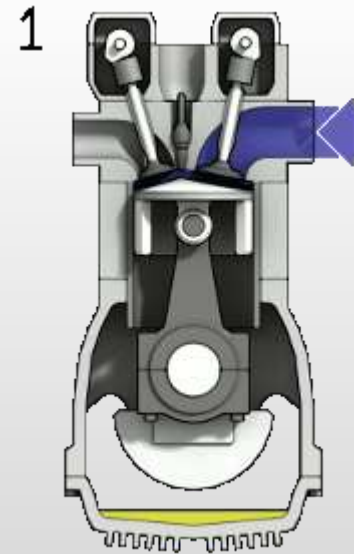


# Kinematics & Dynamics of Linkages

## Lecture 17: Cams

# Introduction and Applications

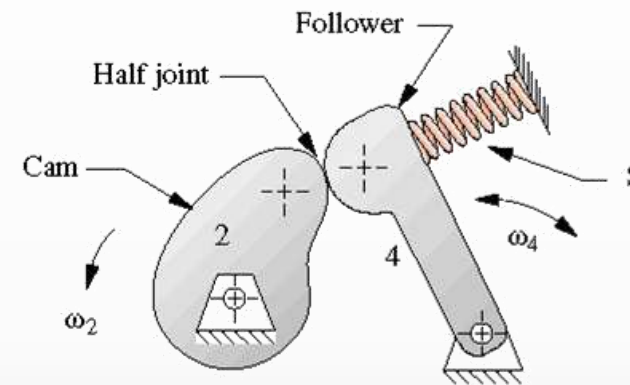
- Cams can be observed in many designs
- The most common type of cam is the one observed in an internal combustion engine



# Cam Design

Cams produce a specific output function

- Usually either cyclic or repeating (timed)
- Cam-followers are 4-bars with variable length links
- Cams systems are function generators
  - When a specific output function is desired
  - We create a curved surface on the cam to generate that function in the motion of the follower



