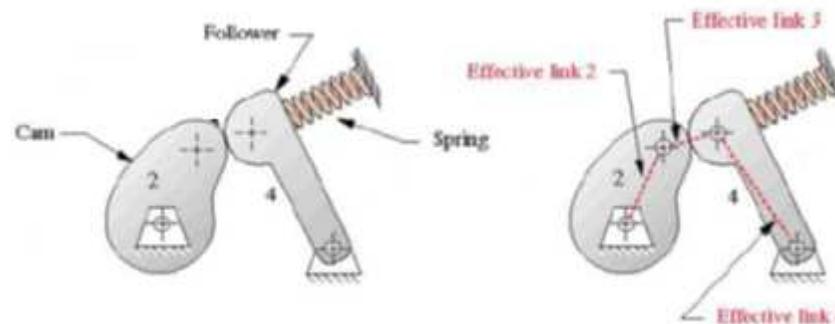
# 4. Followers clasification

- Followers can also be classified according to their motion:

## ► Translational



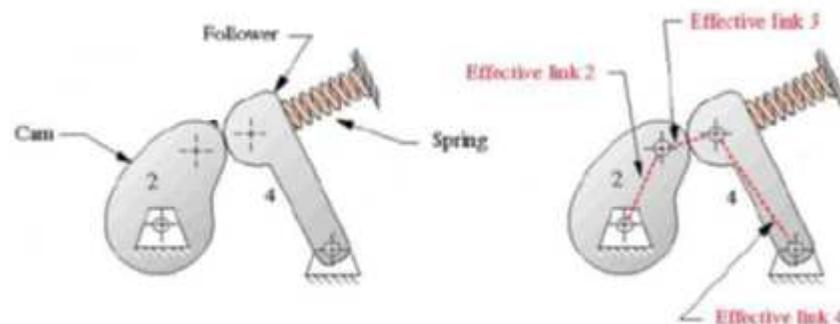
## ► Oscillating



## 5. Closure Joints clasification

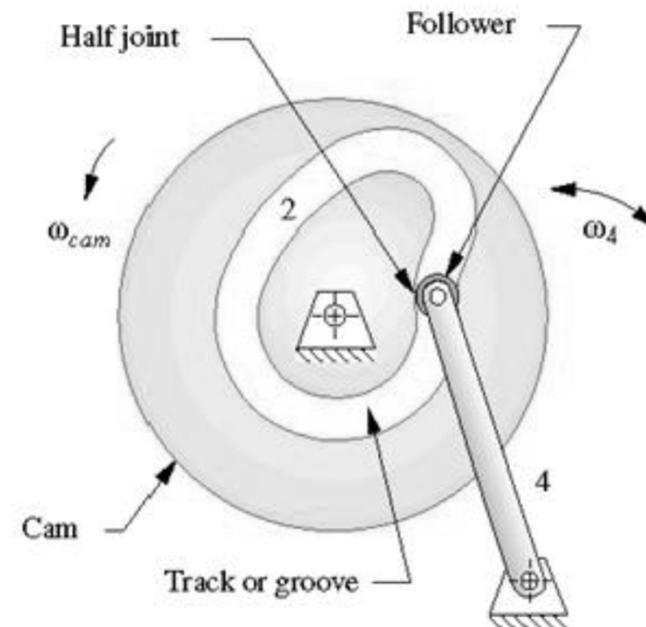
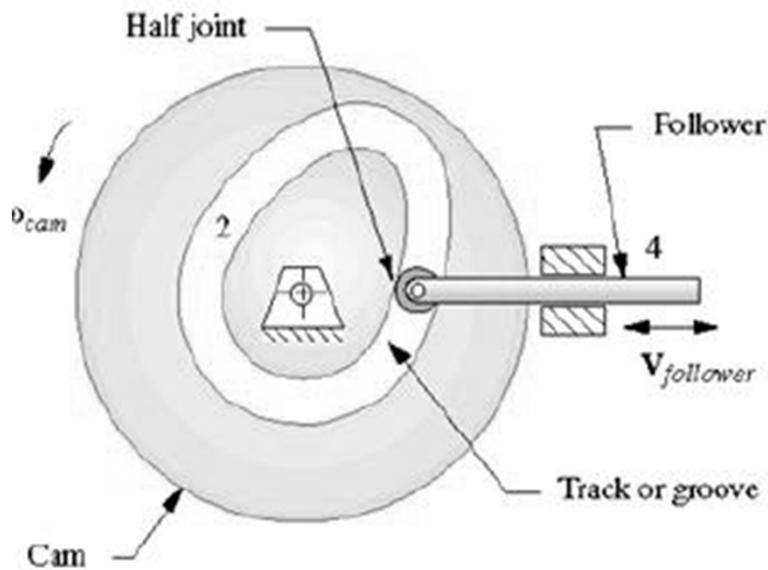
- Joint closure between the cam and the follower is an important point to take into account when design a cam mechanism. It is a high kinematic pair (See *Introduction to kinematics and mechanisms*)

- **Force Joints:** An external force assure permanent contact between the follower and the cam surface. Springs, gravity and inertial systems.



# 5. Closure Joints clasification

- **Form joints:** An appropriated form of a groove in the cam provides the path to be covered by the follower. No external force is needed.





## 6. Classification of Cam mechanisms

- Cam mechanisms can be classified according to motion restrictions:
  - ▶ **CEP**: Critical extreme position. Only define start and stop position of the follower.
  - ▶ **CPM**: Critical path motion. Path and/or one or more of its derivatives are carefully specified.
- Cams can be classified according to their motion program:
  - ▶ **RF**: Rise-Fall. CEP (No Dwell)
  - ▶ **RFD**: Rise-Fall-Dwell. CEP (Single Dwell)
  - ▶ **RDFD**: Rise-Dwell-Fall-Dwell. CEP (Double Dwell)



## 7. SVAJ Diagrams

- The first step when design cam is to define the mathematical functions to be used to define the motion of the follower.
- SVAJ diagrams are a useful tool:

S: displacement of the follower vs  $\theta$  of the cam.

S

V: velocity.

$\partial s / \partial t$

A: acceleration.

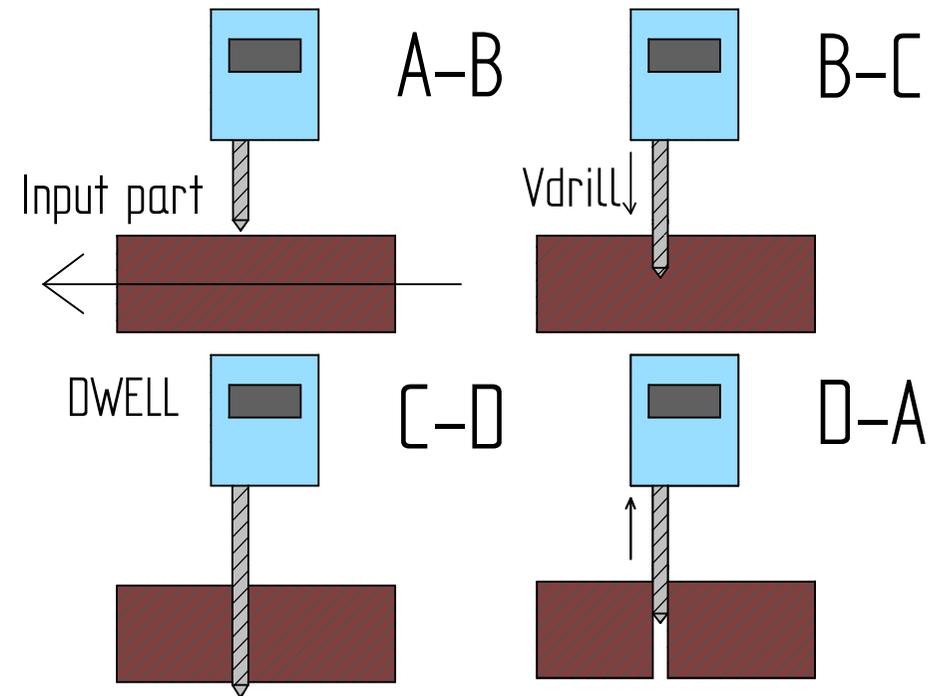
$\partial^2 s / \partial t^2$

J: Jerk. (golpe)

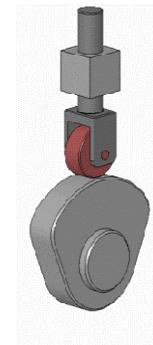
$\partial^3 s / \partial t^3$

# 7. SVAJ Diagrams

- E.g.:
- A cam mechanism will be designed for a driller machine.
- Operation conditions:
  - One part each 20s. Initial position: **A**
  - DRILL IN: 25 mm in 5 s. **B-C**
  - DWELL: 5 s finishing the drill. **C-D**
  - DRILL OUT: 25 mm in 5s. **D-A**
  - DWELL: Wait for another part. **A-B** 5s

