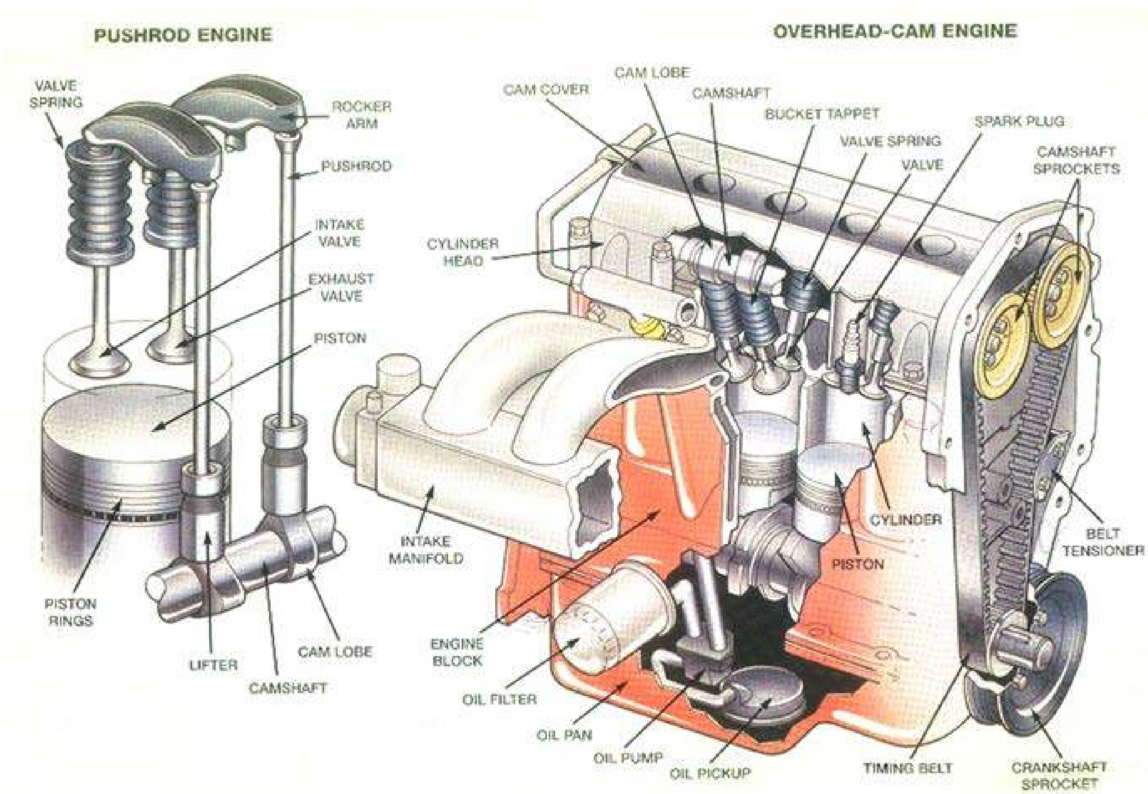
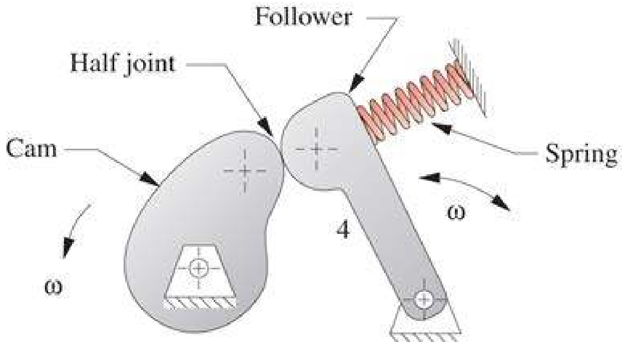
Cams

Cam-follower systems are frequently used in all kinds of machines. <u>The valves in an automobile engine are opened by cams</u>. In the following figure a cam is machined on a shaft. As the cam rotates, a rocker arm imparts a linear reciprocating motion to a valve system. Notice that a spring is used around the valve system. The rocker arm follower needs to maintain contact with the cam surface.