# Classification of cams

## Type of follower motion

- Translating
- Rotating

## Type of follower

- Curved or flat
- Rolling or sliding

## Type of cam

- Radial
- Axial
- Three dimensional

## Type of joint closure

- Force-closed
- Form-closed

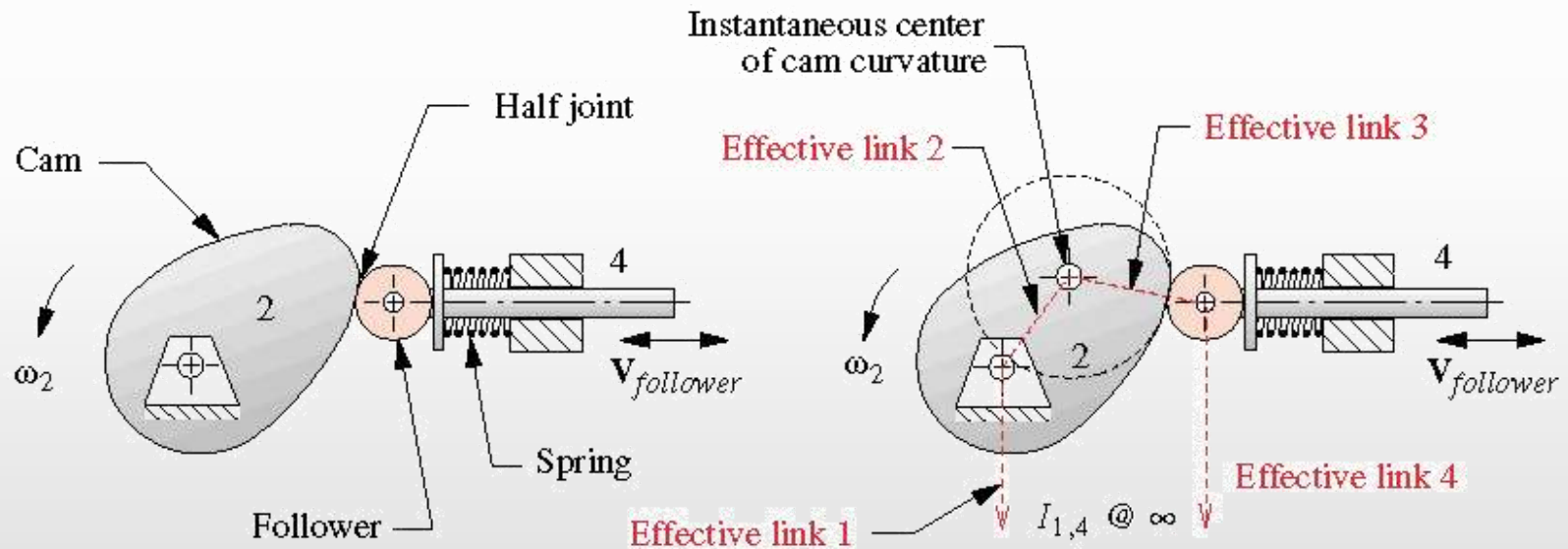
## Type of motion constraints

- Critical extreme position
- Critical path motion

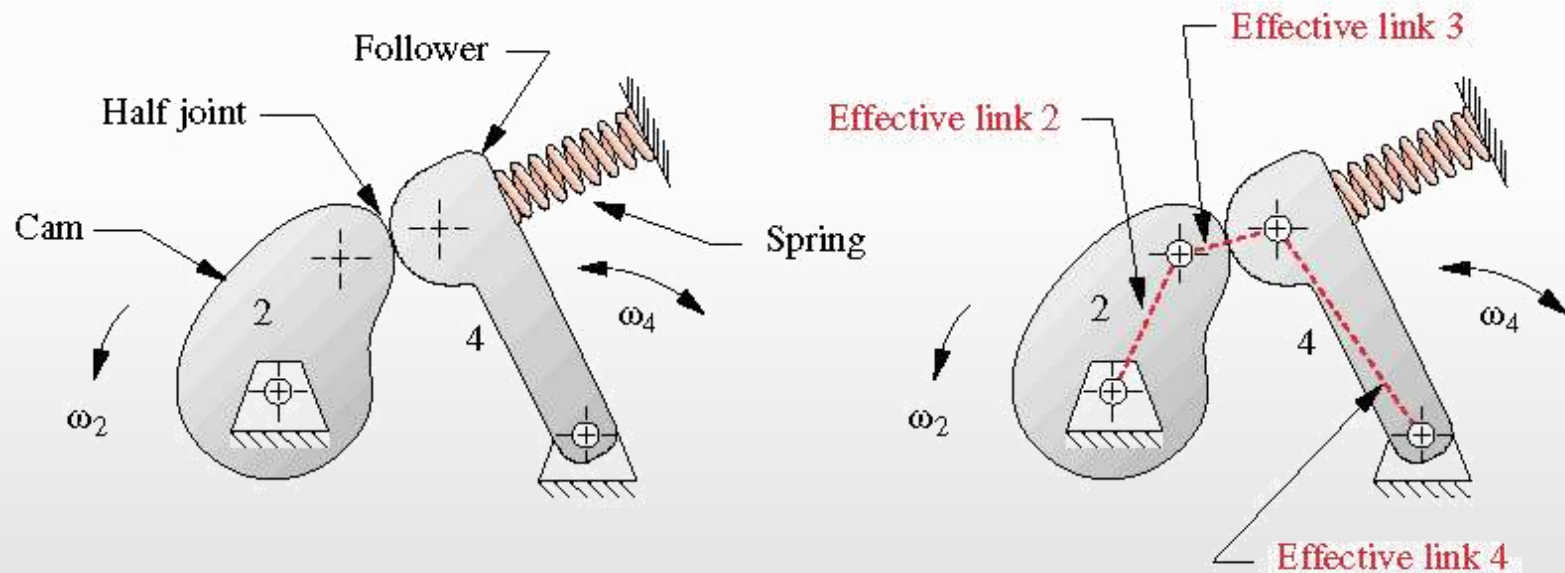
## Type of motion program

- rise-fall (RF)
- rise-fall-dwell (RFD)
- rise-dwell-fall-dwell (RDFD)