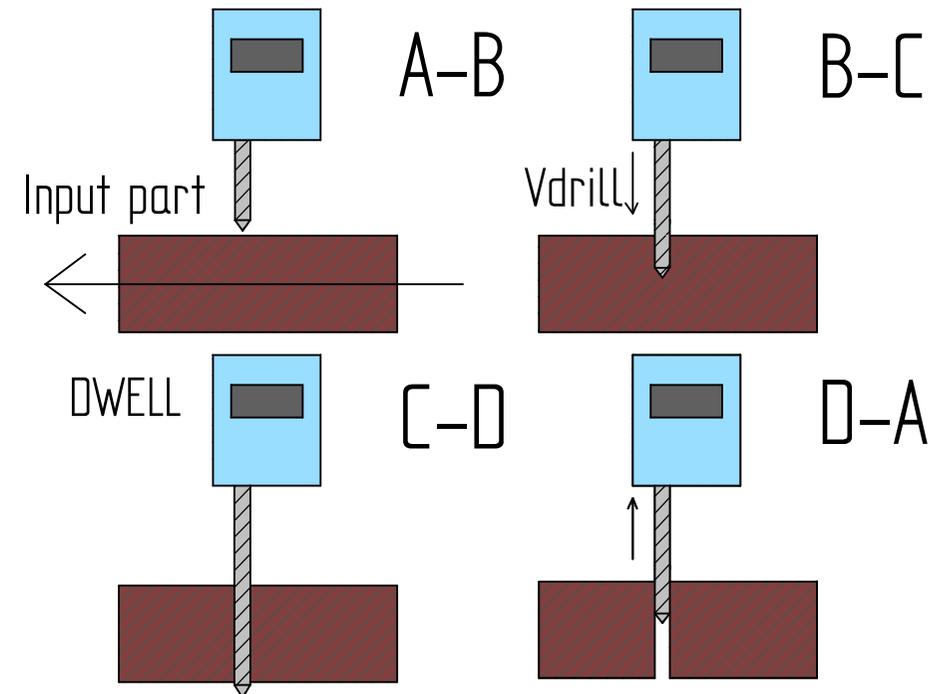


¿? QUESTION ¿? What is the motion program? How many dwells are there?



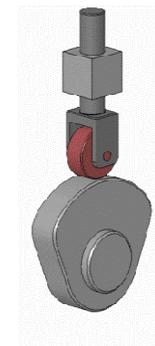
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  - DRILL IN: 25 mm in 5 s. **B-C**
  - DWELL: 5 s finishing the drill. **C-D**
  - DRILL OUT: 25 mm in 5s. **D-A**
  - DWELL: Wait for another part. **A-B** 5s



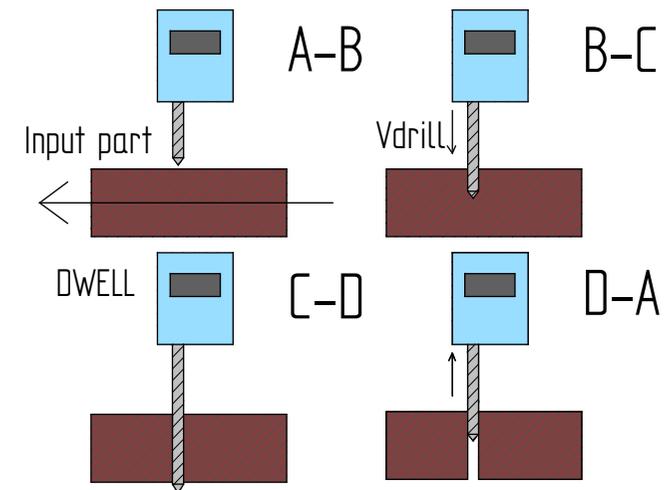
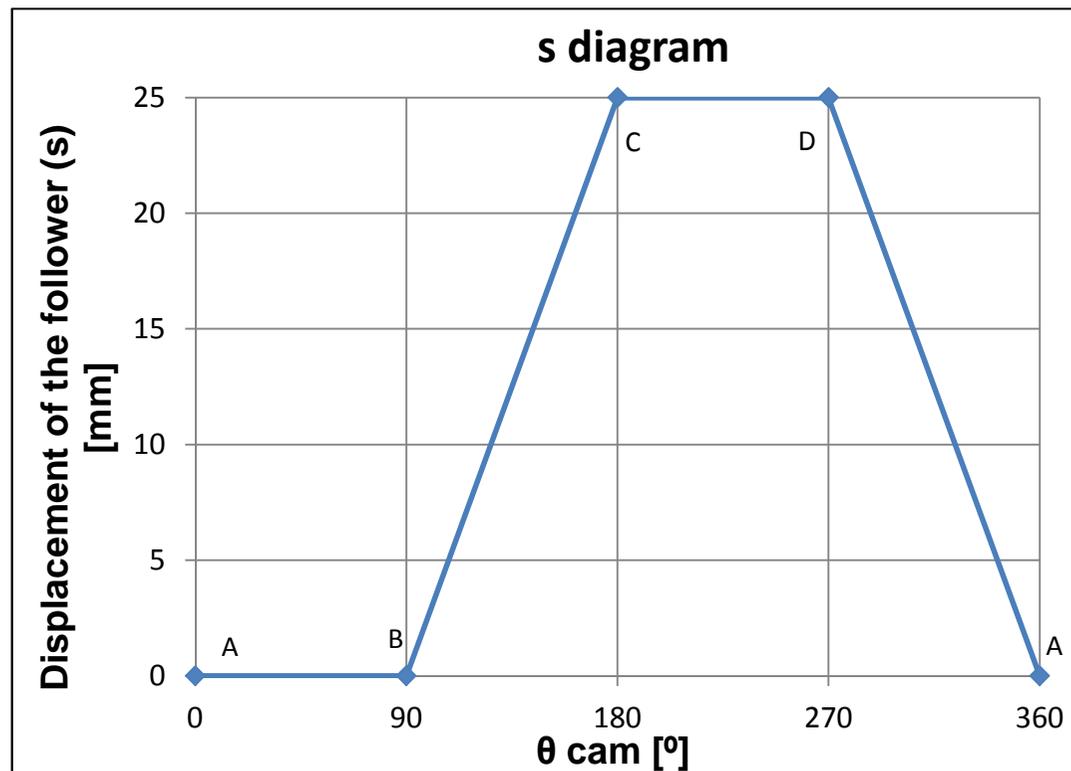
¿? QUESTION ¿? What is the motion program? How many dwells are there?

RDFD: Rise-Dwell-Fall-Dwell. 2Dwells



# 7. SVAJ Diagrams

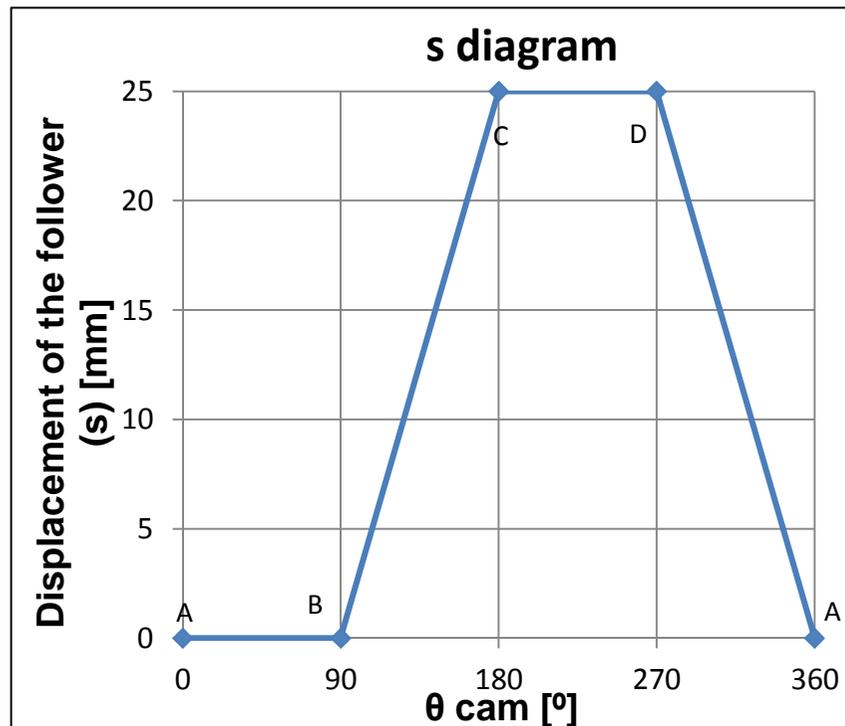
- First step:
  - ❖ Define the displacement diagram:





# 7. SVAJ Diagrams

It is very useful to divide the displacement function in several parts. These functions are called:  
**piecewise functions:**



## From A to B

$$0 \leq \theta < 90 \quad s = 0 \text{ [mm]}$$

## From B to C

$$90 \leq \theta < 180 \quad s = K_1 \cdot [\theta - 90] \text{ where } K_1 = \frac{\Delta s}{\Delta \theta} = \frac{25}{90} = \frac{5}{18} \text{ [mm/°]}$$

