Cams

- A ***cam*** is a rotating machine element which gives reciprocating or oscillating motion to another element known as ***follower*****.**
- The cam and the follower have a line contact and forms a higher pair.
- The cams are rotated at uniform speed by a shaft, but the follower motion is predetermined and will be according to the shape of the cam.
- The cams are widely used for operating
  - inlet and exhaust valves of internal combustion engines,
  - automatic attachment of machineries,
  - paper cutting machines,
  - spinning and weaving textile machineries,
  - feed mechanism of automatic lathes

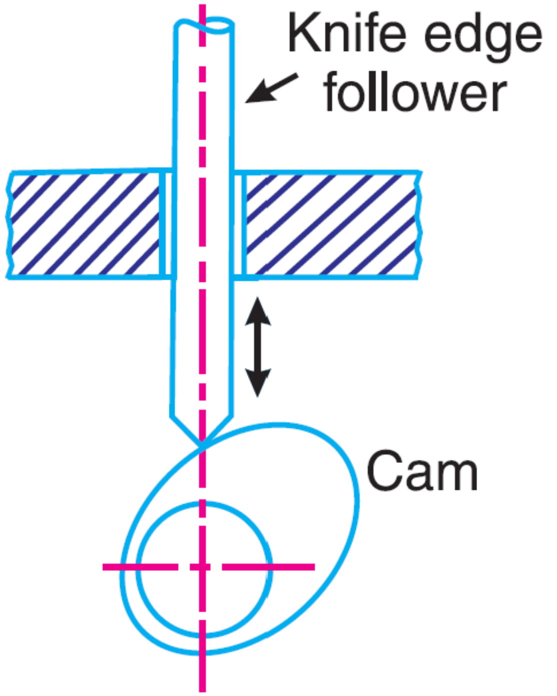
Classification of Followers

- ***According to the surface in contact***

1. *Knife edge follower*

The contacting end of the follower has a sharp knife edge, it is called a knife edge follower.

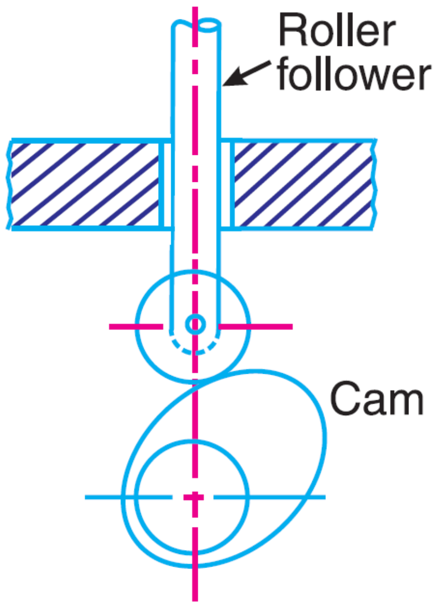
The sliding motion takes place between the contacting surfaces (the knife edge and the cam surface)



2. *Roller follower*

The contacting end of the follower is a roller, it is called a roller follower.

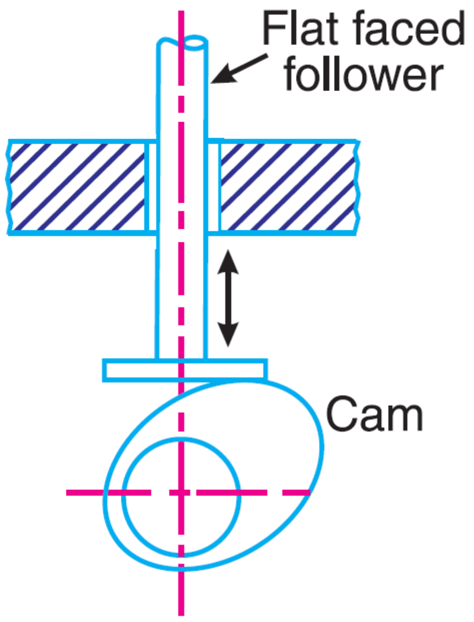
The rolling motion takes place between the contacting surfaces (the roller and the cam)

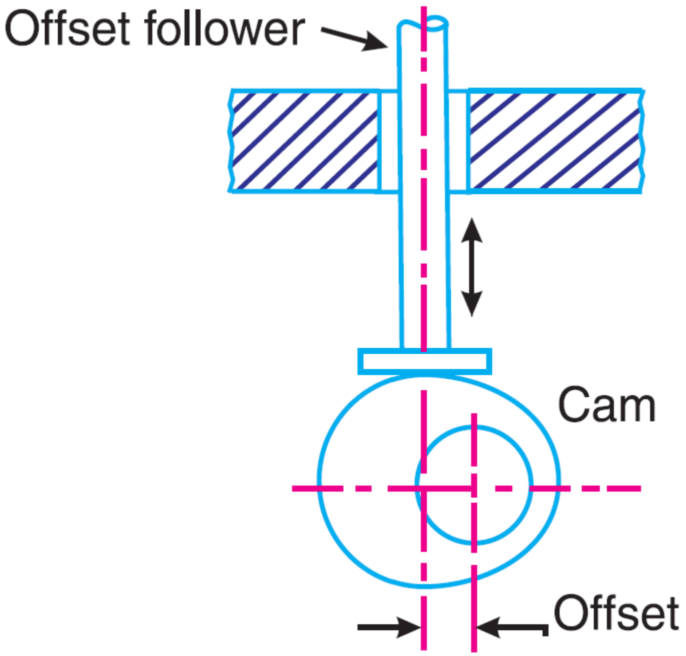


3. *Flat faced follower*

The contacting end of the follower is a perfectly flat face, it is called a flat-faced follower.