# Follower Motion Types: Translating

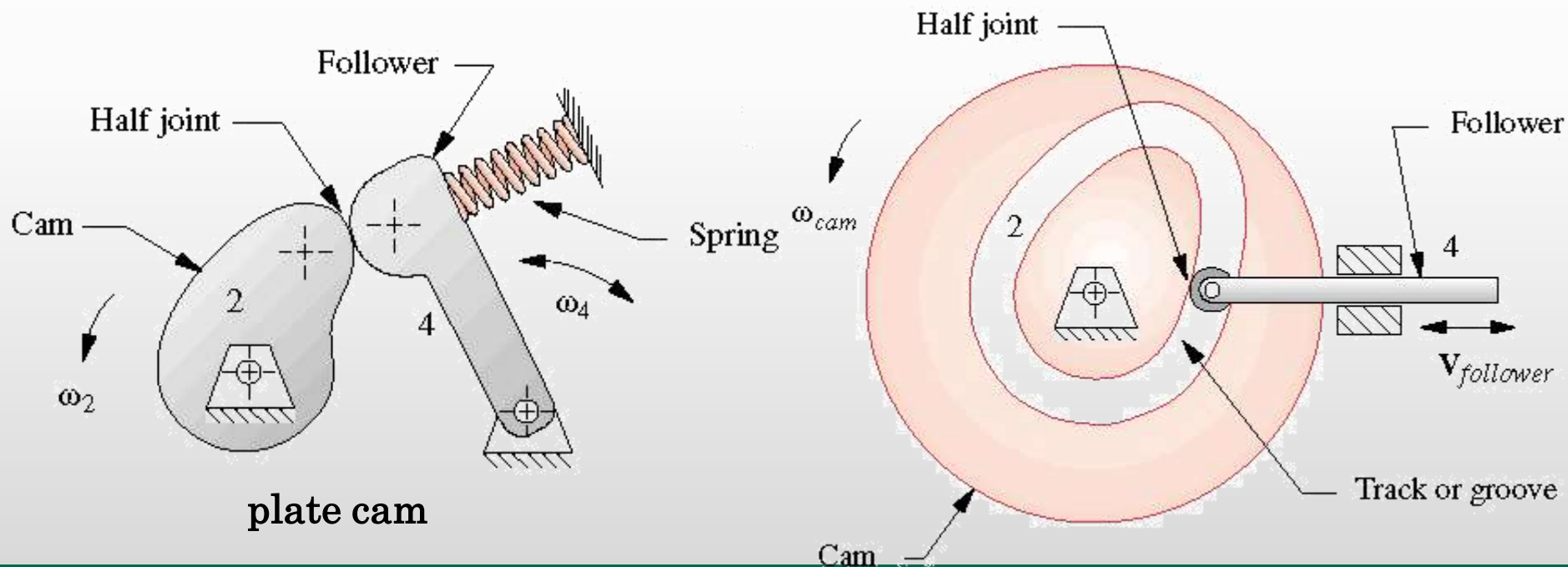


# Follower Motion Types: Rotating



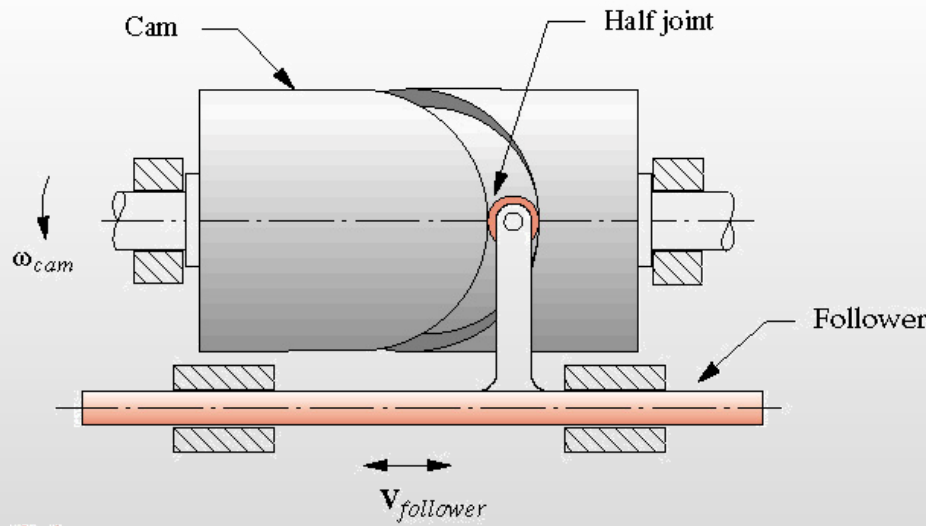
# Type of Cam: Radial

- The follower motion is in a radial direction
- Plate cam : radial, open (force-closed) cam



# Type of Cam: Axial

- Follower moves parallel to the axis of cam rotation
- Face cam : axial, force-closed cam
- Cylindrical or barrel : axial, form-closed cam