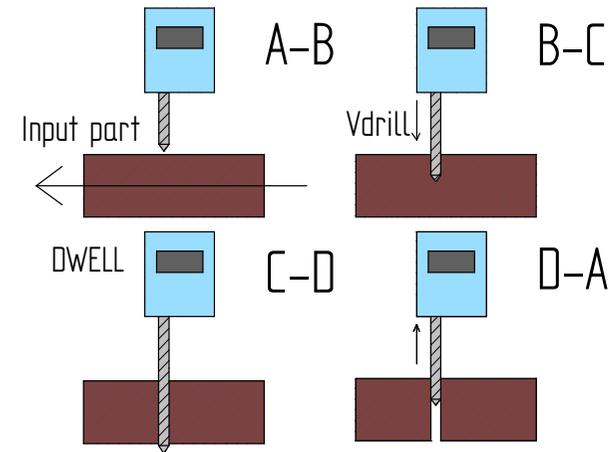
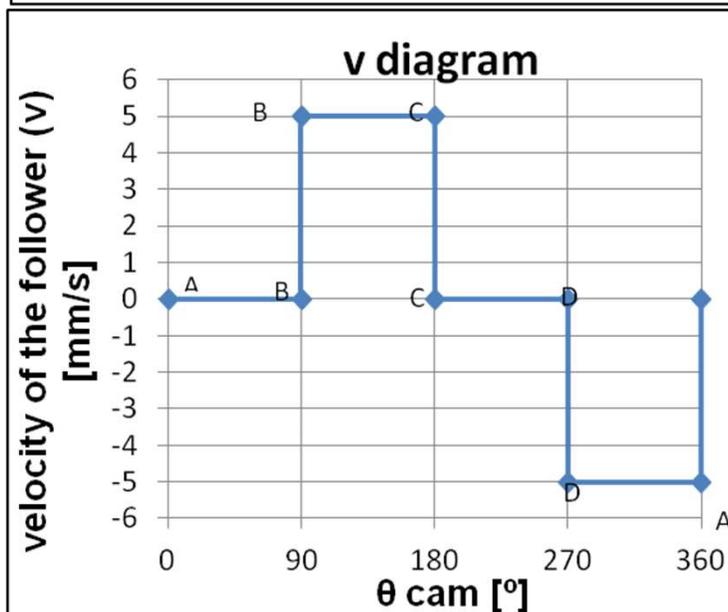
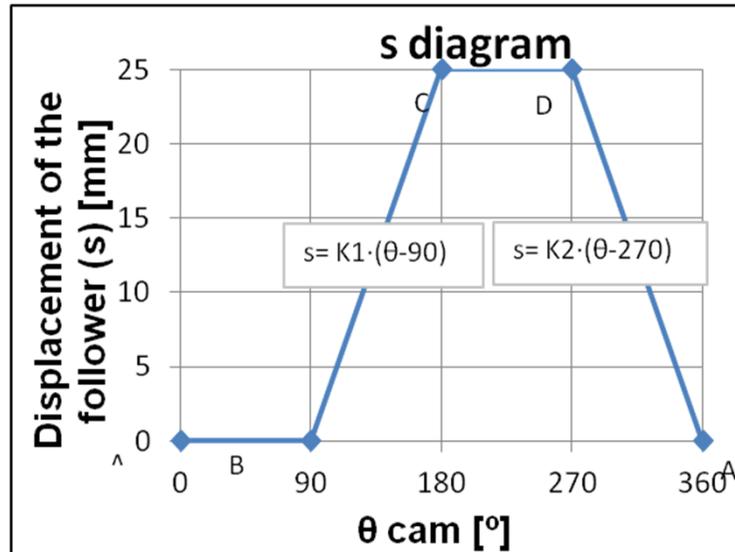
## From C to D

$$180 \leq \theta < 270 \quad s = 25 \text{ [mm]}$$

## From D to A

$$270 \leq \theta < 360 \quad s = K_2 \cdot [\theta - 270] \text{ where } K_2 = \frac{\Delta s}{\Delta \theta} = \frac{-25}{90} = -\frac{5}{18} \text{ [mm/°]}$$

# 7. SVAJ Diagrams



Velocity =  $\partial s / \partial t$  or  $\partial s / \partial \theta$

$\omega_{leva} = \Delta \theta / \Delta t$

$\omega_{leva} = 18 [^\circ/s] = 3 \text{ r.p.m}$  constant.

$V = \Delta s / \Delta t = \omega_{leva} \cdot \Delta s / \Delta \theta = \omega_{leva} \cdot K_n = \text{constant}$

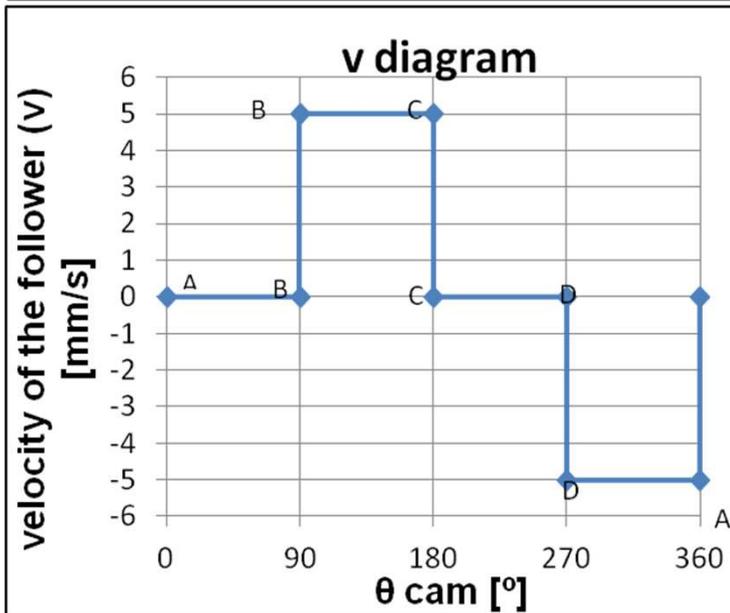
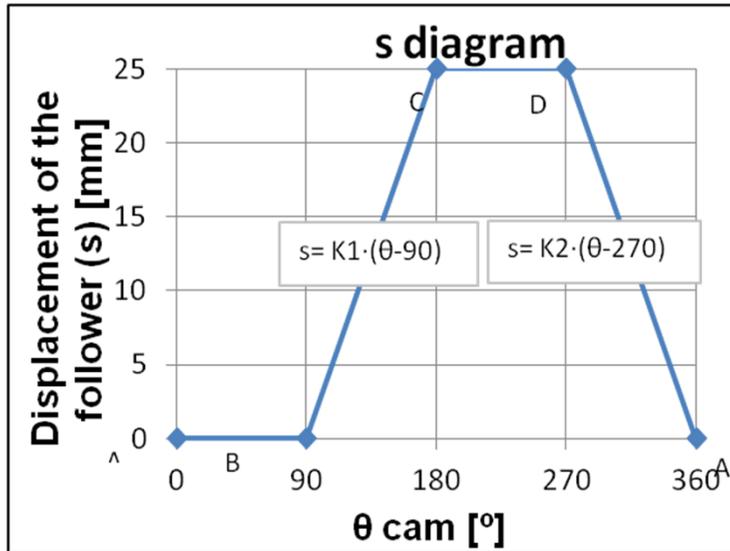
$K_1 = 5/18 \text{ [mm/}^\circ]$   $V_1 = 5 \text{ mm/s}$