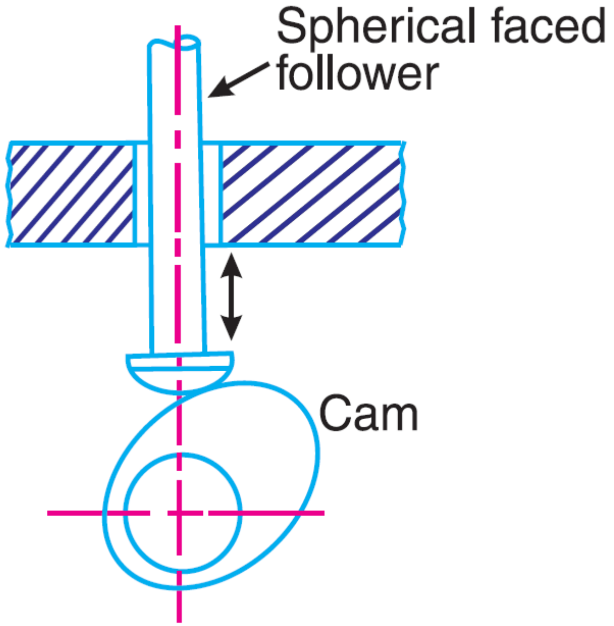
The relative motion between these surfaces is sliding motion.

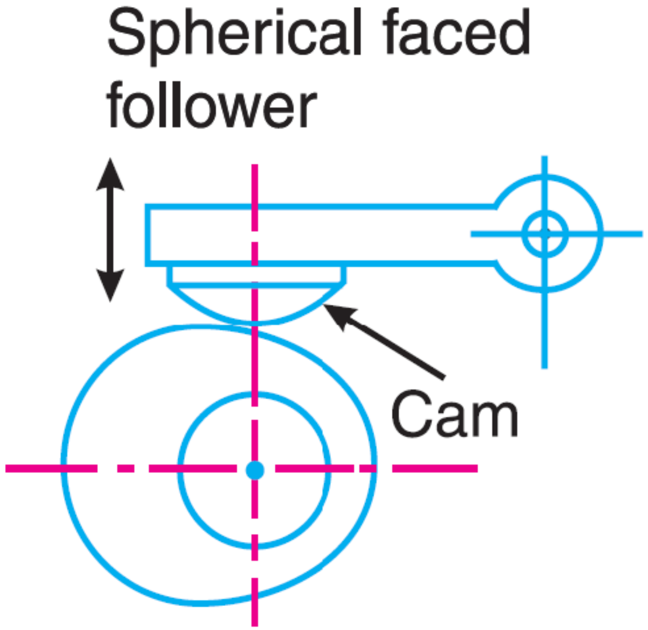




4. *Spherical faced follower*

The contacting end of the follower is of spherical shape, it is called a spherical faced follower.





- ***According to the motion of the follower***

1. *Reciprocating or translating follower*

The follower reciprocates in guides as the cam rotates uniformly.

2. *Oscillating or rotating follower*

The uniform rotary motion of the cam is converted into predetermined oscillatory motion of the follower.

- ***According to the path of motion of the follower***

1. *Radial follower*

The motion of the follower is along an axis passing through the centre of the cam