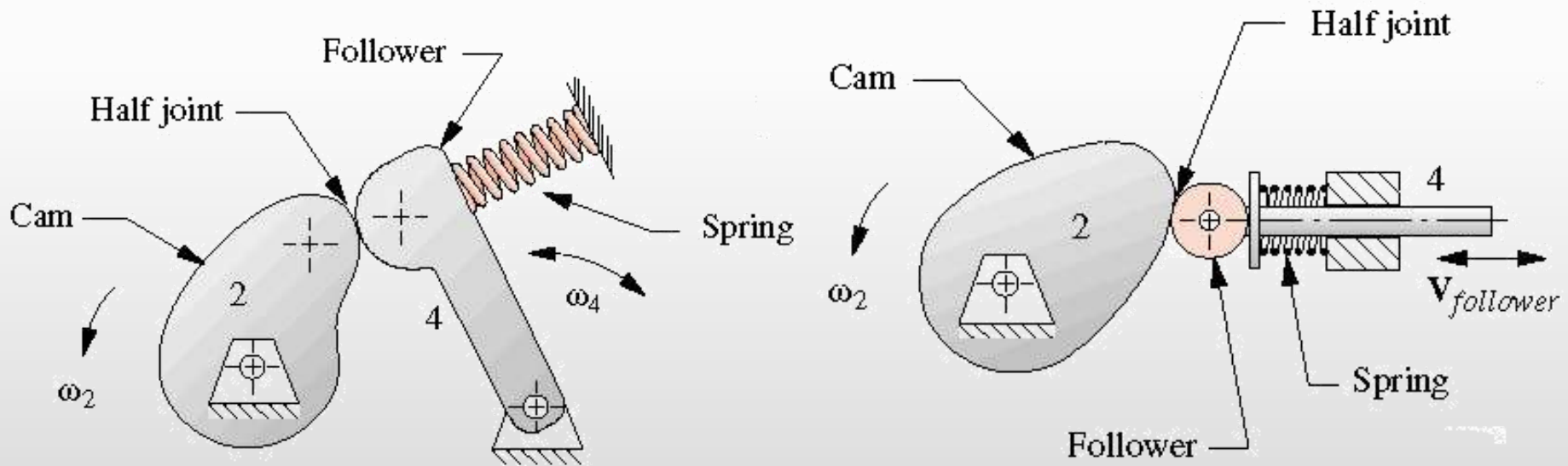


Cylindrical or barrel cam



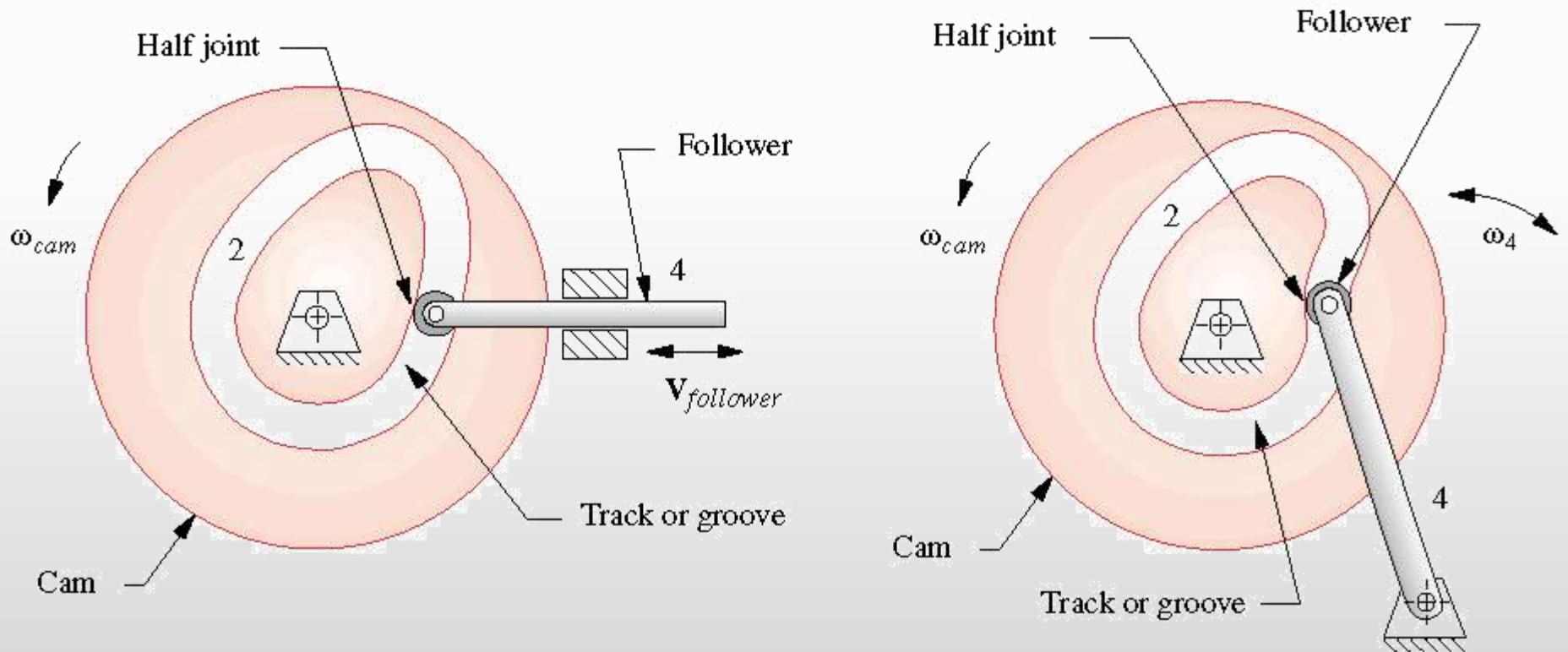
# Type of joint closure: Force-Closed

- Requires an external force be applied to the joint in order to
- keep the two links, cam and follower, physically in contact