$K_2 = -5/18 \text{ [mm/}^\circ]$   $V_2 = -5 \text{ mm/s}$

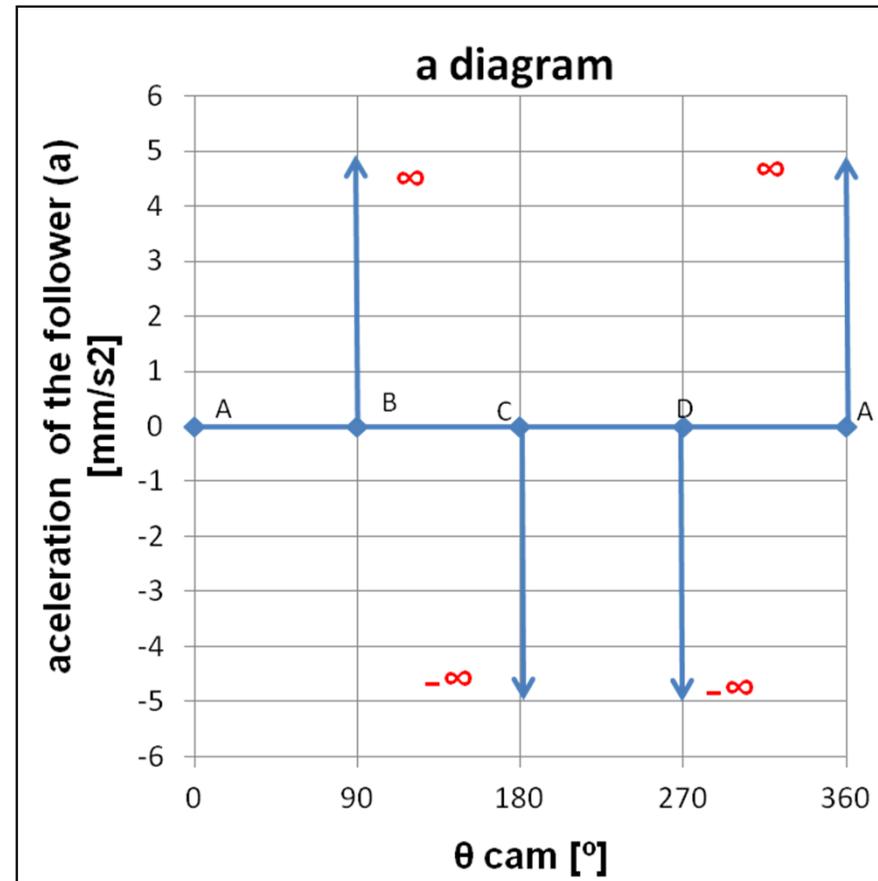
VELOCITY IS USUALLY EXPRESSED IN FUNCTION OF THE ROTATED ANGLE OF THE CAM [length/angle]. In this example it could be  $v = 5/18 \text{ [mm/}^\circ]$



# 7. SVAJ Diagrams



$a = \partial v / \partial t$  or  $\partial v / \partial \theta$

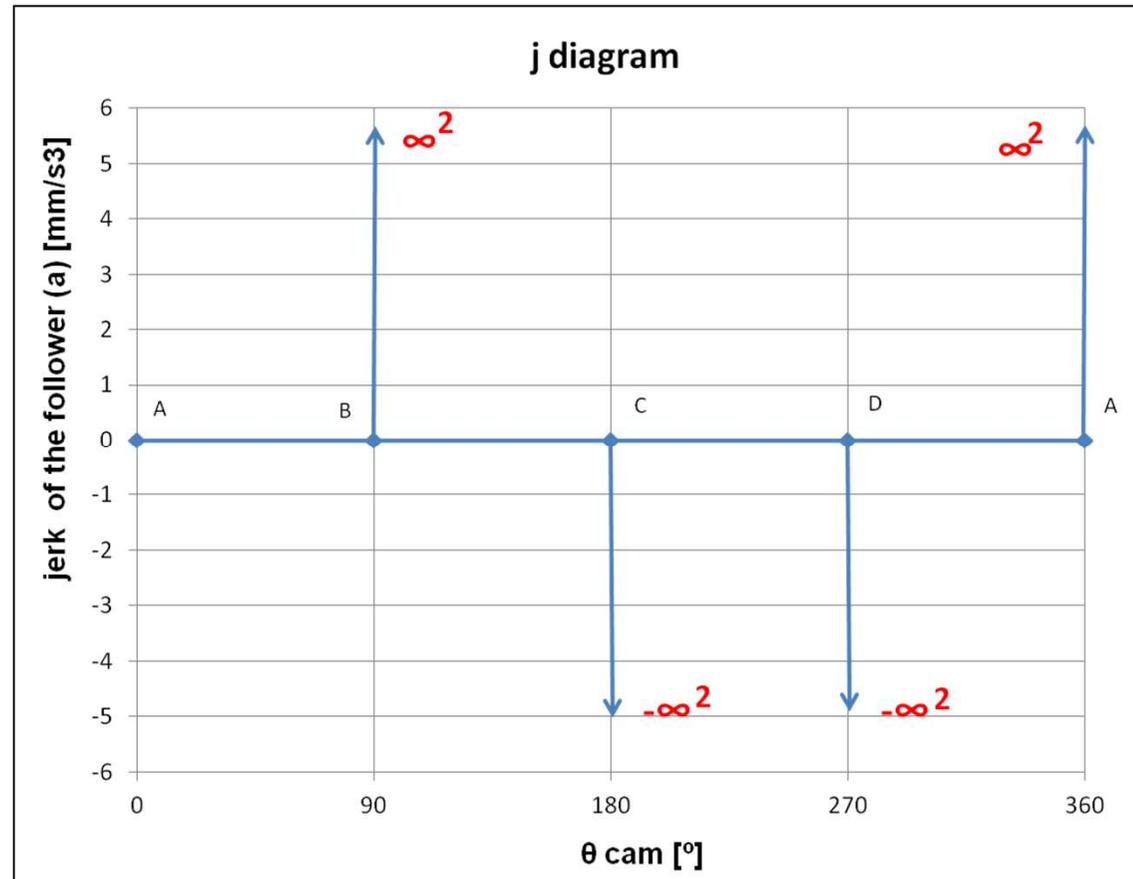


$\infty$  a,  $\infty$  F? Dirac Delta function. SPIKES



# 7. SVAJ Diagrams

$j = \frac{\partial a}{\partial t}$  or  $\frac{\partial a}{\partial \theta}$



CONCLUSION= BAD DESIGN OF  
DISPLACEMENT FUNCTION



# 8. Fundamental Law of Cams Design

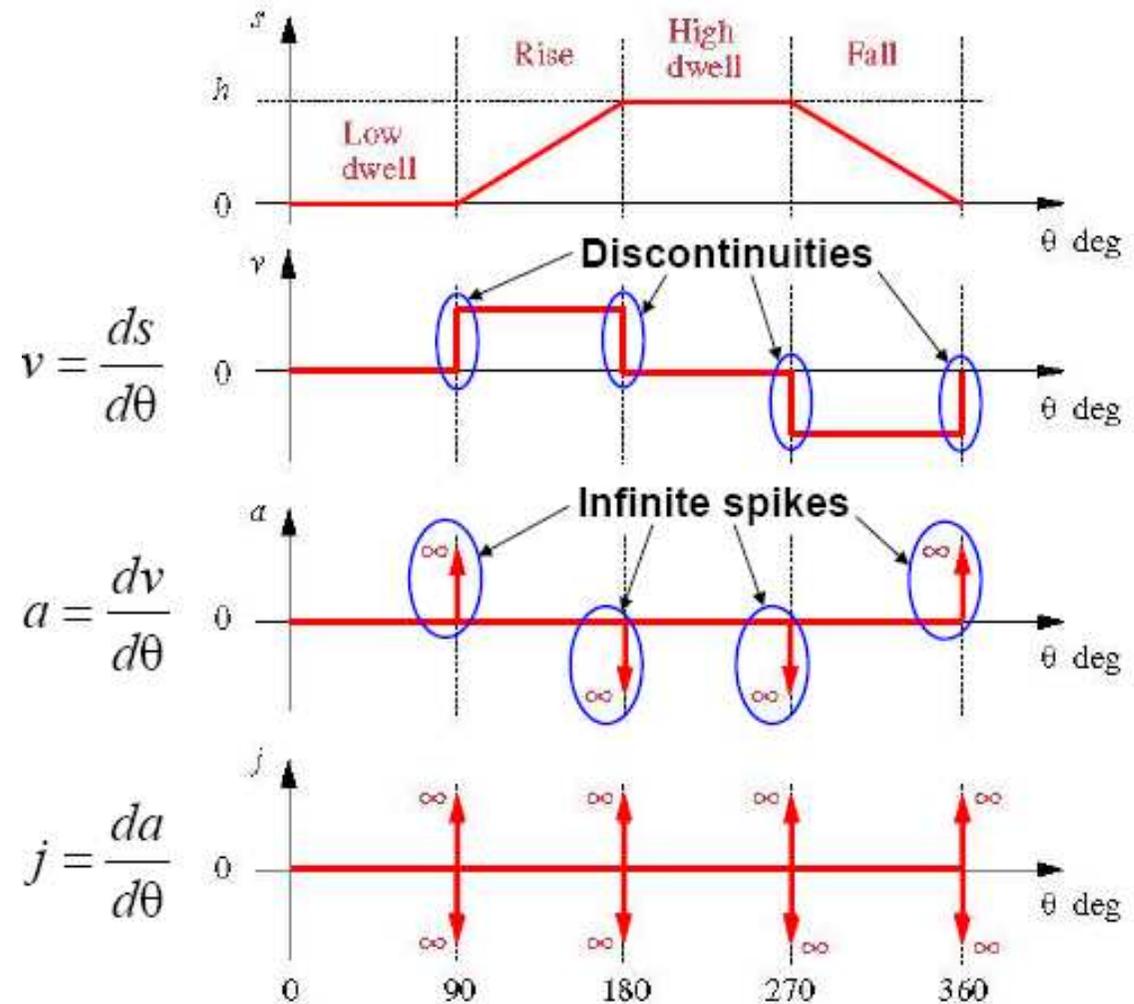
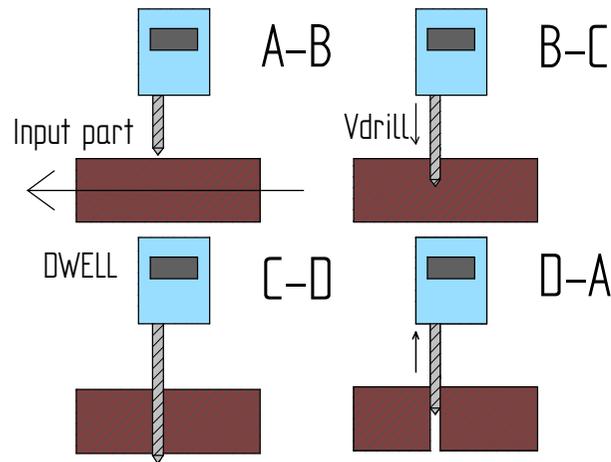
1. “The cam function must be continuous through the first and second derivatives of displacement across the entire interval”
2. “The jerk function must be finite across the entire interval”

## SOME CONSIDERATIONS

1. In any but the simplest of cams, the cam motion program cannot be defined by a single mathematical expression, but rather must be defined by several separate functions, each of which defines the follower behavior over one segment, or piece, of the cam. These expressions are sometimes called **piecewise functions**.
2. These functions must have **third-order continuity** (the function plus two derivatives) at all boundaries.
3. The displacement, velocity and acceleration functions must have **no discontinuities** in them.