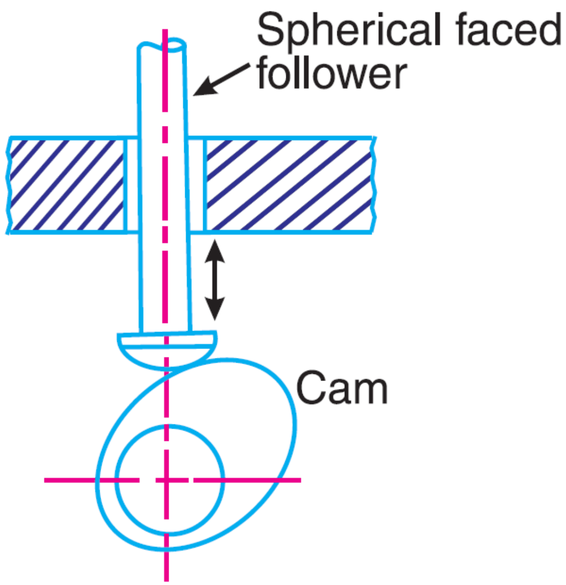
2. *Off-set follower*

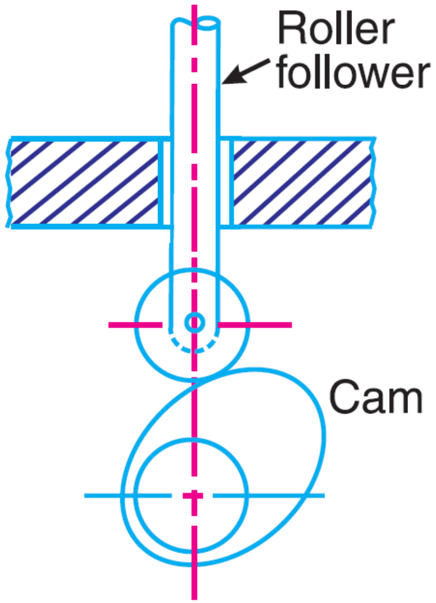
The motion of the follower is along an axis away from the axis of the cam centre

Classification of Cams

- ***Radial or disc cam*.**

In radial cams, the follower reciprocates or oscillates in a direction perpendicular to the cam axis.

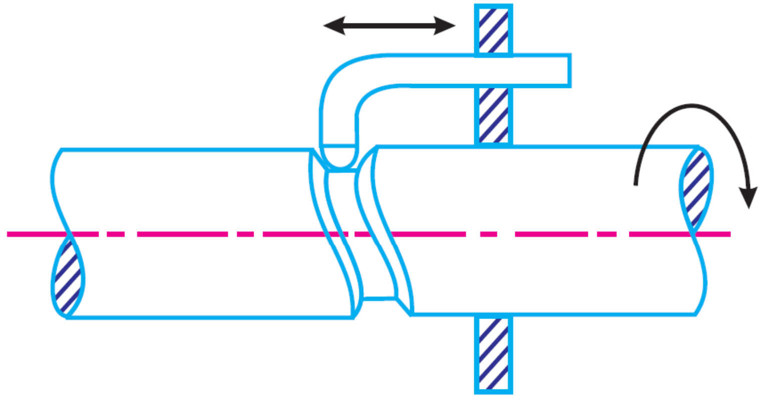




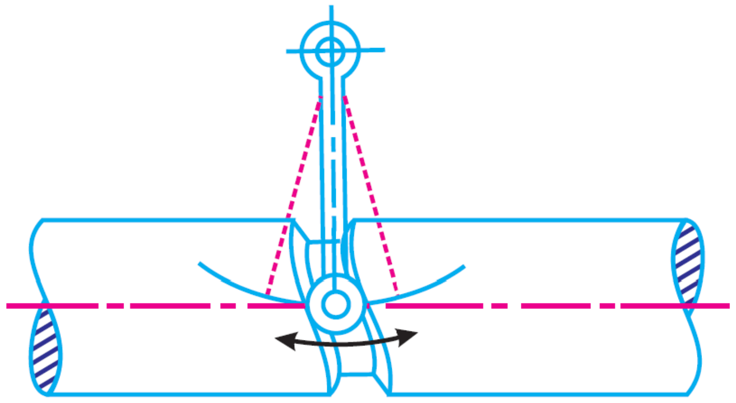
- ***Cylindrical cam***

In cylindrical cams, the follower reciprocates or oscillates in a direction parallel to the cam axis.

The follower rides in a groove at its cylindrical surface.



(*a*) Cylindrical cam with reciprocating follower.



(*b*) Cylindrical cam with oscillating follower.

Terms Used in Radial Cams

Base circle - It is the smallest circle that can be drawn to the cam profile.

Trace point - It is a reference point on the follower and is used to generate the *pitch curve*.

In case of knife edge follower, the knife edge represents the trace point and the pitch curve corresponds to the cam profile.

In a roller follower, the centre of the roller represents the trace point.

Pressure angle - It is the angle between the direction of the follower motion and a normal to the pitch curve.

Pitch point - It is a point on the pitch curve having the maximum pressure angle.

Pitch circle - It is a circle drawn from the centre of the cam through the pitch points.

Pitch curve - It is the curve generated by the trace point as the follower moves relative to the cam.

For a knife edge follower, the pitch curve and the cam profile are same.

For a roller follower, they are separated by the radius of the roller.