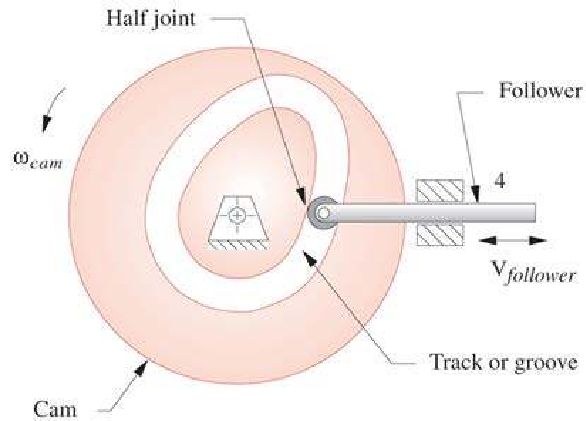


(http://www.nomenclaturo.com/tag/gasoline-engine)

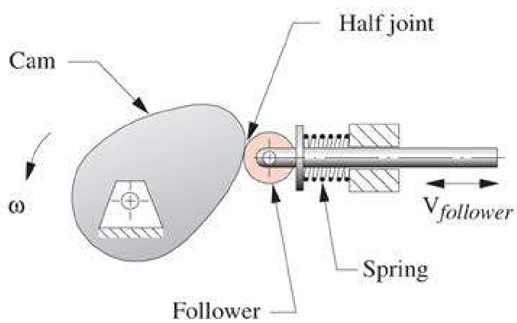
Cam and follower



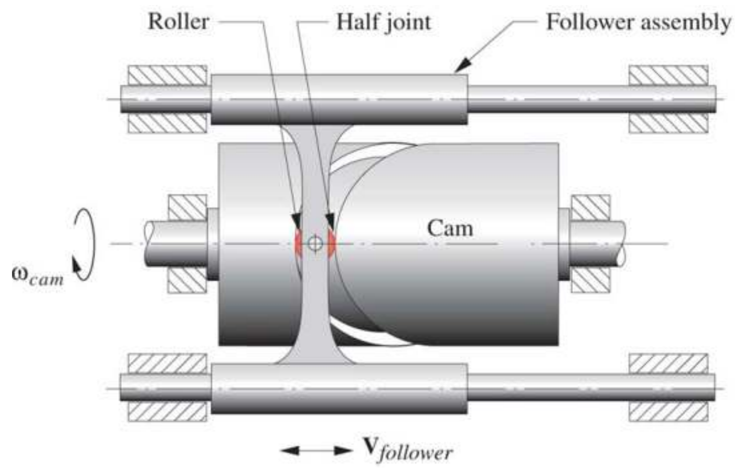
Rotating follower



Translating follower



Translating follower



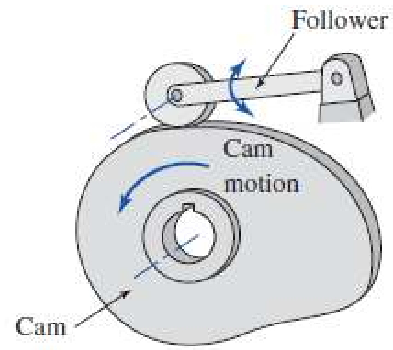
Translating follower

(Design of Machinery, Robert L. Norton, fourth Edition)

Types of cams

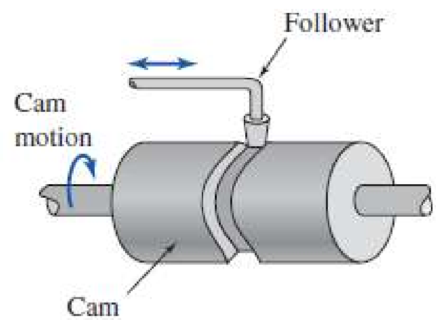
The great majority of cams can be separated into the following ***three general types****:* *(Machines & Mechanisms, Applied Kinematic Analysis, D.H. Myszka, Fourth Edition)*

Plate (or disk) cams *are the simplest and most common type of cam. This type of cam is formed on a plate. The radial distance from the center of the disk is varied throughout the circumference of the cam.*



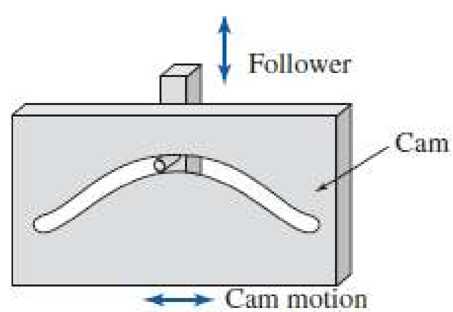
(a) Plate Cam

Cylindrical (or drum) cam *is formed on a cylinder. A groove is cut into the cylinder. A follower moves along the axis of rotation.*