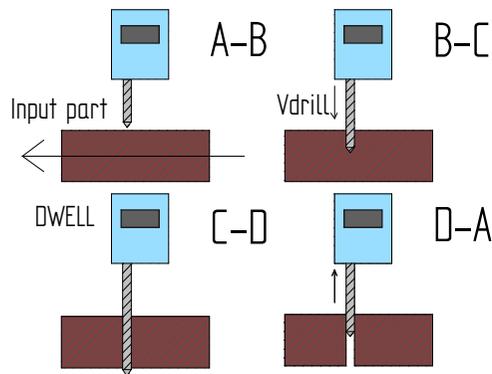
# 8. Fundamental Law of Cams Design



The example analyzed before does not comply with the fundamental law of cam design!!!!

# 8.1 Simple Harmonic Motion

The simple harmonic motion is a mathematical function that remain continuous throughout any number of diferentiations.



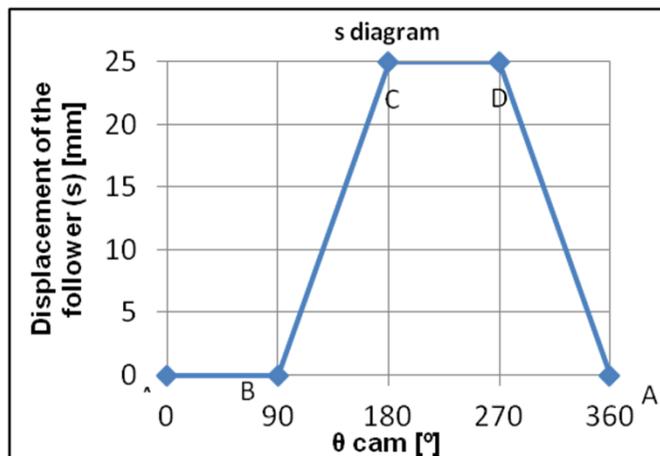
**RISE  $0 \leq \theta < 90^\circ$ :**

$$s = \frac{h}{2} \left[ 1 - \cos \left( \pi \frac{\theta}{\beta} \right) \right]$$

$$v = \frac{\pi h}{\beta} \sin \left( \pi \frac{\theta}{\beta} \right)$$

$$a = \frac{\pi^2}{\beta^2} \frac{h}{2} \cos \left( \pi \frac{\theta}{\beta} \right)$$

$$j = -\frac{\pi^3}{\beta^3} \frac{h}{2} \sin \left( \pi \frac{\theta}{\beta} \right)$$



Where:

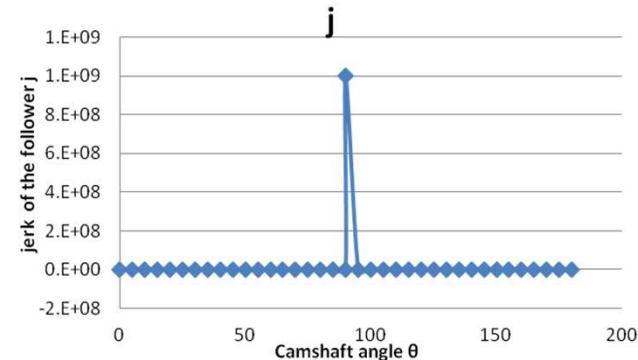
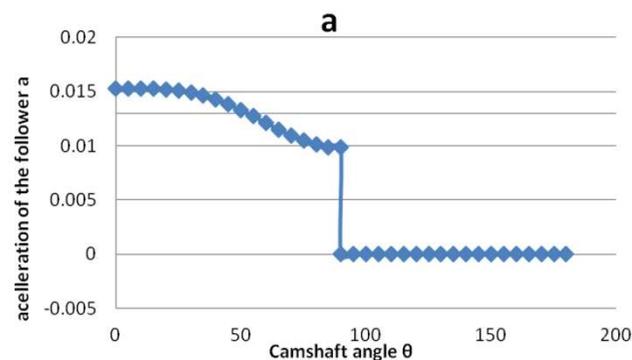
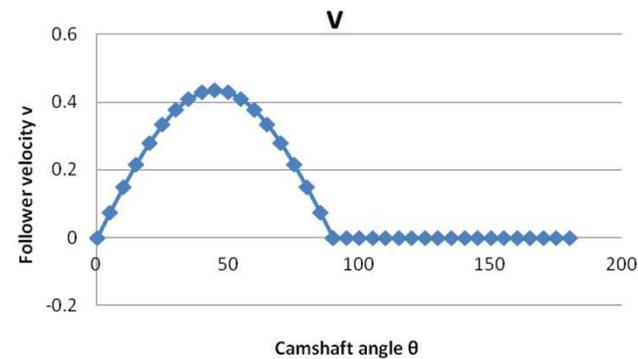
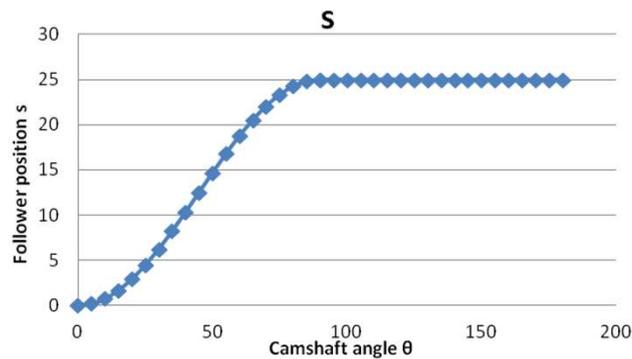
- h is the total stroke of the follower.
- $\theta$  is the camshaft angle in each moment.
- $\beta$  is the maximum angle in this stage.

Footnote  $\theta/\beta$  is a dimensionless parameter that oscillate between 0 and 1.



# 8.1 Simple Harmonic Motion

**S= OK; V= OK, A is not continuous, infinite jerk spikes!!!! Is not a good design yet**



**Despite this deficiency, this profile is popular for cam design in low-speed applications because it is easy to manufacture**



## 8.2 Polynomial Functions

- This class of motion function is one of the more versatile types that can be used for cam design. They are not limited by the number of dwells. The general form of a polynomial function is:

$$s = C_0 + C_1x + C_2x^2 + C_3x^3 + C_4x^4 + C_5x^5 + C_6x^6 + \dots + C_nx^n$$

- Where  $x$  is the **independent variable** ( $\theta/\beta$ ).
- The **degree of the polynomial is defined by the number of boundary conditions minus one (because constant  $C_0$ )**.
- The constant coefficients must be determined for an specific design.

## 8.2 Polynomial Functions

- ◉ In our example there are:
  - ▶ We divide in fall and rise.

RISE

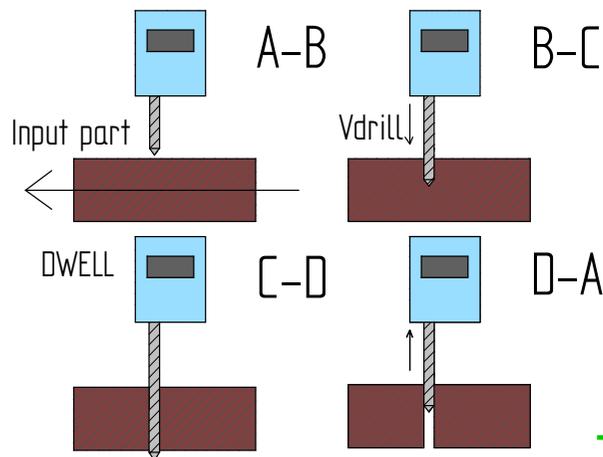
$$\theta = 0^\circ \rightarrow s = 0; v = 0; a = 0$$

$$\theta = 90^\circ \rightarrow s = h; v = 0; a = 0$$

FALL

$$\theta = (\theta_c - \theta_i) = 0^\circ \rightarrow s = h; v = 0; a = 0$$

$$\theta = (\theta_c - \theta_i) = (270 - 180) = 90^\circ \rightarrow s = 0; v = 0; a = 0$$



There are six boundary conditions for each stage.  
Then, a 5 degree polynomial equation is needed.