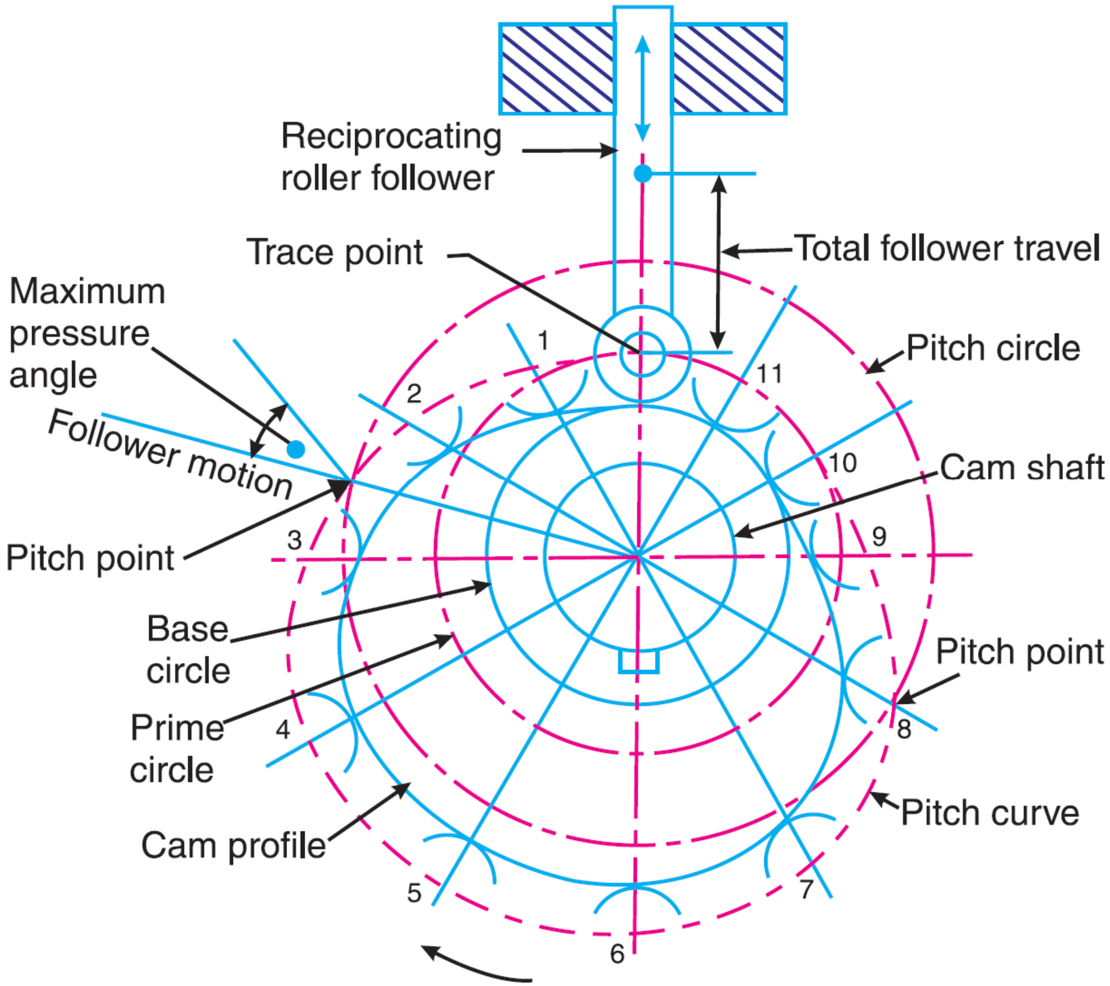
***Prime circle* - It is the smallest circle that can be drawn from the centre of the cam and tangent to the pitch curve.**

For a knife edge and a flat face follower, the prime circle and the base circle are identical.

For a roller follower, the prime circle is larger than the base circle by the radius of the roller.

***Lift or stroke* - It is the maximum travel of the follower from its lowest position to the topmost position.**

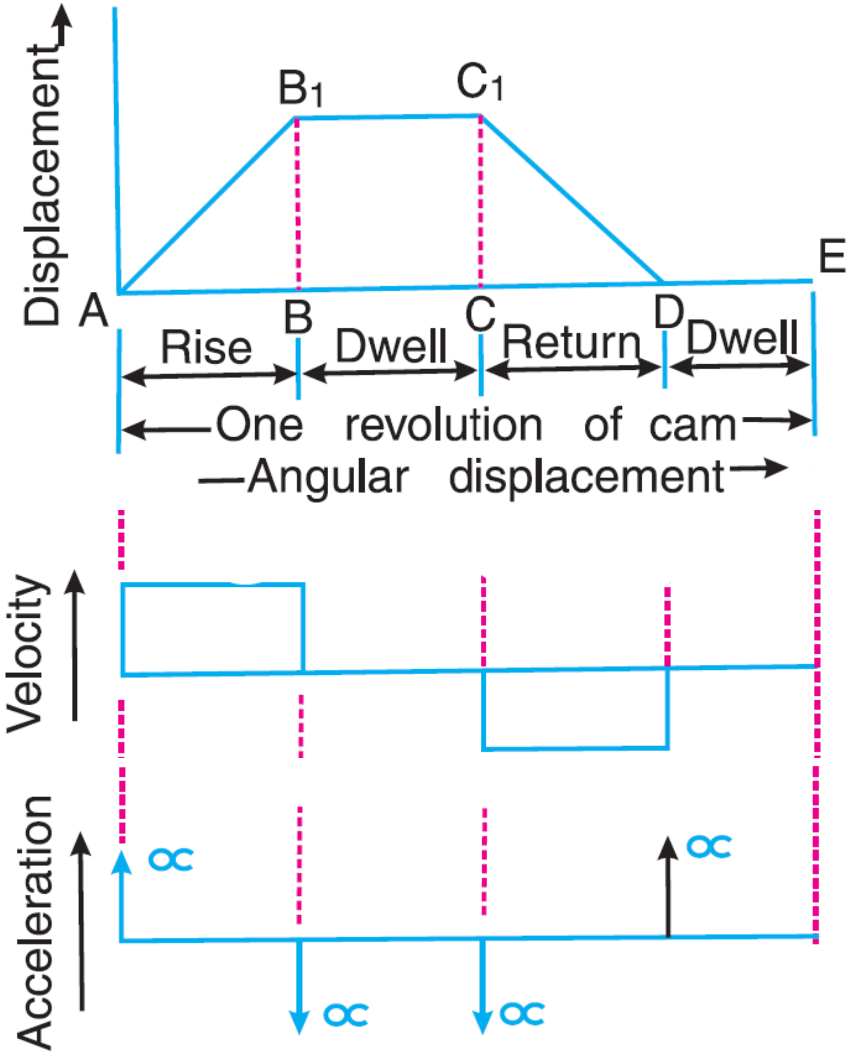
Terms used in radial cams.

