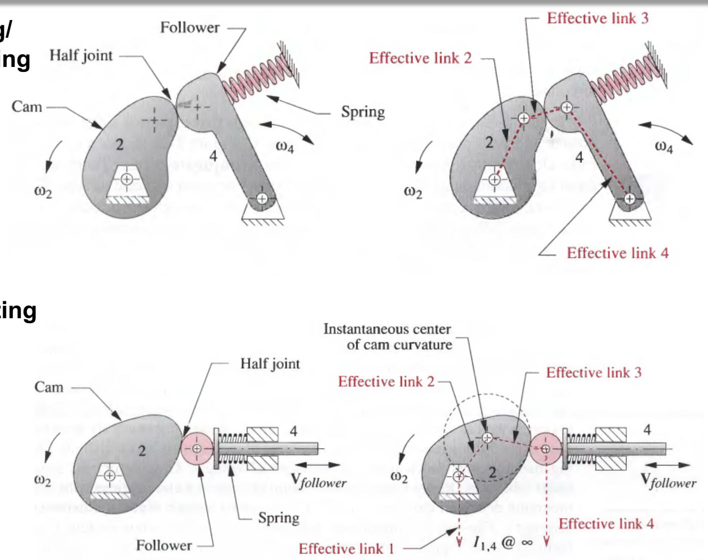
ME 222: Kinematics of Machines and Mechanisms

[L29] Cam Design 1

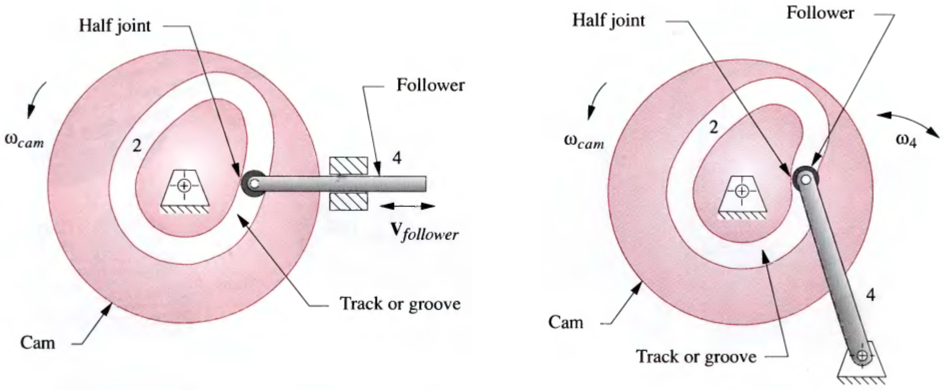
Types of follower motion

Rotating/ Oscillating

Translating



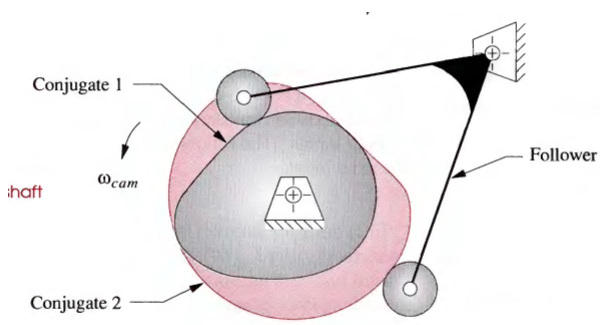
Forced and Formed closed



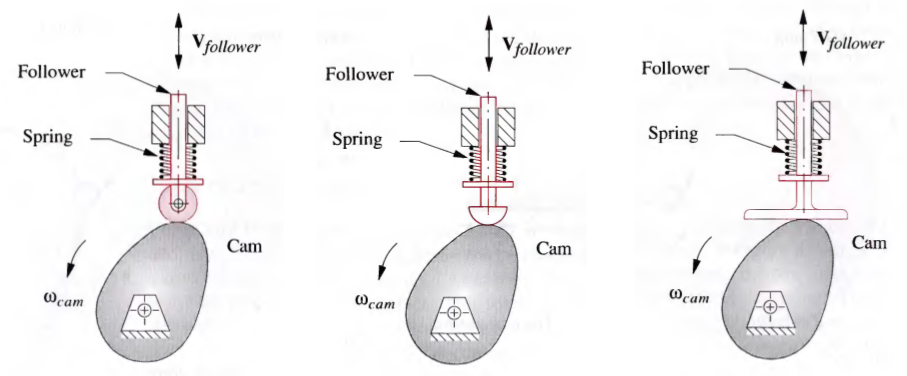
(a) Form-closed cam with translating follower