(b) Cylindrical Cam

Linear cam *is formed on a translated block. A groove is cut into the block. The follower rides in the groove. The follower motion is perpendicular to the plane of translation.*



(c) Linear Cam

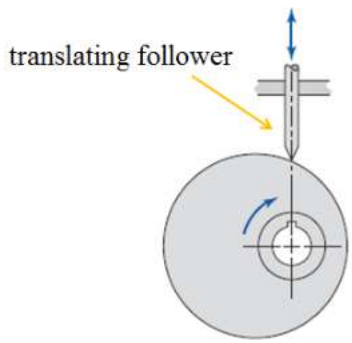
Types of followers

*Followers are classified by their **motion**, **shape** and **position**.*

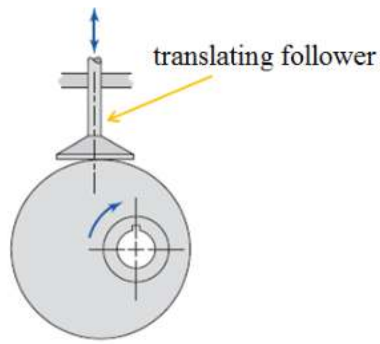
Follower motion

Follower motion can be separated into the following two categories

- ***Translating followers** are constrained to motion in a straight line*

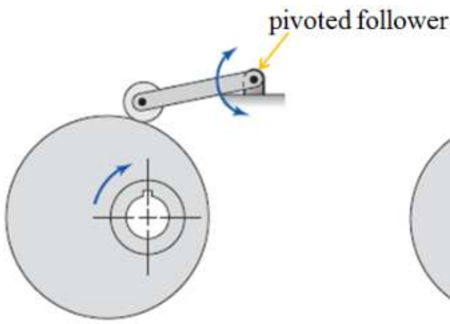


In-line, knife-edge follower

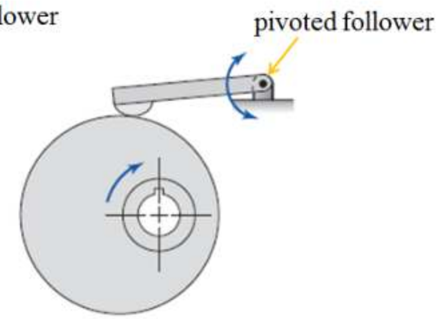


Offset, flat-face follower

- ***Swinging arm (or pivoted) followers** are constrained to rotational motion.*



Pivoted, roller follower



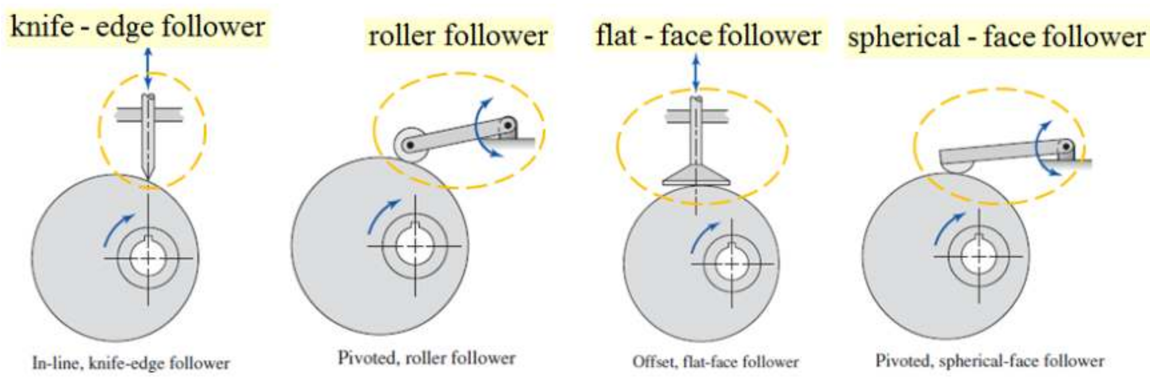
Pivoted, spherical-face follower

Follower shape

A follower shape can be separated into the following four categories:

- *A **knife-edge follower** is the simplest form. But the sharp edge produces high contact stress and wears rapidly.*