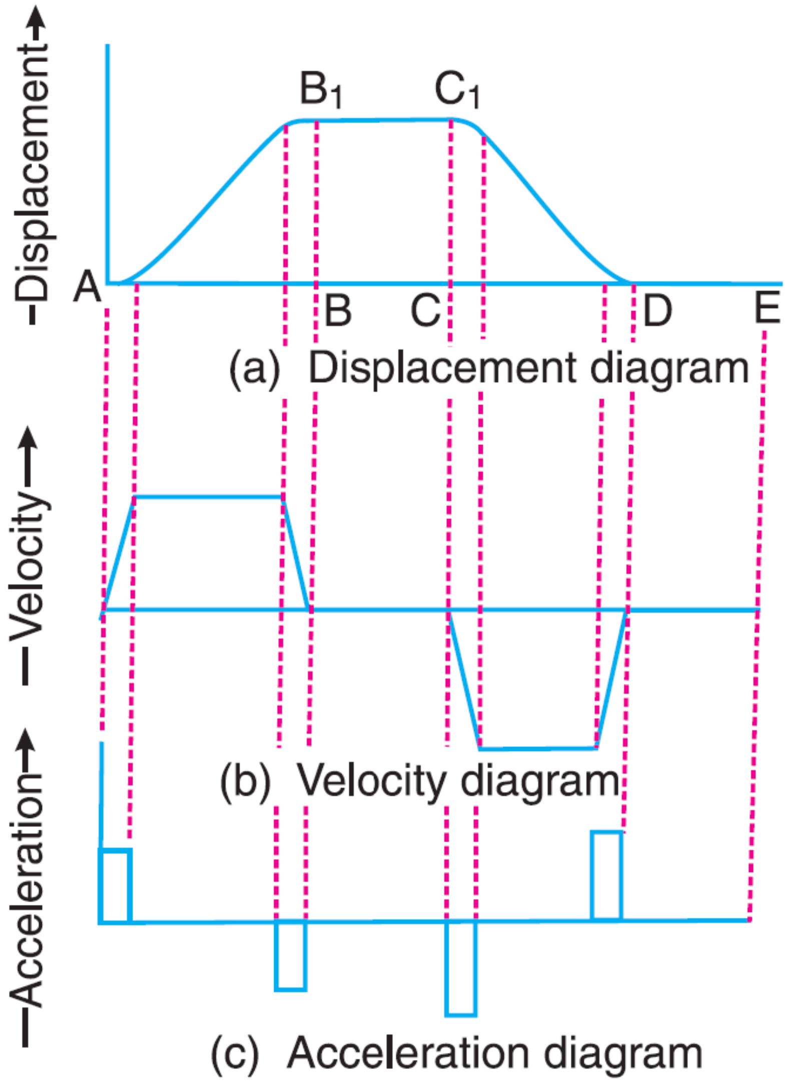


Motion of the Follower

- Uniform velocity
- Simple harmonic motion
- Uniform acceleration and retardation
- Cycloidal motion.