(b) Form-closed cam with oscillating follower

Formed closed cam and follower

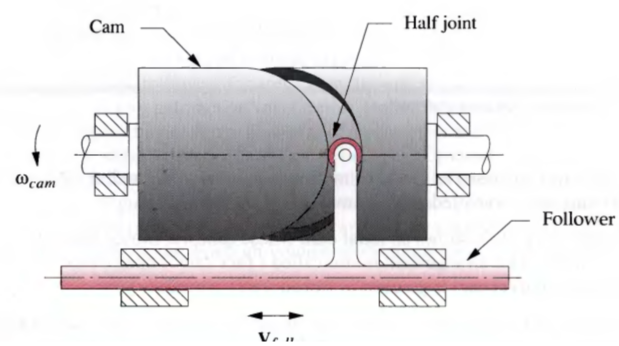


Types of Follower

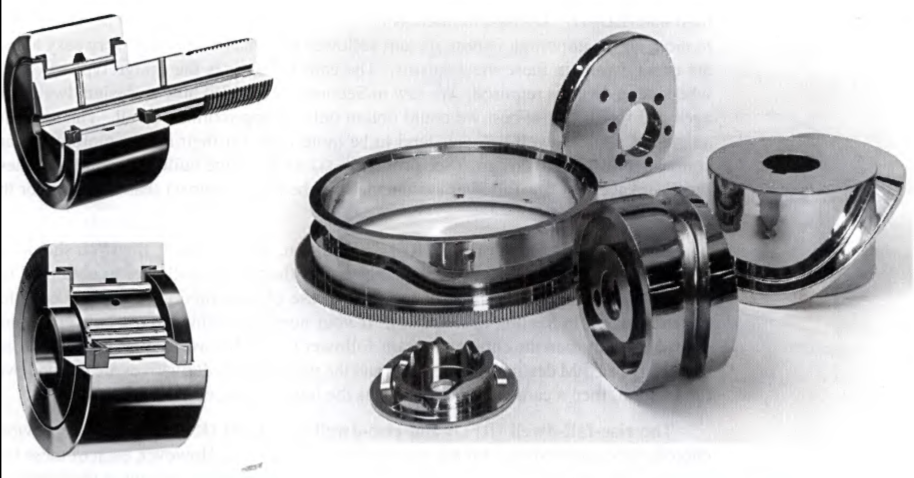


(a) Roller follower (b) Mushroom follower (c) Flat-faced follower

Axial cam with form closed follower



Some Cams and follower



(a) Commercial roller followers
Courtesy of McGill Manufacturing Co. South Bend, IN

(b) Commercial cams of various types
Courtesy of The Ferguson Co. St. Louis, MO

Type of motion constraints

- Critical Extreme Position (CEP)
- Critical Path Motion (CPM)

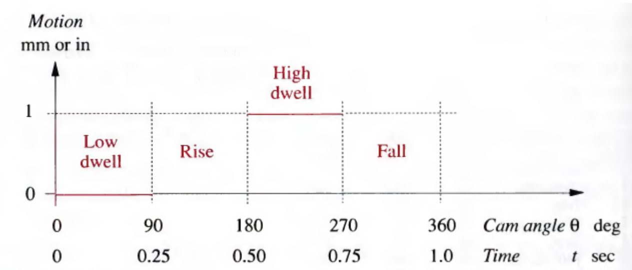
Type of Motion Program

- Rise-Fall
- Rise-Fall-Dwell
- Rise-Dwell-Fall-Dwell

CAM Design

- **Follower function**
- CAM profile

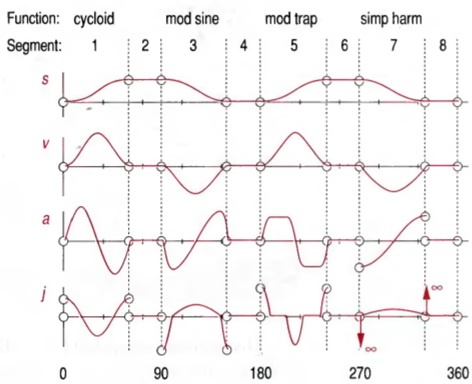
Cam timing diagram



SVAJ DIAGRAMS

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

Naive Cam Design—A Bad Cam.