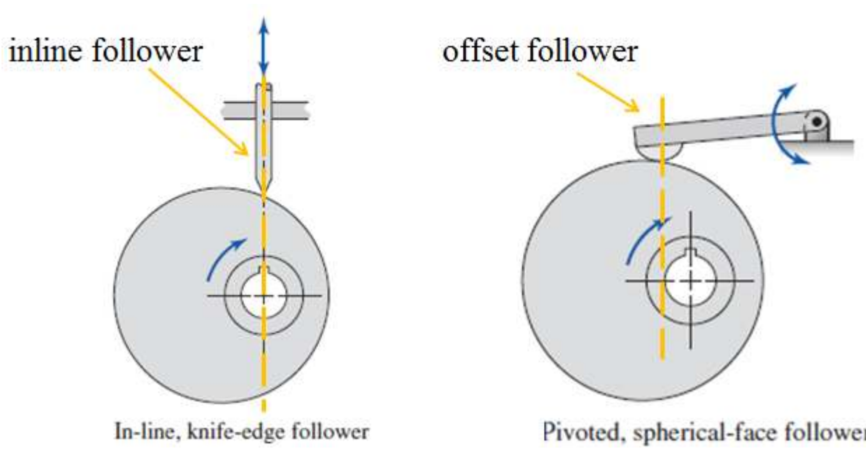
- *A **roller follower** has a separate part. The roller is pinned to the follower stem. As the cam rotates, the roller maintains contact with the cam and rolls on the cam surface. This is the most commonly used follower.*
- *A **flat-face** follower is formed with a large flat surface available to contact the cam.*
- *A **spherical-face** follower is formed with a radius face that contacts the cam.*



Follower position

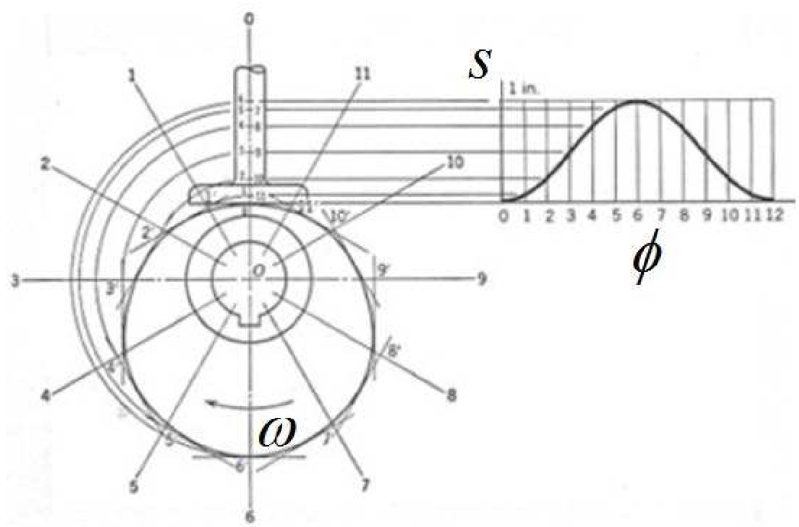
The position of translating followers can be separated into two categories:

- ***In-line follower** shows straight-line motion, such that the line of translation extends through the center of rotation of the cam*
- ***Offset follower** shows straight-line motion, such that the line of the motion is offset from the center of rotation of the cam*

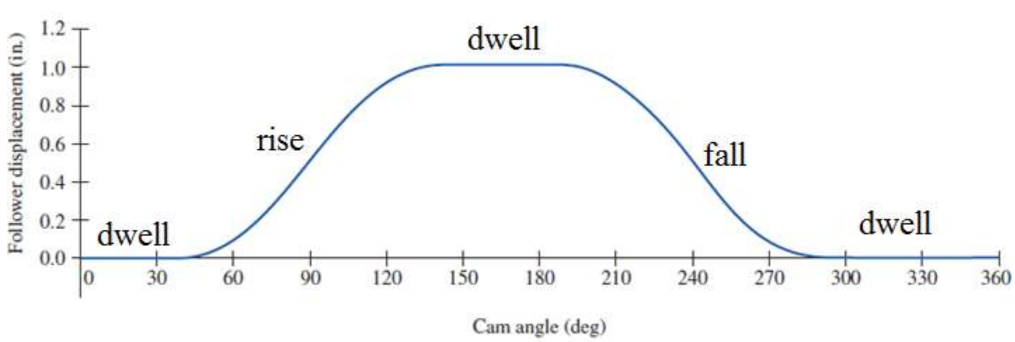


S V A J DIAGRAMS

- *The first task to design a cam is <u>to select the mathematical functions for defining the motion of the follower</u>.*
- *The easiest approach is to unwrap the cam from its circular shape and consider it as a function plotted on the x-y axes.*
- *We plot the <u>displacement function of the follower</u> **s**, its first derivative **v**, its second derivative acceleration **a**, and its third derivative jerk **j** <u>**WITH RESPECT TO CAM SHAFT ANGLE**</u> θ <u>**OR TIME**</u> **t**.*
- *For the constant angular velocity ω of the cam shaft there is a conversion between angular displacement and time:* $\theta = \omega t$