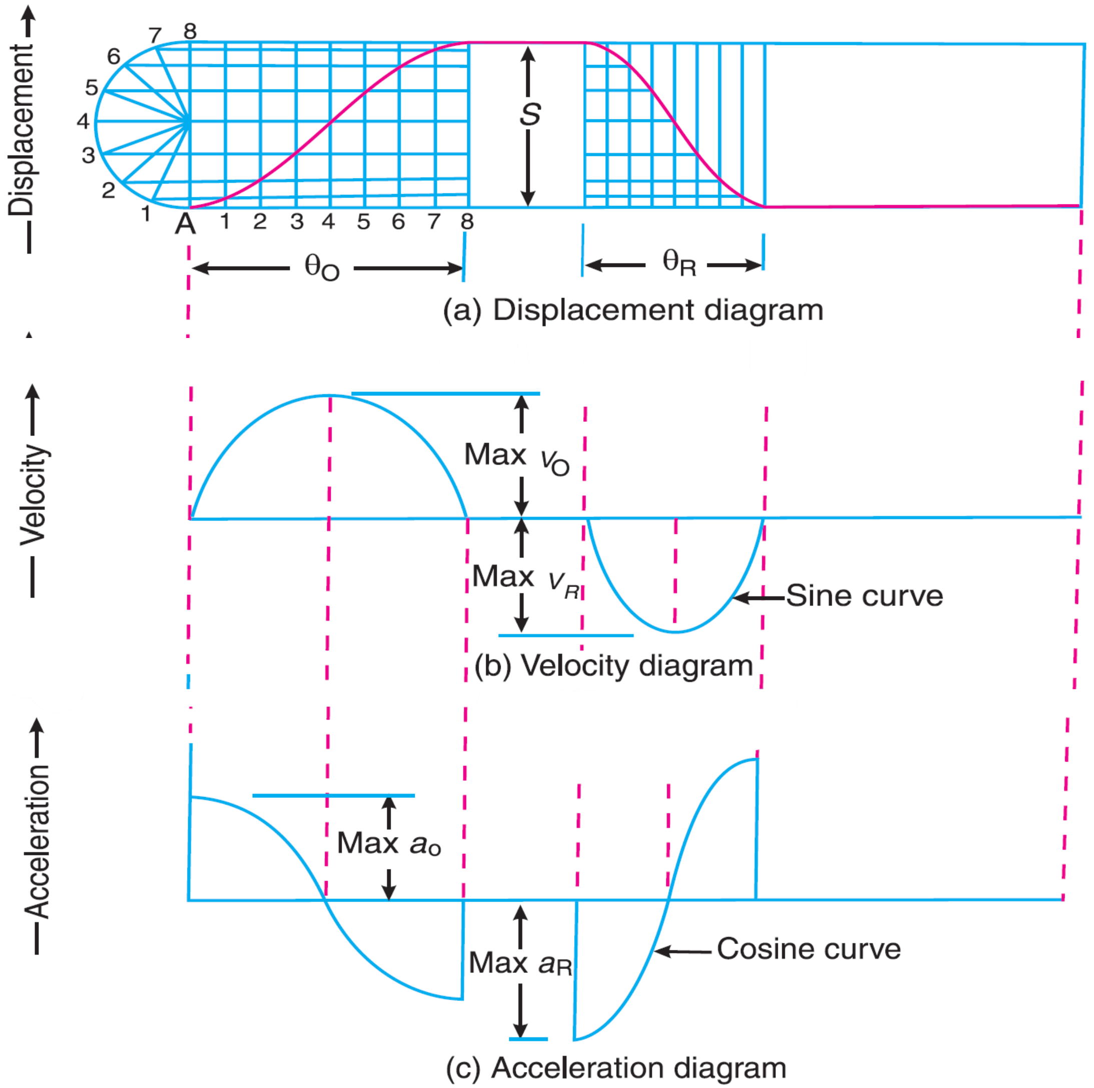
Displacement, Velocity and Acceleration Diagrams when the Follower Moves with Uniform Velocity





(a) Displacement diagram
(b) Velocity diagram
(c) Acceleration diagram

Displacement, Velocity and Acceleration Diagrams when the Follower Moves with Simple Harmonic Motion



The displacement diagram is drawn as follows :

1. Draw a semi-circle on the follower stroke as diameter.

2. Divide the semi-circle into any number of even equal parts.

3. Divide the angular displacements of the cam during out stroke and return stroke into the same number of equal parts.

4. The displacement diagram is obtained by projecting the points as shown.

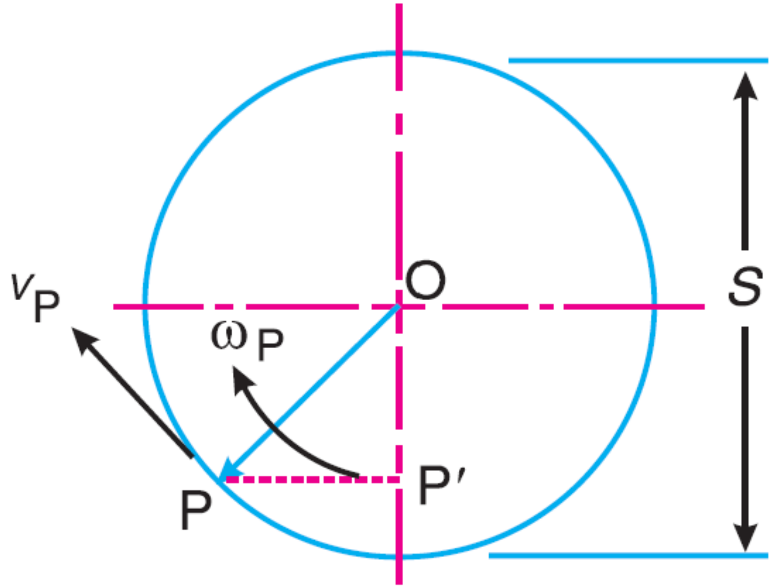
Maximum velocity and acceleration of follower in simple harmonic motion