Problem: Consider the following cam design CEP specification:

dwell	at zero displacement for 90 degrees (low dwell)
rise	1 in (25 mm) in 90 degrees
dwell	at 1 in (25 mm) for 90 degrees (high dwell)
fall	1 in (25 mm) in 90 degrees
cam ω	2π rad/sec = 1 rev/sec

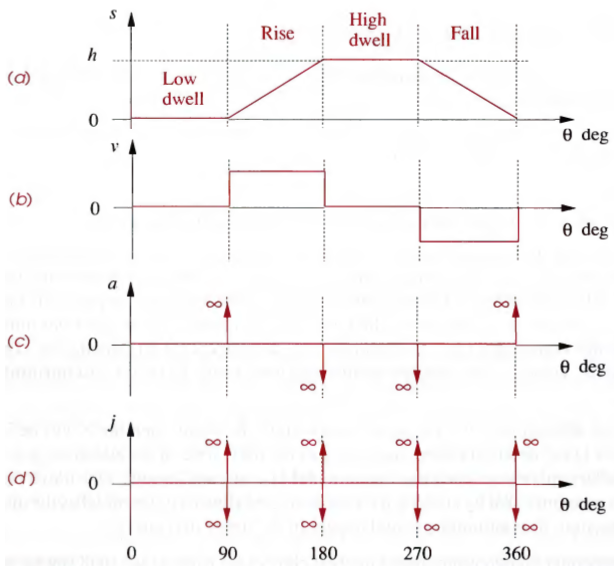
Naive Cam Design—A Bad Cam.

$y = mx + b$

$s = K_v \theta$

$v = K_v = \text{constant}$

$a = 0$



The Fundamental Law of Cam Design

- Any cam designed for operation at other than very low speeds must be designed with the following constraints:
  - The cam function must be continuous through the first and second derivatives of displacement across the entire interval (360 degrees).

Corollary:

- The jerk function must be finite across the entire interval (360 degrees).

Simple Harmonic Motion (SHM)

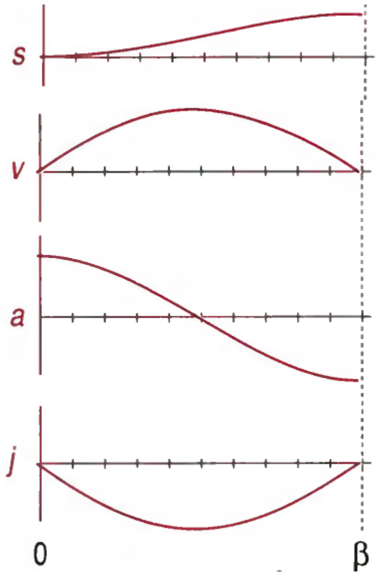
$$s = \frac{h}{2}\left[1 - \cos\left(\pi\frac{\theta}{\beta}\right)\right]$$

$$v = \frac{\pi}{\beta}\frac{h}{2}\sin\left(\pi\frac{\theta}{\beta}\right)$$

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

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

- where h is the total rise, or lift,
- θ is the camshaft angle, and
- β is the total angle of the rise interval.



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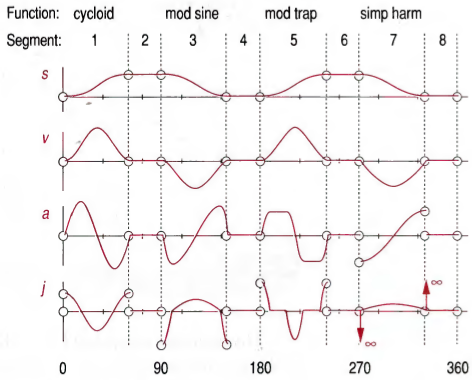
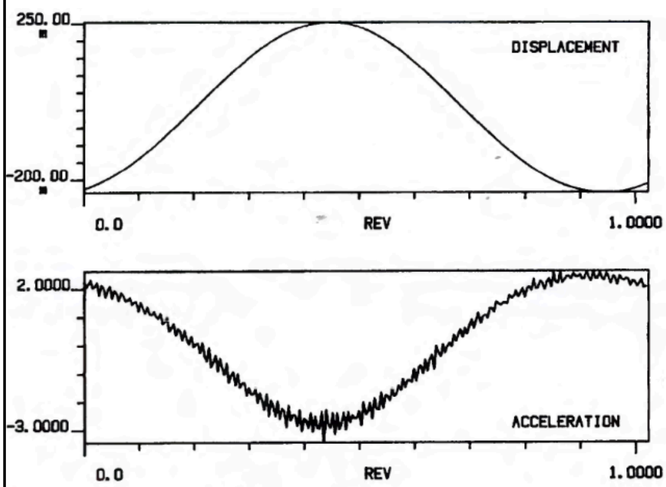
(a) Cam program specifications