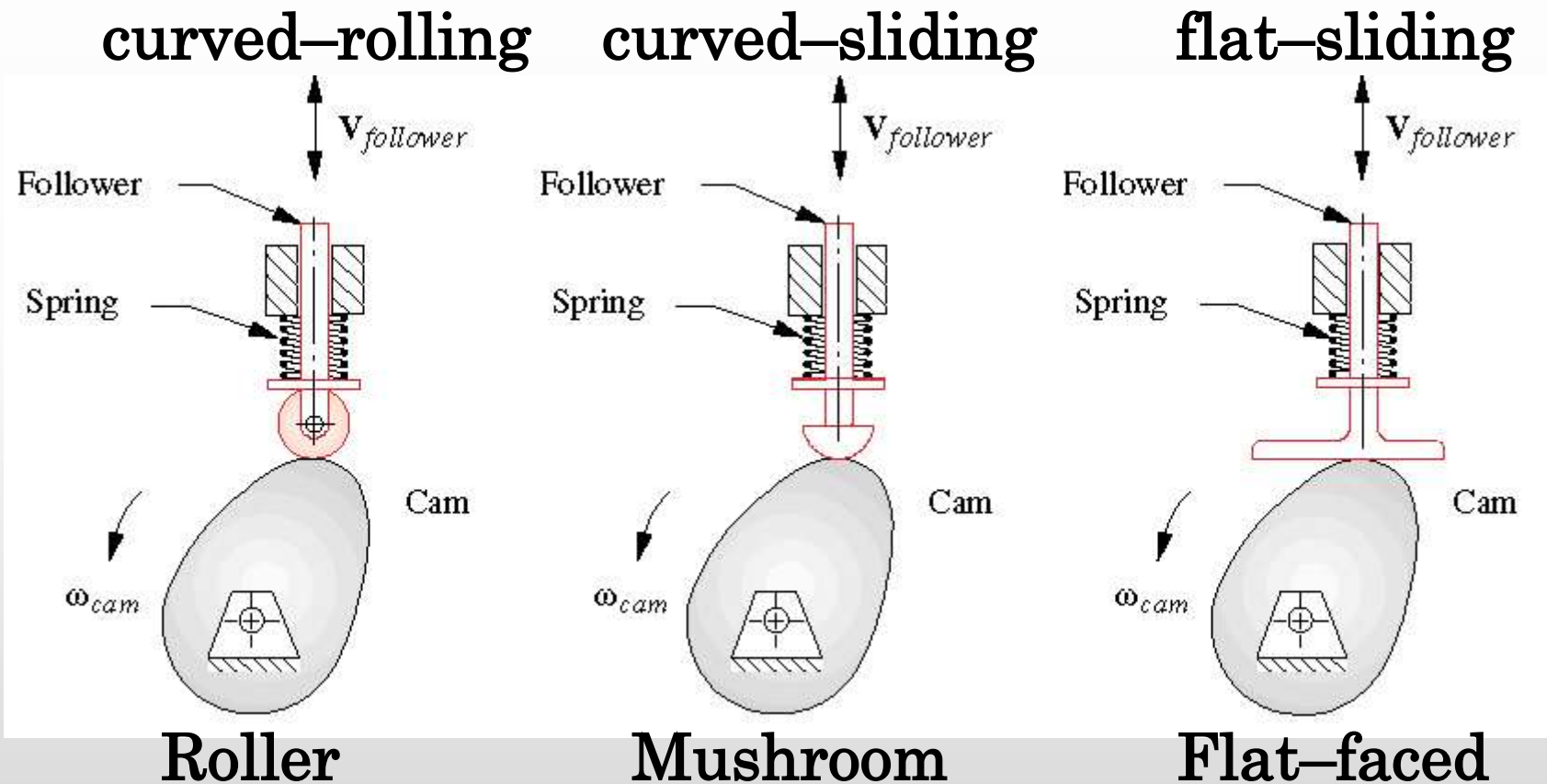


# Type of joint closure: Form-Closed

- Closes the joint by geometry



# Type of followers

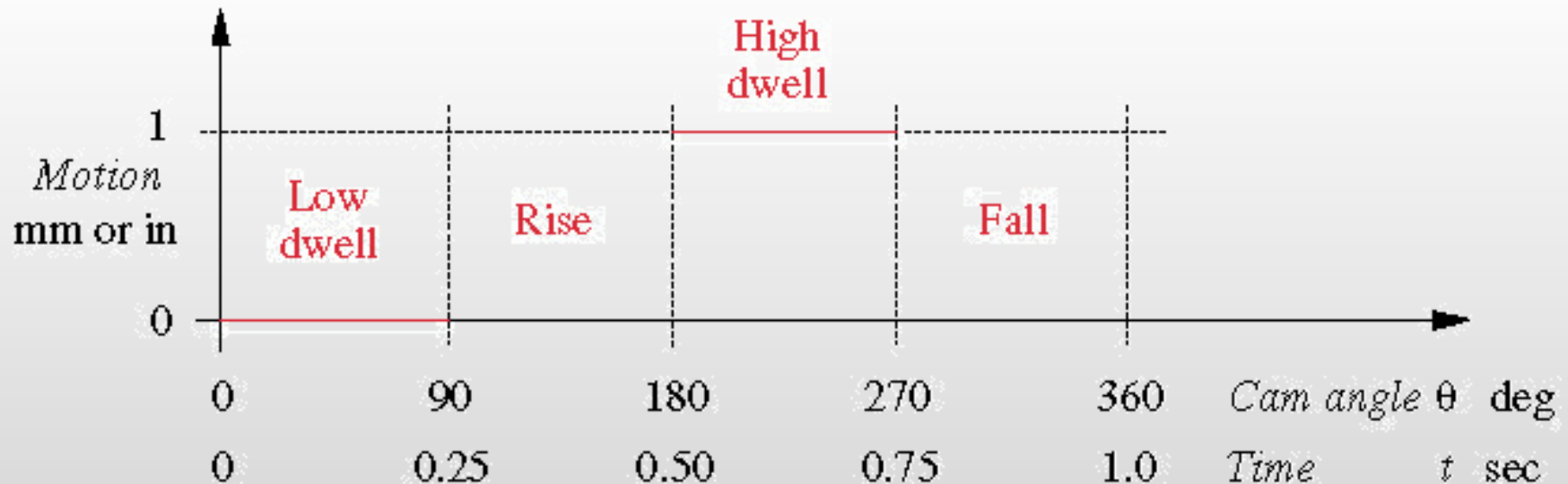


# Type of motion constraints

- Critical Extreme Position (CEP) (most of what we will do)
  - Design specifies start & finish positions of the follower
    - Endpoint specifications
  - No constraints on path motion between extreme positions
- Critical Path Motion (CPM)
  - Path motion defined
  - Function generation