Time required for the out stroke of the follower

$$t_O = \frac{\theta_O}{\omega}$$

Peripheral speed of the point P'

$$v_p = \frac{\pi S}{2} \times \frac{1}{t_O} = \frac{\pi S}{2} \times \frac{\omega}{\theta_O}$$



Maximum velocity of the follower on the outstroke

$$v_O = v_p = \frac{\pi \omega S}{2\theta_O}$$

Centripetal acceleration of the point P

$$a_p = \frac{v_p^2}{OP} = \left(\frac{\pi \omega S}{2\theta_O}\right)^2 \times \frac{2}{S} = \frac{\pi^2 \omega^2 S}{2\theta_O^2}$$

Maximum acceleration of the follower on the outstroke

$$a_O = a_p = \frac{\pi^2 \omega^2 S}{2\theta_O^2}$$

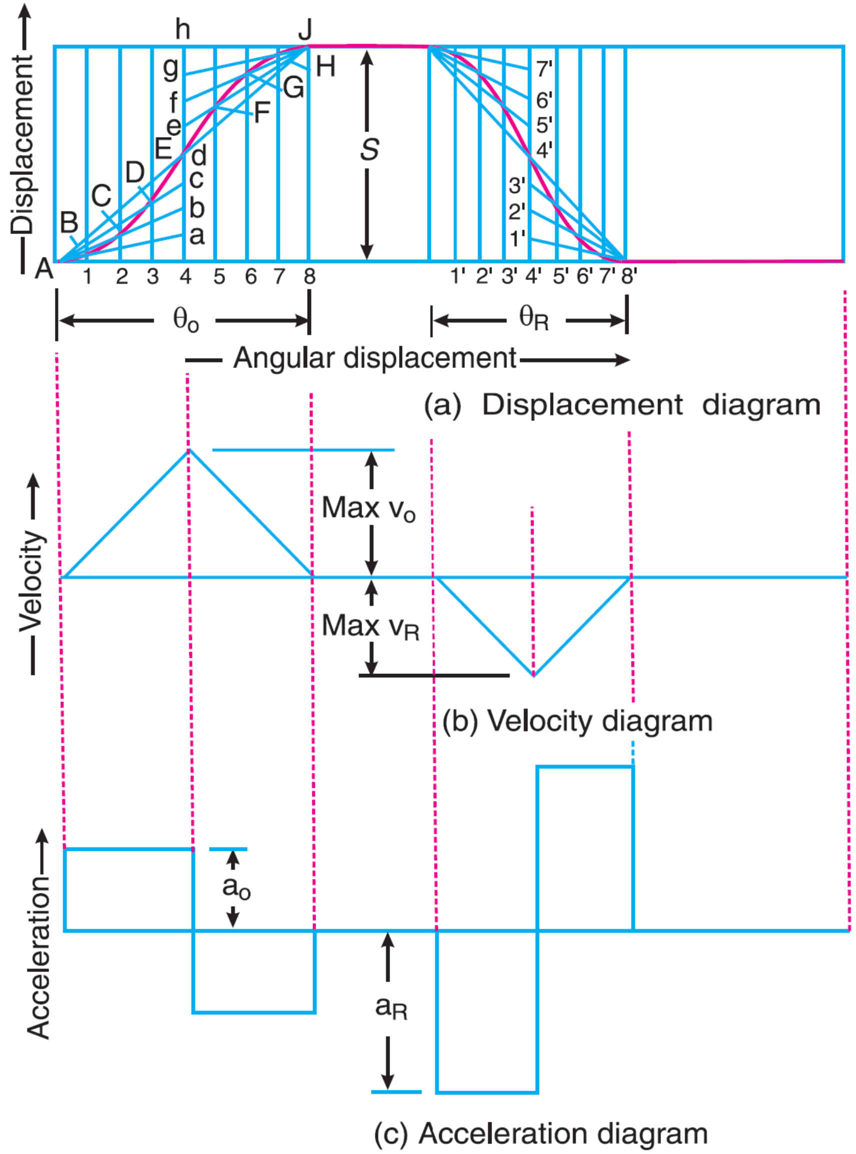
Maximum velocity of the follower on the return stroke

$$v_R = \frac{\pi \omega S}{2\theta_R}$$

Maximum acceleration of the follower on the return stroke

$$a_R = \frac{\pi^2 \omega^2 S}{2\theta_R^2}$$

Displacement, Velocity and Acceleration Diagrams when the Follower Moves with Uniform Acceleration and Retardation



1) Divide the angular displacement of the cam during outstroke into any even number of equal parts and draw vertical lines through these points as shown.
2) Divide the stroke of the follower (*S*) into the same number of equal even parts.
3) Join *Aa* to intersect the vertical line through point 1 at *B*. Similarly, obtain the other points *C*, *D* etc. as shown.
4) Join these points to obtain the parabolic curve for the out stroke of the follower.