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

non-quick-return RF case: rise in 180 and fall in 180°



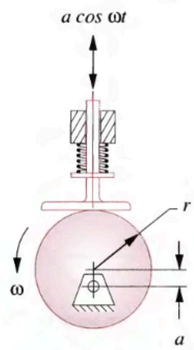
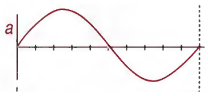


FIGURE 8-10
A flat-faced follower on an eccentric cam has simple harmonic motion

Cycloidal displacement

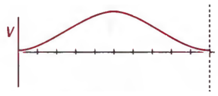
$$a = C\sin\left(2\pi\frac{\theta}{\beta}\right)$$



$$v = -C\frac{\beta}{2\pi}\cos\left(2\pi\frac{\theta}{\beta}\right) + k_1$$

$$v = 0 \text{ at } \theta = 0, \quad k_1 = C\frac{\beta}{2\pi}$$

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

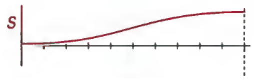


$$s = C\frac{\beta}{2\pi}\theta - C\frac{\beta^2}{4\pi^2}\sin\left(2\pi\frac{\theta}{\beta}\right) + k_2$$

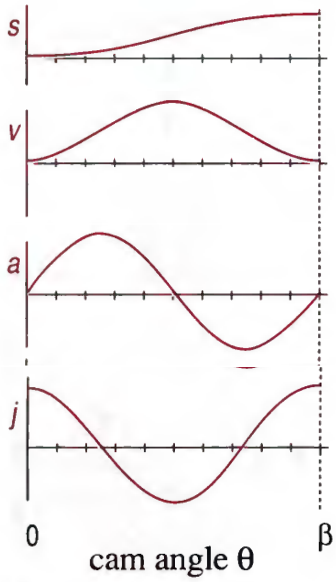
$$s = 0 \text{ at } \theta = 0, \qquad k_2 = 0$$

$$s = h \text{ at } \theta = \beta, \quad C = 2\pi\frac{h}{\beta^2}$$

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



Cycloidal displacement



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

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

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

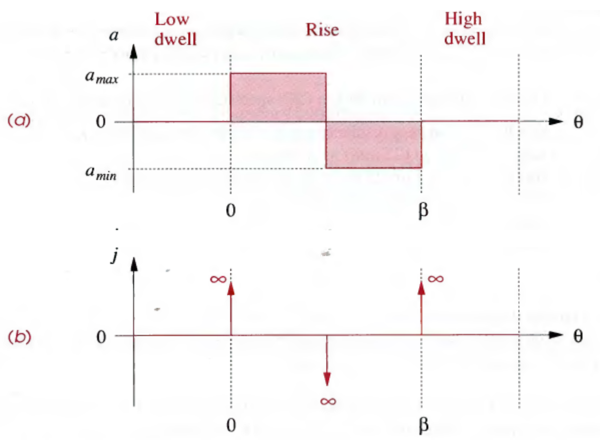
$$j = 4\pi^2\frac{h}{\beta^3}\cos\left(2\pi\frac{\theta}{\beta}\right)$$