# 8.2 Polynomial Functions

## RISE

$$\theta = 0^\circ \rightarrow s = 0; v = 0; a = 0$$

$$\theta = 90^\circ \rightarrow s = h; v = 0; a = 0$$

$$s = C_0 + C_1 \frac{\theta}{\beta} + C_2 \left(\frac{\theta}{\beta}\right)^2 + C_3 \left(\frac{\theta}{\beta}\right)^3 + C_4 \left(\frac{\theta}{\beta}\right)^4 + C_5 \left(\frac{\theta}{\beta}\right)^5$$

$$v = \frac{1}{\beta} \left[ C_1 + 2C_2 \left(\frac{\theta}{\beta}\right) + 3C_3 \left(\frac{\theta}{\beta}\right)^2 + 4C_4 \left(\frac{\theta}{\beta}\right)^3 + 5C_5 \left(\frac{\theta}{\beta}\right)^4 \right]$$

$$a = \frac{1}{\beta^2} \left[ 2C_2 + 6C_3 \left(\frac{\theta}{\beta}\right) + 12C_4 \left(\frac{\theta}{\beta}\right)^2 + 20C_5 \left(\frac{\theta}{\beta}\right)^3 \right]$$

$$j = \frac{1}{\beta^3} \left[ 6C_3 + 24C_4 \left(\frac{\theta}{\beta}\right) + 60C_5 \left(\frac{\theta}{\beta}\right)^2 \right]$$

Constant	Condition	Evaluation
$C_0$	$\theta_0; s=h$	$h$
$C_1$	$\theta_0; v=0$	$0$
$C_2$	$\theta_0; a=0$	$0$
$C_3$	$\theta_{90}; \text{eq.}$	$10h = 250$
$C_4$	$\theta_{90}; \text{eq.}$	$-15h = -375$
$C_5$	$\theta_{90}; \text{eq.}$	$6h = 150$

$$\theta = \beta \rightarrow s = 0 = C_3 + C_4 + C_5$$

$$\theta = \beta \rightarrow v = 0 = 3C_3 + 4C_4 + 5C_5 \rightarrow \rightarrow \rightarrow \rightarrow C_3 = 10h; C_4 = -15h; C_5 = 6h$$

$$\theta = \beta \rightarrow a = 0 = 6C_3 + 12C_4 + 20C_5$$



## 8.2 Polynomial Functions

**RISE**

$$\theta = 0^\circ \rightarrow s = 0; v = 0; a = 0$$

$$\theta = 90^\circ \rightarrow s = h; v = 0; a = 0$$

$$s = C_0 + C_1 \frac{\theta}{\beta} + C_2 \left(\frac{\theta}{\beta}\right)^2 + C_3 \left(\frac{\theta}{\beta}\right)^3 + C_4 \left(\frac{\theta}{\beta}\right)^4 + C_5 \left(\frac{\theta}{\beta}\right)^5$$

$$v = \frac{1}{\beta} \left[ C_1 + 2C_2 \left(\frac{\theta}{\beta}\right) + 3C_3 \left(\frac{\theta}{\beta}\right)^2 + 4C_4 \left(\frac{\theta}{\beta}\right)^3 + 5C_5 \left(\frac{\theta}{\beta}\right)^4 \right]$$

$$a = \frac{1}{\beta^2} \left[ 2C_2 + 6C_3 \left(\frac{\theta}{\beta}\right) + 12C_4 \left(\frac{\theta}{\beta}\right)^2 + 20C_5 \left(\frac{\theta}{\beta}\right)^3 \right]$$

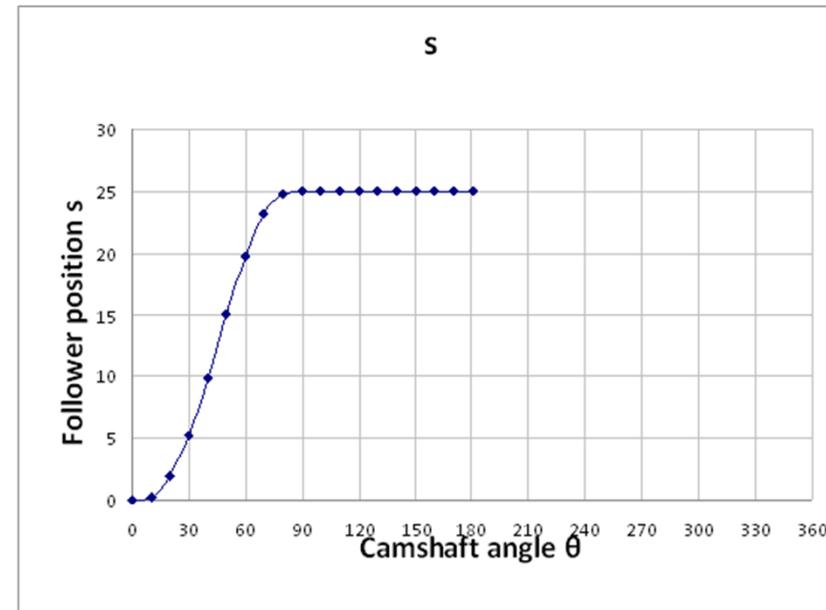
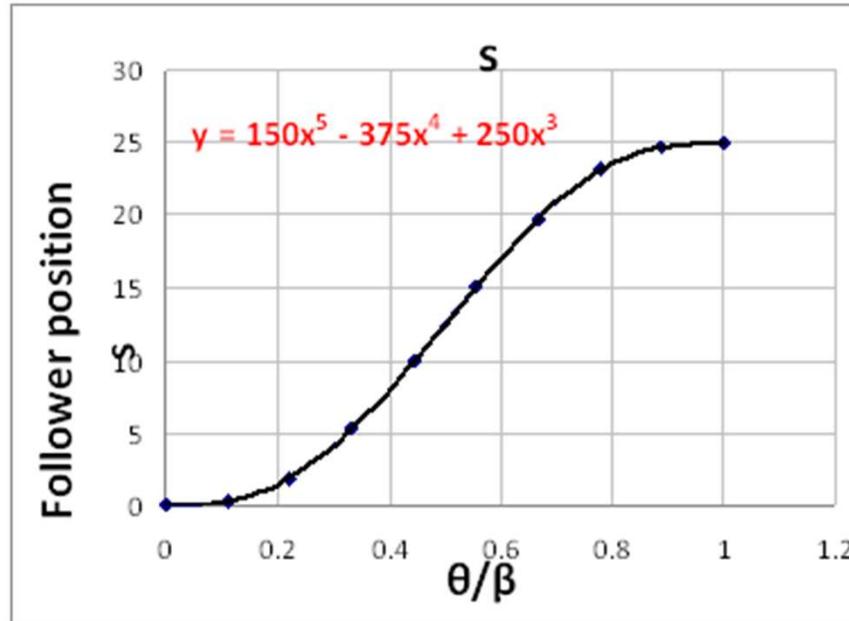
$$j = \frac{1}{\beta^3} \left[ 6C_3 + 24C_4 \left(\frac{\theta}{\beta}\right) + 60C_5 \left(\frac{\theta}{\beta}\right)^2 \right]$$

Constant	Condition	Evaluation
$C_0$	$\theta_0; s=h$	$h$
$C_1$	$\theta_0; v=0$	$0$
$C_2$	$\theta_0; a=0$	$0$
$C_3$	$\theta_{90}; \text{eq.}$	$10h = 250$
$C_4$	$\theta_{90}; \text{eq.}$	$-15h = -375$
$C_5$	$\theta_{90}; \text{eq.}$	$6h = 150$

THIS POLYNOMIAL FUNCTION IS CALLED 3-4-5 POLYNOMIAL MOTION.