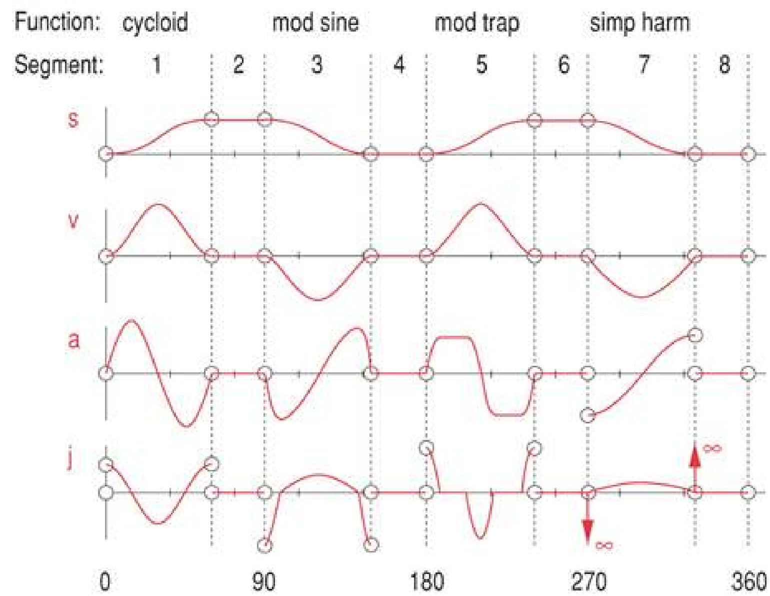
- *<u>The motion of the follower</u> may contain the **Rise(R)**, **Fall (F)**, and **Dwell (D)**, such as **rise-fall**, **rise-fall-dwell**, or **rise- dwell-fall-dwell**.*
  ***Dwells** defined as <u>no output motion</u> for a specified period of input motion.*



✓ *The following figures show the specifications for a* *<u>four-dwell cam</u>* *that has eight segments, RDFDRDFD, and the s,v,a,j curves for the whole cam over 360 degrees of camshaft rotation.*

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

(*a*) Cam program specifications



(*b*) Plots of cam-follower's *s v a j* diagrams

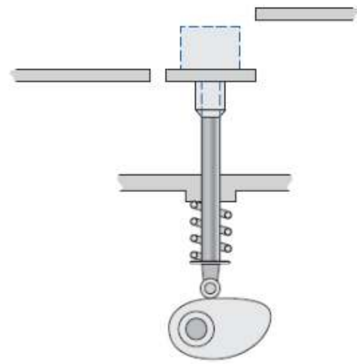
(Design of Machinery, Robert L. Norton, fourth Edition)

A CAM DESIGN BEGINS WITH A DEFINITION OF THE CAM FUNCTIONS AND THEIR s,v,a,j DIAGRAMS.

EXAMPLE 1

A cam is to be used for a platform that will repeatedly lift boxes from a lower conveyor to an upper conveyor. This machine is shown. Plot a displacement diagram and determine the required speed of the cam when the follower motion sequence is as follows:

1. *Rise 2 in. in 1.2 s*
2. *Dwell for 0.3 s*
3. *Fall 1 in. in 0.9 s*
4. *Dwell 0.6 s*
5. *Fall 1 in. in 0.9 s*



(Machines & Mechanisms, Applied Kinematic Analysis, D.H. Myszka, Fourth Edition)

Calculate the time for a full cycle

The total time to complete the full cycle can be found as follows

$$\sum T_i = T_1 + T_2 + T_3 + T_4 + T_5 = 1.2 + 0.3 + 0.9 + 0.6 + 0.9 = 3.9\ s$$