Maximum velocity and acceleration of follower in uniform acceleration and retardation

Time required for the follower during outstroke

$$t_O = \frac{\theta_O}{\omega}$$

Mean velocity of the follower during outstroke $= \dfrac{S}{t_O}$

Maximum velocity of the follower during outstroke $v_O = \dfrac{2S}{t_O} = \dfrac{2\,\omega.S}{\theta_O}$

Maximum velocity of the follower during return stroke $v_R = \dfrac{2\,\omega.S}{\theta_R}$

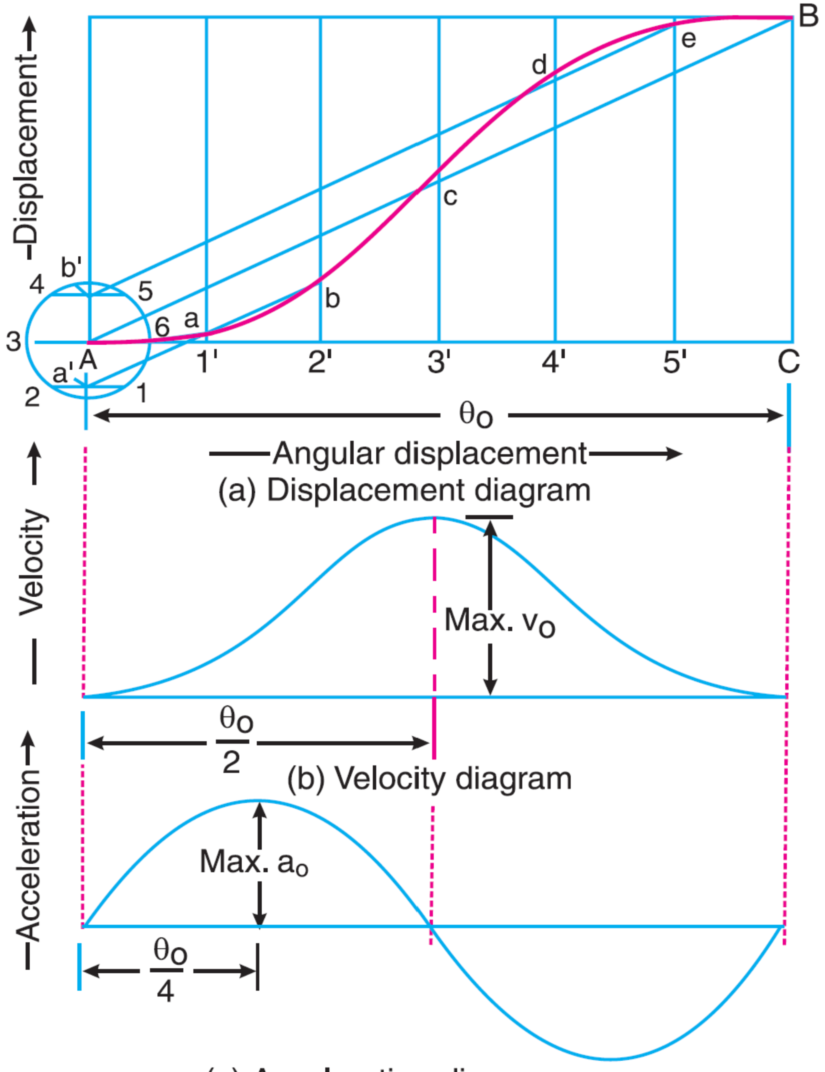
Maximum acceleration of the follower during outstroke

$$a_O = \frac{v_O}{t_O/2} = \frac{2 \times 2\omega.S}{t_O.\theta_O} = \frac{4\omega^2.S}{(\theta_O)^2}$$

Maximum acceleration of the follower during return stroke

$$a_R = \frac{4\omega^2.S}{(\theta_R)^2}$$

Displacement, Velocity and Acceleration Diagrams when the Follower Moves with Cycloidal Motion



1) Draw a circle of radius $S/2\pi$ with A as centre.
2) Divide the circle into any number of equal even parts. Project these points horizontally on the vertical centre line of the circle. These points are shown by a' and b'.
3) Divide the angular displacement of the cam during outstroke into the same number of equal even parts as the circle is divided. Draw vertical lines through these points.
4) Join AB which intersects the vertical line through 3′ at c. From a' draw a line parallel to AB intersecting the vertical lines through 1′ and 2′ at a and b respectively.
5) Similarly, from b' draw a line parallel to AB intersecting the vertical lines through 4′ and 5′ at d and e respectively.
6) Join the points A a b c d e B by a smooth curve. This is the required cycloidal curve for the follower during outstroke

Maximum velocity and acceleration of follower in cycloidal motion

Maximum velocity of the follower during outstroke

$$v_O = \frac{2\omega S}{\theta_O}$$

Maximum velocity of the follower during return stroke

$$v_R = \frac{2\omega S}{\theta_R}$$

Maximum acceleration of the follower during outstroke $a_O = \frac{2\pi\omega^2 . S}{(\theta_O)^2}$

Maximum acceleration of the follower during return stroke $a_R = \frac{2\pi\omega^2 . S}{(\theta_R)^2}$