# Type of motion program (motion of follower)

- CEP cases of motion constraint
- Rise-Fall (RF)
- Rise-Fall-Dwell (RFD)
- Rise-Dwell-Fall-Dwell (RDFD) (also called double dwell)
- Dwell = No output motion for a specified period of input motion

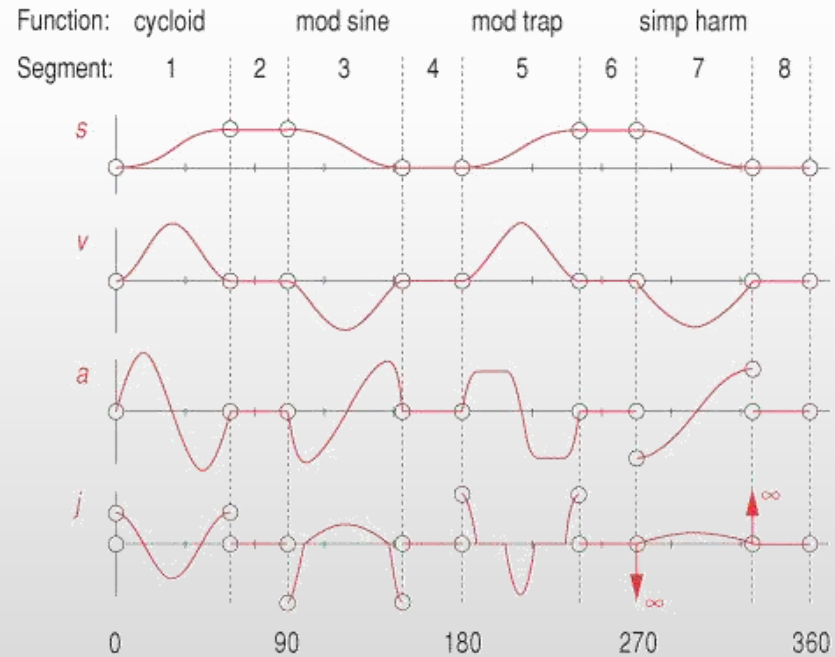


# SVAJ Diagrams

- S = Displacement of the Follower
- V = Velocity of the Follower

- A = Acceleration of the Follower
- J = Jerk of the Follower

Segment Number	Function Used	Start Angle	End Angle	Delta Angle
1	Cycloid rise	0	60	60
2	Dwell	60	90	30
3	ModSine fall	90	150	60
4	Dwell	150	180	30
5	ModTrap rise	180	240	60
6	Dwell	240	270	30
7	SimpHarm fall	270	330	60
8	Dwell	330	360	30



# Define the problem

## Cam Design

- Satisfy some specified follower output with a given camshaft angular velocity –  $\omega$  (normally constant)
- Plot follower displacement as a function of cam angle
- Plot follower velocity – first derivative
- Plot follower acceleration – second derivative
- Plot follower jerk – third derivative

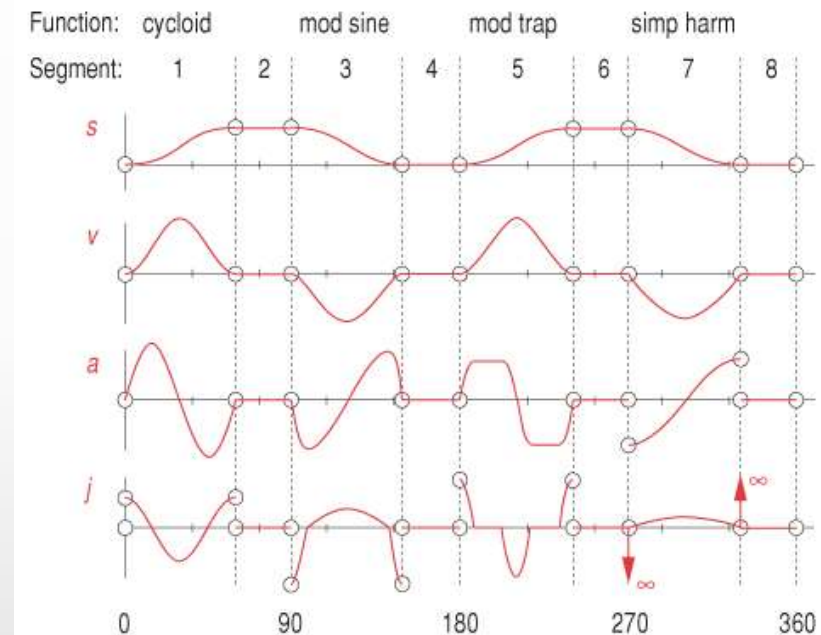
# Example

- Cam Design Example – (double dwell cam)
  - Dwell: Zero displacement for  $90^\circ$  (low dwell)
  - Rise: 1" in  $90^\circ$
  - Dwell: At 1" for  $90^\circ$  (high dwell)
  - Fall: 1" in  $90^\circ$
  - Cam velocity ( $\omega$ ):  $2\pi$  rad/sec = 1 rev/sec
  - Note: Start & stop must be at same position
- Questions
  - Sketch the SVAJ diagrams
  - Draw the cam profile