Calculate the rotational speed of the cam

The rotational speed of the cam can be calculated from

$$\omega = \frac{1\,rev}{\sum T_i} = \frac{1}{3.9} = 0.256\ \ rev/s$$

Determine the cam rotation for each follower motion interval

The angular increment of the cam for each follower motion sequence is determined by

$$\beta_i = \omega T_i$$

$$\beta_1 = \omega T_1 = (0.256\, rev/s)(1.2\, s) = 0.307\, rev \rightarrow \beta_1 = 0.307\, rev\left(\frac{360^0}{1\, rev}\right) = 110.5^0$$

$$\beta_2 = (0.256\, rev/s)(0.3\, s) = 0.077\, rev = 27.6^0$$

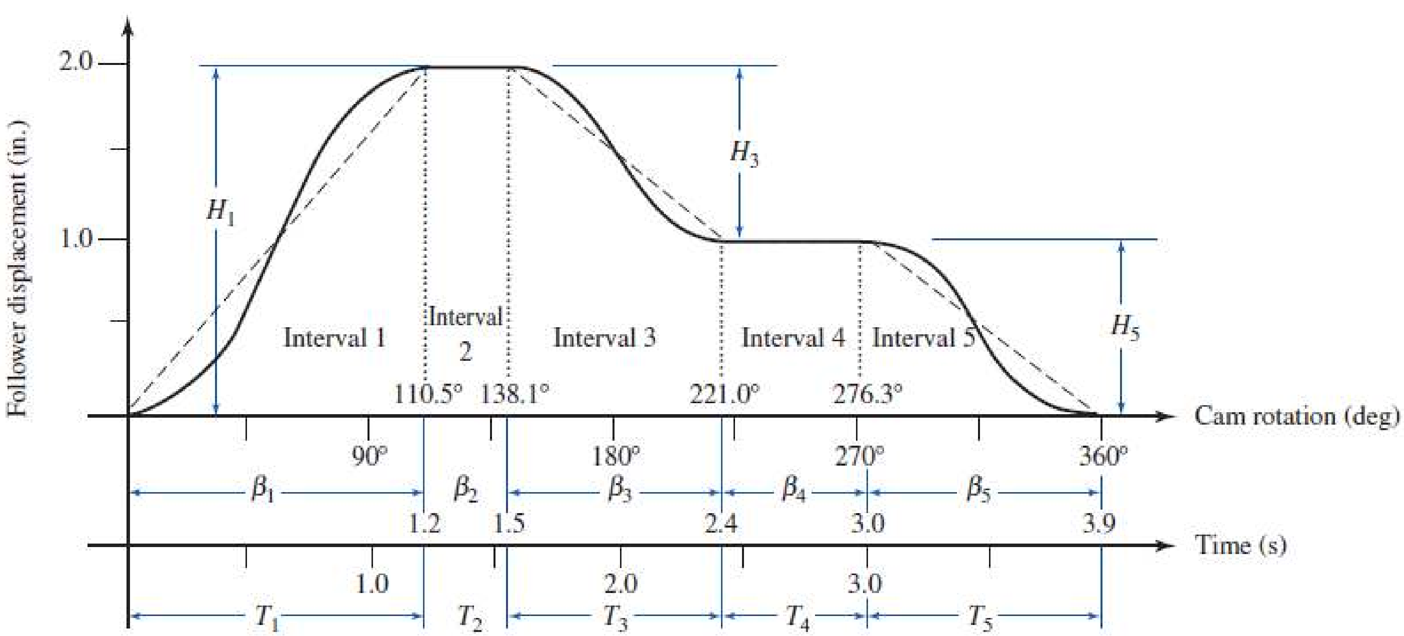
$$\beta_3 = (0.256\, rev/s)(0.9\, s) = 0.230\, rev = 82.9^0$$

$$\beta_4 = (0.256\, rev/s)(0.6\, s) = 0.154\, rev = 55.3^0$$

$$\beta_5 = (0.256\, rev/s)(0.9\, s) = 0.230\, rev = 82.9^0$$

Plot the displacement diagram

The resulting displacement diagram with both cam angle and time displayed on the horizontal axis is shown in the following figure. ***Note that*** *the* *<u>curved displacement profiles during the rise and fall sequences will be explained later</u>.*



H: Total follower displacement during the rise or fall interval under consideration.

T: Total time period for the rise or fall interval under consideration.

β: *Rotation angle of cam during the rise or fall interval under consideration (deg)*

t: time for the interval.

ϕ: *Camshaft angle*

ω: *Speed of the cam*

s: magnitude of instantaneous follower displacement at time t or cam angle β

v: magnitude of instantaneous follower velocity, $v = dv / dt$

a*: magnitude of instantaneous follower acceleration,* $a = dv / dt$