## 8.2 Polynomial Functions



$C_3$	$\theta_{90}; \text{eq.}$	$10h=250$
$C_4$	$\theta_{90}; \text{eq.}$	$-15h=375$
$C_5$	$\theta_{90}; \text{eq.}$	$6h=150$



# 8.2 Polynomial Functions

$$\theta = (\theta_c - \theta_i) = 0^\circ \rightarrow s = h; v = 0; a = 0$$

**FALL**

$$\theta = (\theta_c - \theta_i) = (270 - 180) = 90^\circ \rightarrow s = 0; v = 0; a = 0$$

$$s = C_0 + C_1 \frac{\theta}{\beta} + C_2 \left(\frac{\theta}{\beta}\right)^2 + C_3 \left(\frac{\theta}{\beta}\right)^3 + C_4 \left(\frac{\theta}{\beta}\right)^4 + C_5 \left(\frac{\theta}{\beta}\right)^5$$

$$v = \frac{1}{\beta} \left[ C_1 + 2C_2 \left(\frac{\theta}{\beta}\right) + 3C_3 \left(\frac{\theta}{\beta}\right)^2 + 4C_4 \left(\frac{\theta}{\beta}\right)^3 + 5C_5 \left(\frac{\theta}{\beta}\right)^4 \right]$$

$$a = \frac{1}{\beta^2} \left[ 2C_2 + 6C_3 \left(\frac{\theta}{\beta}\right) + 12C_4 \left(\frac{\theta}{\beta}\right)^2 + 20C_5 \left(\frac{\theta}{\beta}\right)^3 \right]$$

$$j = \frac{1}{\beta^3} \left[ 6C_3 + 24C_4 \left(\frac{\theta}{\beta}\right) + 60C_5 \left(\frac{\theta}{\beta}\right)^2 \right]$$

Constant	Condition	Evaluation
$C_0$	$\theta_0; s=h$	$h$
$C_1$	$\theta_0; v=0$	$0$
$C_2$	$\theta_0; a=0$	$0$
$C_3$	$\theta_{90}; \text{eq.}$	$-10h = -250$
$C_4$	$\theta_{90}; \text{eq.}$	$15h = 375$
$C_5$	$\theta_{90}; \text{eq.}$	$-6h = -150$

$$\theta = \beta \rightarrow s = 0 = h + C_3 + C_4 + C_5$$

$$\theta = \beta \rightarrow v = 0 = 3C_3 + 4C_4 + 5C_5 \rightarrow \rightarrow \rightarrow \rightarrow C_3 = -10h; C_4 = 15h; C_5 = -6h$$

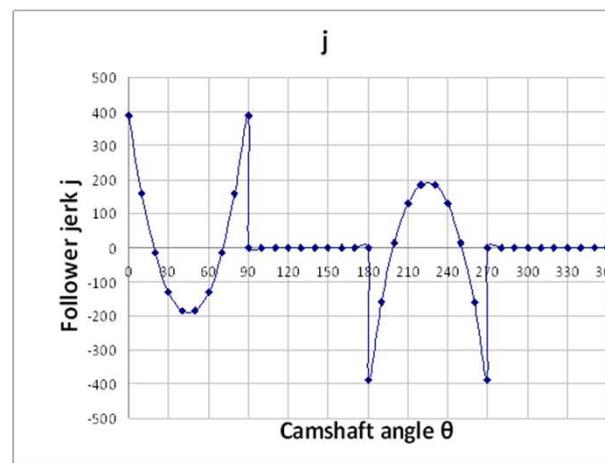
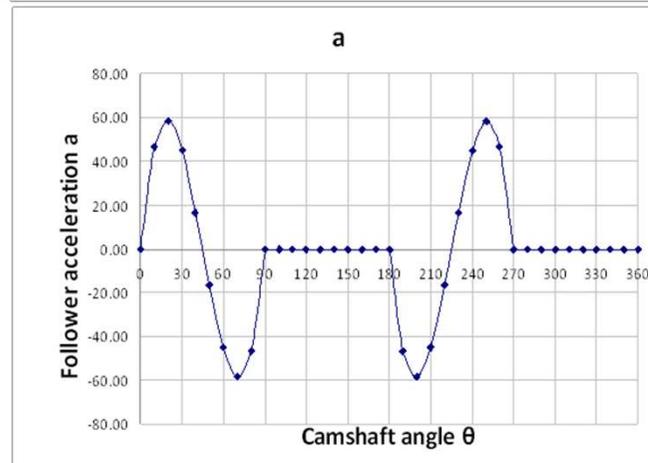
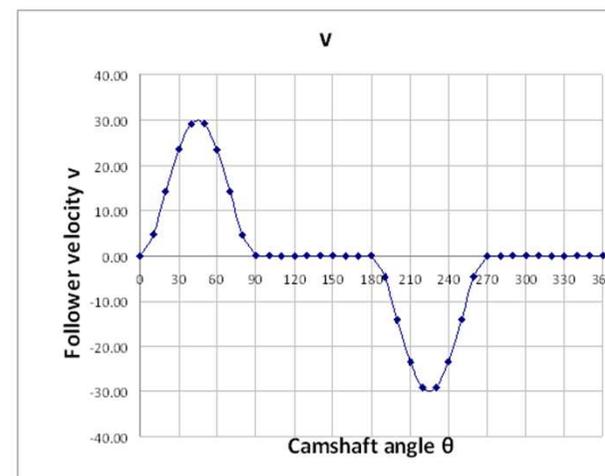
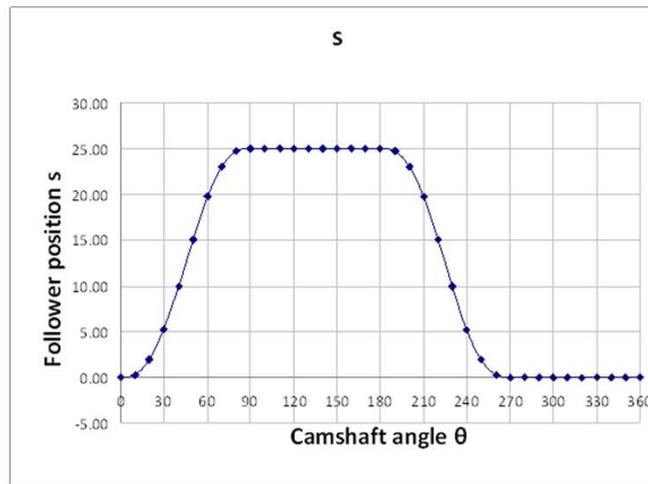
$$\theta = \beta \rightarrow a = 0 = 6C_3 + 12C_4 + 20C_5$$

**Footnote:** Please notice that C factors are the opposite to the RISE stage



## 8.2 Polynomial Functions

- Design is acceptable. No discontinuities and jerk is finite for any camshaft angle (fundamental satisfied). However, jerk is “out of control”!





## 8.2 Polynomial Functions

### ◉ The 4-5-6-7 POLYNOMIAL MOTION

- ▶ We can control jerk by adding two more restrictions and therefore avoid the initial jerk ( $\theta=0^\circ; j>0$ ) which could be harmful:

Fall

$$\theta = 0^\circ \rightarrow s = 0; v = 0; a = 0; j = 0$$

$$\theta = 90^\circ \rightarrow s = h; v = 0; a = 0; j = 0$$

Rise

$$\theta = (\theta_c - \theta_i) = 0^\circ \rightarrow s = h; v = 0; a = 0; j = 0$$

$$\theta = (\theta_c - \theta_i) = (270 - 180) = 90^\circ \rightarrow s = 0; v = 0; a = 0; j = 0$$



## 8.2 Polynomial Functions

### POLYNOMIAL 4-5-6-7 JERK CONTROL

$$s = C_0 + C_1 \frac{\theta}{\beta} + C_2 \left(\frac{\theta}{\beta}\right)^2 + C_3 \left(\frac{\theta}{\beta}\right)^3 + C_4 \left(\frac{\theta}{\beta}\right)^4 + C_5 \left(\frac{\theta}{\beta}\right)^5 + C_6 \left(\frac{\theta}{\beta}\right)^6 + C_7 \left(\frac{\theta}{\beta}\right)^7$$

$$v = \frac{1}{\beta} \left[ C_1 + 2C_2 \left(\frac{\theta}{\beta}\right) + 3C_3 \left(\frac{\theta}{\beta}\right)^2 + 4C_4 \left(\frac{\theta}{\beta}\right)^3 + 5C_5 \left(\frac{\theta}{\beta}\right)^4 + 6C_6 \left(\frac{\theta}{\beta}\right)^5 + 7C_7 \left(\frac{\theta}{\beta}\right)^6 \right]$$

$$a = \frac{1}{\beta^2} \left[ 2C_2 + 6C_3 \left(\frac{\theta}{\beta}\right) + 12C_4 \left(\frac{\theta}{\beta}\right)^2 + 20C_5 \left(\frac{\theta}{\beta}\right)^3 + 30C_6 \left(\frac{\theta}{\beta}\right)^4 + 42C_7 \left(\frac{\theta}{\beta}\right)^5 \right]$$

$$j = \frac{1}{\beta^3} \left[ 6C_3 + 24C_4 \left(\frac{\theta}{\beta}\right) + 60C_5 \left(\frac{\theta}{\beta}\right)^2 + 120C_6 \left(\frac{\theta}{\beta}\right)^3 + 210C_7 \left(\frac{\theta}{\beta}\right)^4 \right]$$