# Fundamental Law of Cam Design

- The cam function must be continuous through the first and second derivatives of displacement across the entire interval  
The jerk function must be finite across the entire interval
- No discontinuities in displacement, velocity or acceleration functions are allowed (Third order continuity)



# Fundamental Law of Cam Design

- Polynomials are one of the best choices for cams
  - Each differentiation reduces the function by one degree
- We need to start with a 5<sup>th</sup> degree polynomial for the
- displacement function of a double dwell cam
  - $S \rightarrow 5\text{th}$
  - $V \rightarrow 4\text{th}$
  - $A \rightarrow 3\text{rd}$  (cubic)
  - $J \rightarrow 2\text{nd}$  (parabolic)

# Solution : DYNACAM

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**Cam Data**

Cam Omega (rad/sec)  
6.283

No. Segments  
4

Delta Theta (deg)  
1.0

**Follower**

Translating  
 Oscillating

**Starting Angle**  
0 deg

External Force

**Function**

Motion  
 Force

Calc All  
Clear Segs  
Clear All  
Copy Print  
< Back Next >

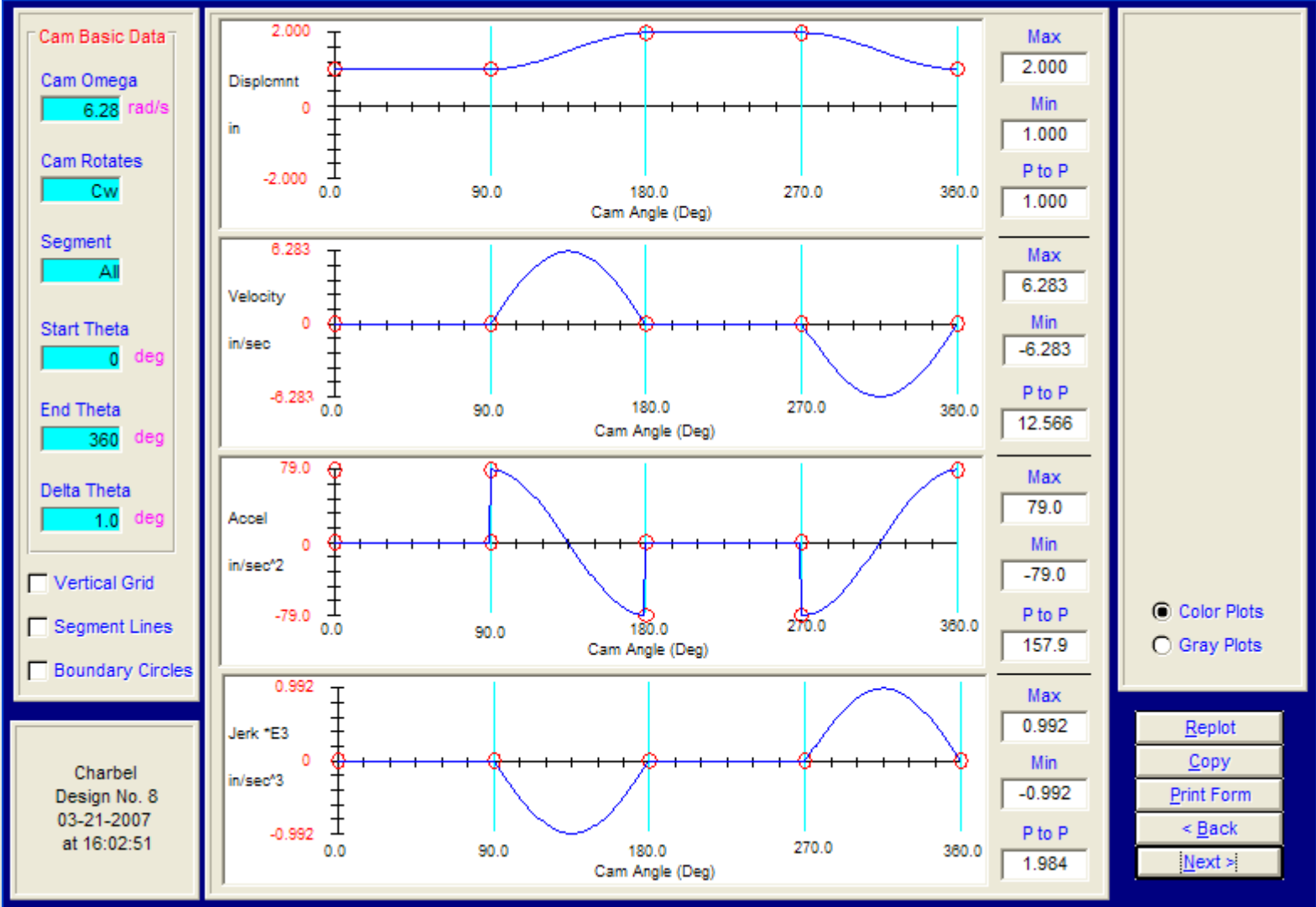
Seg	Angles			Cam Contour		Position (in)	
	Beta	Start	End	Motion	Program	Start	End
1	90	0	90.	Dwell	DW - Dwell	1	1
2	90	90.	180.	Rise	SF - SHM Full	1	2
3	90	180.	270.	Dwell	DW - Dwell	2	2
4	90	270.	360.	Fall	SF - SHM Full	2	1
5							
6							
7							
8							
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10							
11							
12							
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15							
16							
17							
18							
19							
20							