Combined functions

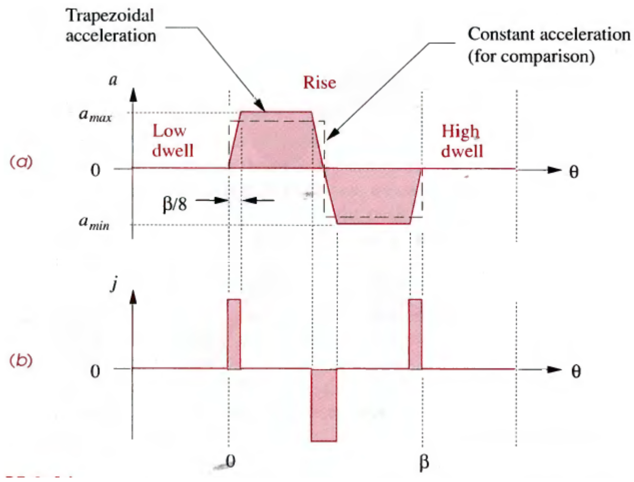
- Dynamic force is proportional to acceleration.
- To minimize dynamic forces,
  - should minimize the magnitude of the acceleration
  - keep it continuous.
- Kinetic energy is proportional to velocity squared.
  - We also would like to minimize stored kinetic energy,

Constant Acceleration

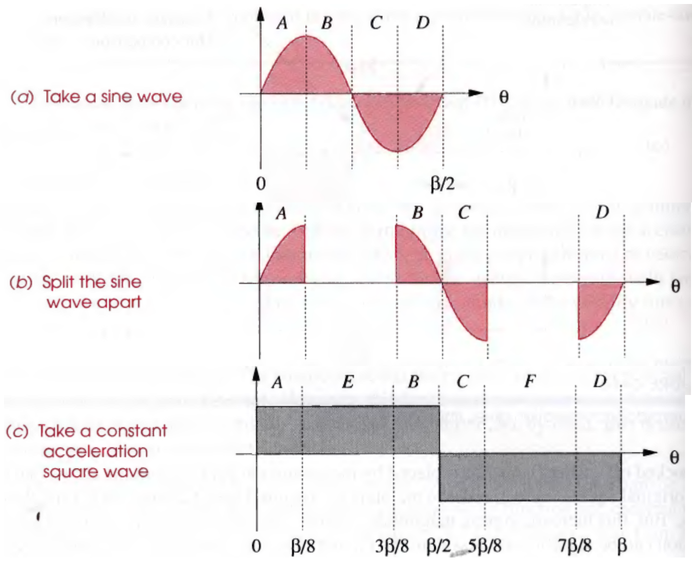
- Function that minimize the peak value of the magnitude of the acceleration for a given area in a given interval