$$\theta = \beta \rightarrow s = 0 = C_4 + C_5 + C_6 + C_7$$

$$\theta = \beta \rightarrow v = 0 = 4C_4 + 5C_5 + 6C_6 + 7C_7$$

$$\theta = \beta \rightarrow a = 0 = 12C_4 + 20C_5 + 30C_6 + 42C_7$$

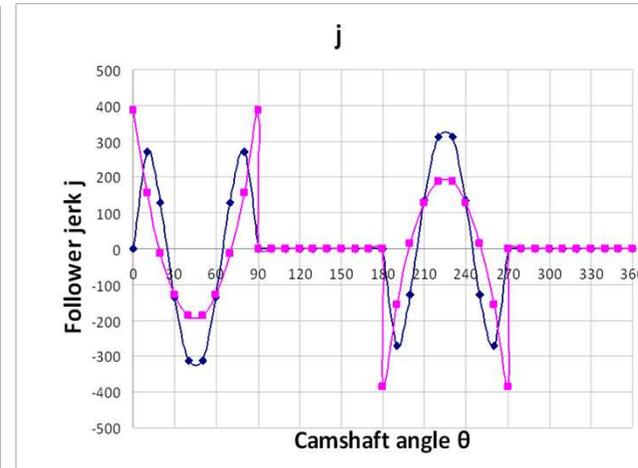
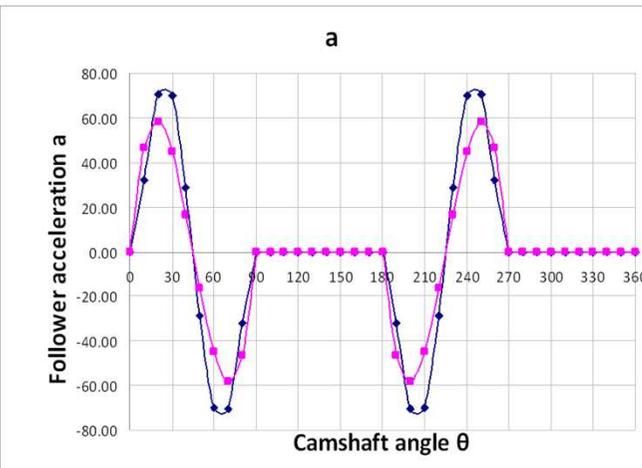
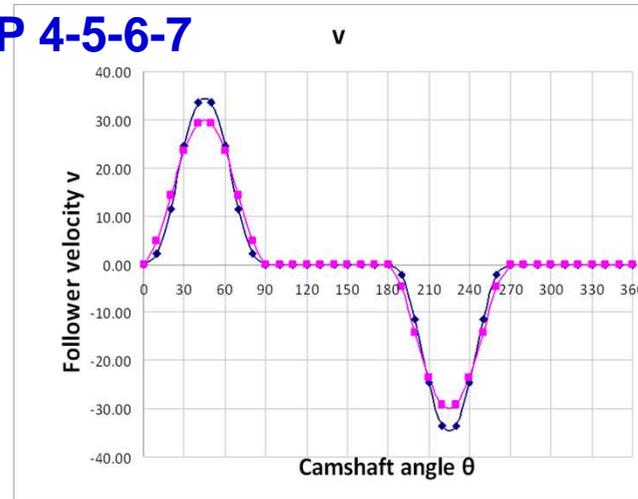
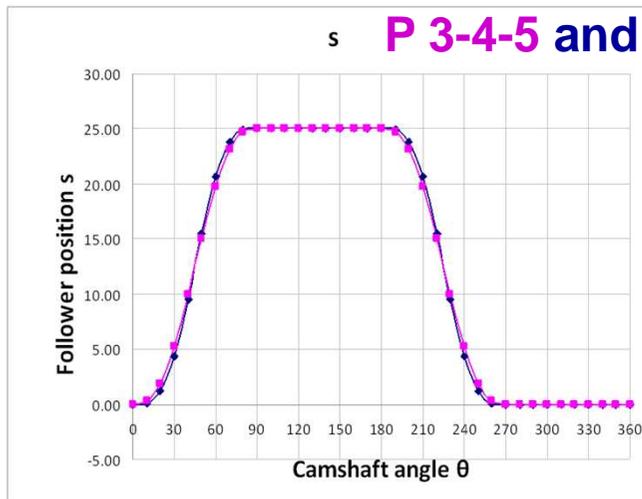
$$\theta = \beta \rightarrow j = 0 = 24C_4 + 60C_5 + 120C_6 + 210C_7$$

Constant	Condition	Evaluation
$C_0$	$\theta_0; s=0$	0
$C_1$	$\theta_0; v=0$	0
$C_2$	$\theta_0; a=0$	0
$C_3$	$\theta_0; j=0$	0
$C_4$	$\theta_{90}; eq.$	-35h
$C_5$	$\theta_{90}; eq.$	-84h
$C_6$	$\theta_{90}; eq.$	70h
$C_7$	$\theta_{90}; eq.$	-20h



# 8.2 Polynomial Functions

- Comparing both polynomial methods:



- The follower position is the same.
- Maximum and minimum velocities are lower in **P 3-4-5**, therefore, the kinetic energy is also lower.
- Max and min acceleration are lower **P 4-5-6-7**.
- Initial jerk=0 **P 4-5-6-7**. Jerk function continuous.



## 8.2 Polynomial Functions

- There are many other motion functions which can be used (see literature).
  - ▶ The best function motion will depend on the concrete application:
    - Single Dwell
    - Double Dwell
    - Low-speed applications
    - High-speed applications
    - Displacement, velocity or acceleration specifications.
    - Some examples are: cycloidal displacement, modified trapezoidal accelerations, modified sinusoidal acceleration....



# 9. SC Levas

- We will provide you **SC levas**. It is a cam design, simulation and evaluation software.
- Very useful tool. Many motion functions available.
- Extremely easy to use. Very intuitive
- We will use it again in laboratory sessions.

Concepto	Máximo	Mínimo	Comentarios
Desplazamiento (mm)	50.	0.	Continua
Velocidad (mm/s)	59.68	-41.72	Discontinua
Aceleración (mm/s <sup>2</sup> )	182.27	-182.27	Continua
Sobresobrecarga (mm/s <sup>3</sup> )	1620.66	-1300.18	Discontinua
Radio de Curvatura Convexo (mm)	---	9.27	El perfil está libre de cúspides y/o rebajes
Ángulo de Presión (°)	45.3	-15.7	Ángulo de Presión > 30°

Forma del Seguidor:  Rodillo  Cara Plana

Movimiento del Seguidor:  Traduacional  Oscilante

Magnitudes Geométricas y Velocidad Angular:  
Radio Base = 50 mm, Excentricidad = 15 mm  
Radio Seguidor = 5 mm,  $\omega = 60$  rad/s

Construcción del Movimiento de Salida:  
Velocidad Constante: L = -35 mm, B = 90°

Tramo	Tipo de Movimiento	L	B
1	Polinómico 3-4-5	50	90
2	Detenimiento	0	45
3	Polinómico 4-5-6-7	-15	45
4	Detenimiento	0	90
5	Velocidad Constante	-35	90

Gráficos: Desplazamiento (mm), Velocidad (mm/s), Aceleración (mm/s<sup>2</sup>), Sobresobrecarga (mm/s<sup>3</sup>) vs. Ángulo Rotación (°)

Datos de la Simulación:  
118 Ángulo de Rotación (°)  
2.06 Tiempo (s)  
8.29 Ángulo de Presión (°)

Desplazamiento: 50.00 mm  
Aceleración: 0.00 mm/s<sup>2</sup>

Velocidad: 0.00 mm/s  
Sobresobrecarga: 0.00 mm/s<sup>3</sup>

Coordenadas del puntero:  
Coordenada X (mm): 63, Coordenada Y (mm): -111

Opciones de Visualización:  
 Círculo Base  Curva de Paso  Círculo Trámico  Ejes Coordinados

Velocidad de la Simulación: [Slider]

Detener



# 10 What can do cams?

<http://www.youtube.com/watch?v=2Ah9Mhd6CRA>

<http://www.youtube.com/watch?v=ykx1DettTDM>

<http://www.youtube.com/watch?v=ocfIYUc5bpU>

<http://www.youtube.com/watch?v=ttZJQldd6qM>

<http://www.youtube.com/watch?v=ESRsd1TeOSg&feature=related>

<http://www.youtube.com/watch?v=MgklyL0wkVM>

<http://www.youtube.com/watch?v=0dDiXJsmDOQ>



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- Shigley, J.E. & Uicker, J.J. Teoría de máquinas y mecanismos. McGraw-Hill, 1998
  
- SOFTWARE
  - ▶ SC levas
  
- VIDEOS
  - ▶ <http://www.youtube.com/watch?v=2Ah9Mhd6CRA>
  - ▶ <http://www.youtube.com/watch?v=ykx1DettTDM>
  - ▶ <http://www.youtube.com/watch?v=ocf1YUc5bpU>
  - ▶ <http://www.youtube.com/watch?v=ttZJQldd6qM>
  - ▶ <http://www.youtube.com/watch?v=ESRsd1TeOSg&feature=related>
  - ▶ <http://www.youtube.com/watch?v=MgklyL0wkVM>
  - ▶ <http://www.youtube.com/watch?v=0dDiXJsmDOQ>