**Examples**

Calc Plot Print  
Calc Plot Print  
Calc Plot Print  
Calc Plot Print

# Solution : DYNACAM

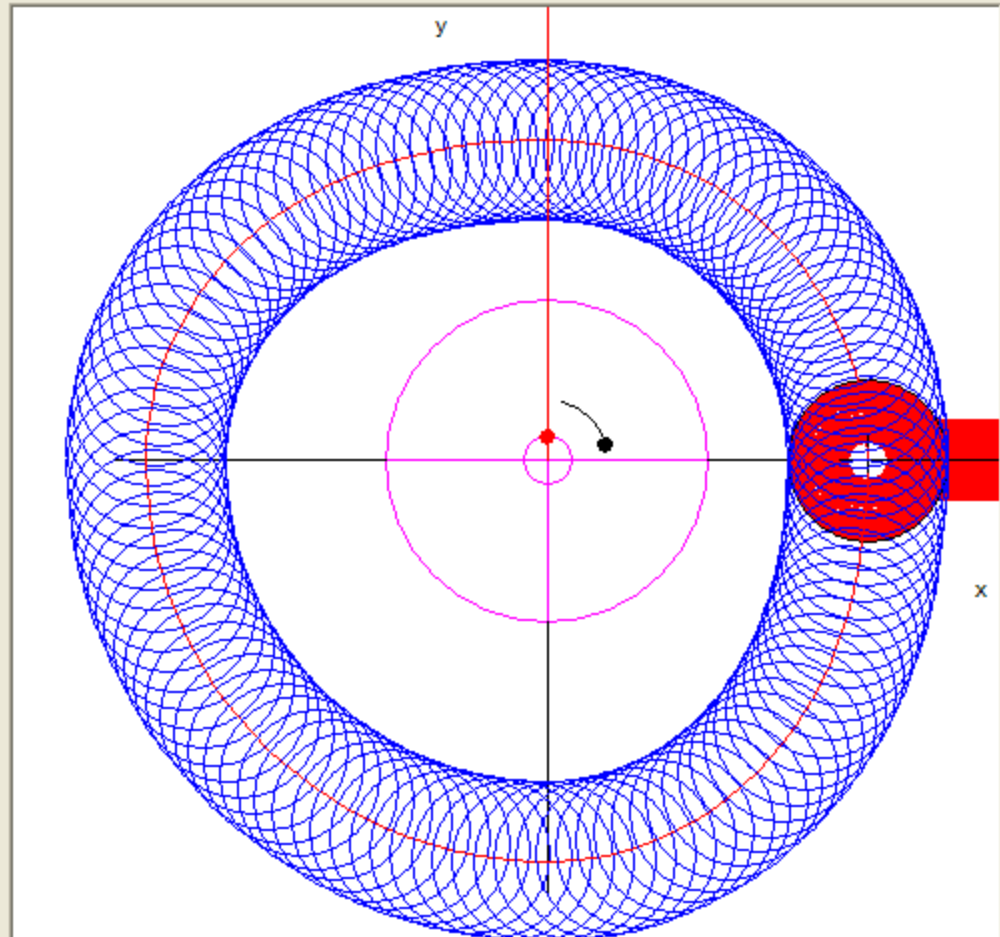
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# Solution : DYNACAM

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Inner Surface  Outer Surface  Follower Path  Cutter Path  Cam vs Machine Zero



Note: Initial follower position is shown at cam zero, not at machine zero. Key is at machine zero.

**Cam Basic Data**

Cam Rotates  
 Cw  Ccw

Cam Omega  
6.28 rad/s

Delta Theta  
1.0 deg

**Cam Angle Data**

At Machine Zero, Keyway is at:  
12 O'clock

Cam Start Angle  
0 deg

Follower Angle  
0 deg

Charbel  
Design No. 8  
03-21-2007  
at 16:04:12

**Cam Size Data**

Prime Radius  
3.000 in

Folwr Radius  
1.000 in

Offset  
0.00 in

Max Phi  
12.6 deg

Min Phi  
-12.6 deg

Min Rho +  
3.57 in

Min Rho -  
None in

Show Cam  
 Show Summary  
 Show Conjugate

ReDraw Cam  
Copy  
Print Form  
< Back  
Next >