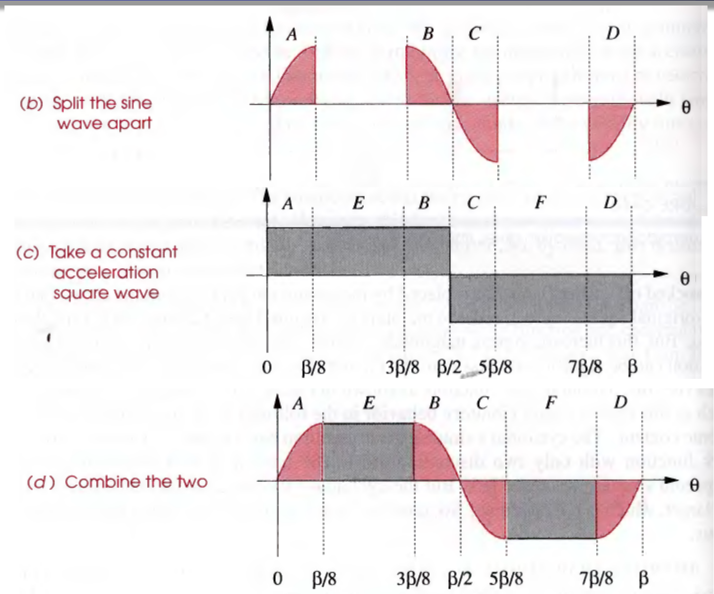
Trapezoidal Acceleration



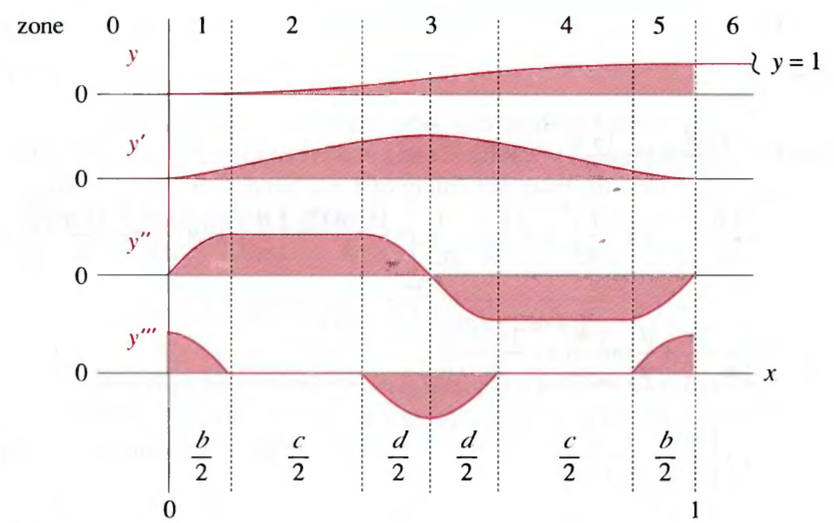
Modified Trapezoidal Acceleration



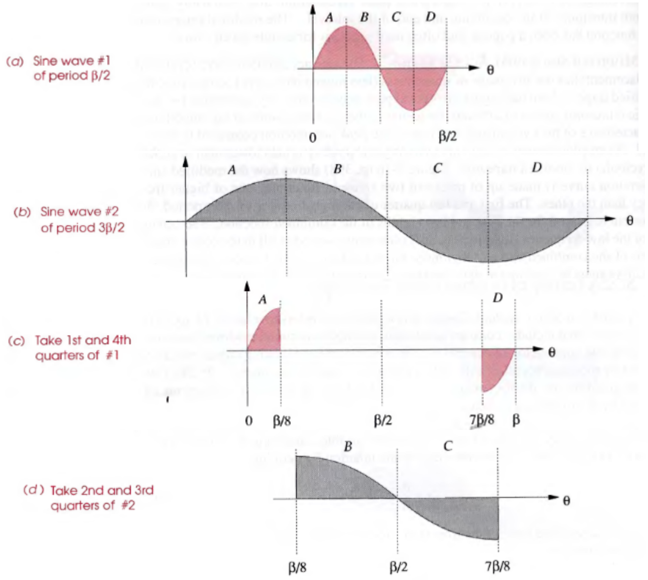
Modified Trapezoidal Acceleration



Modified Trapezoidal Acceleration



Modified Sinusoidal Acceleration



Modified Sinusoidal Acceleration

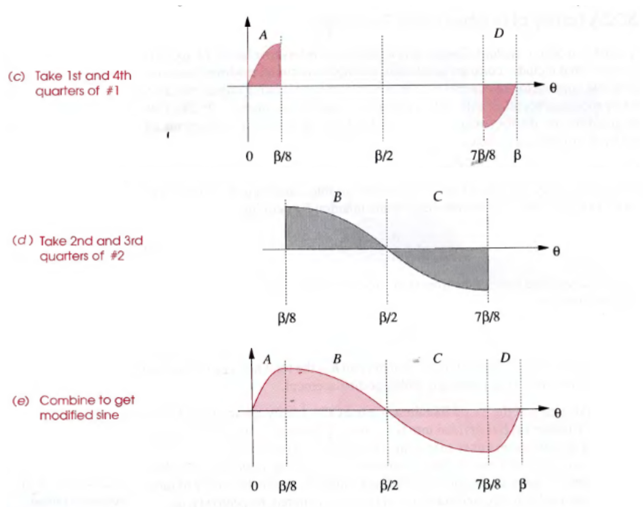


TABLE 8-3 Factors for Peak Velocity and Acceleration of Some Cam Functions

Function	Max. Veloc.	Max. Accel.	Max. Jerk	Comments
Constant accel.	$2.000\ h/\beta$	$4.000\ h/\beta^2$	Infinite	∞ jerk—not acceptable
Harmonic disp.	$1.571\ h/\beta$	$4.945\ h/\beta^2$	Infinite	∞ jerk—not acceptable
Trapezoid accel.	$2.000\ h/\beta$	$5.300\ h/\beta^2$	$44\ h/\beta^3$	Not as good as mod. trap.
Mod. trap. accel.	$2.000\ h/\beta$	$4.888\ h/\beta^2$	$61\ h/\beta^3$	Low accel. but rough jerk
Mod. sine accel.	$1.760\ h/\beta$	$5.528\ h/\beta^2$	$69\ h/\beta^3$	Low veloc., good accel
Cycloidal disp.	$2.000\ h/\beta$	$6.283\ h/\beta^2$	$40\ h/\beta^3$	Smooth accel. and jerk.

Thank you

Next Class: Cam Design