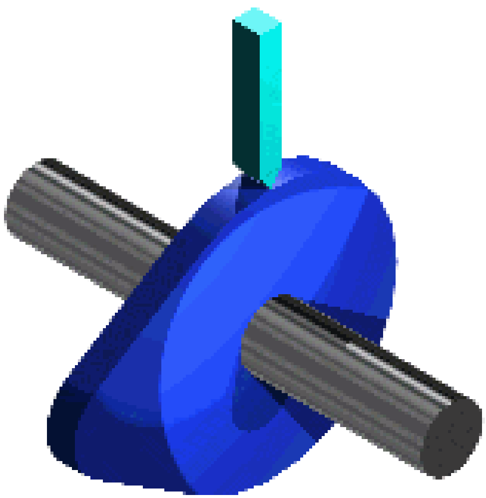
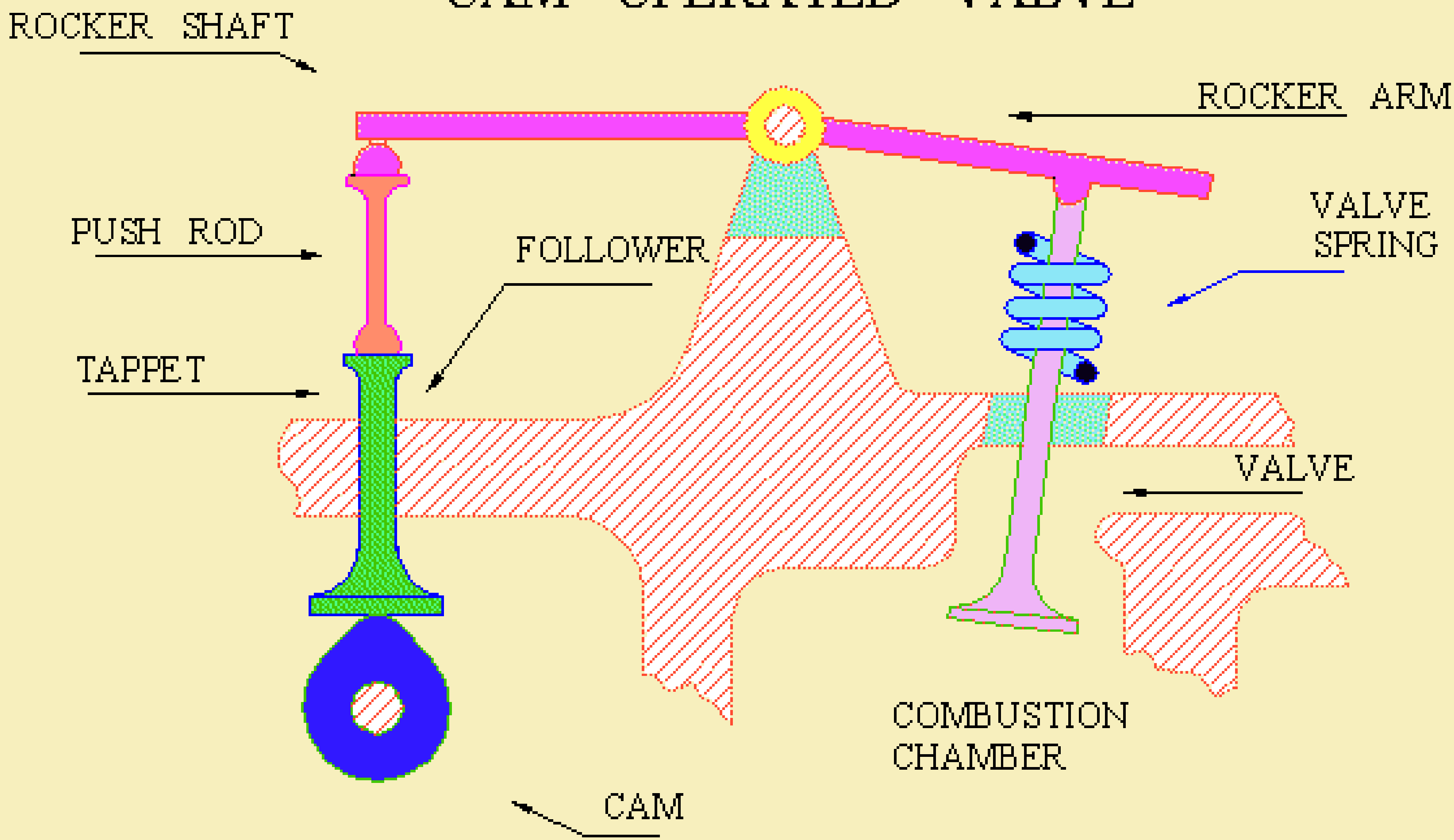
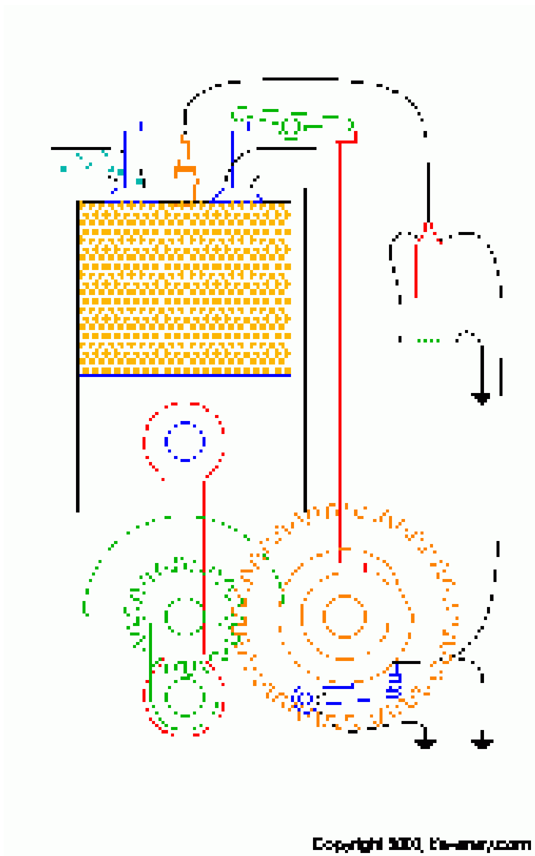
CAMS

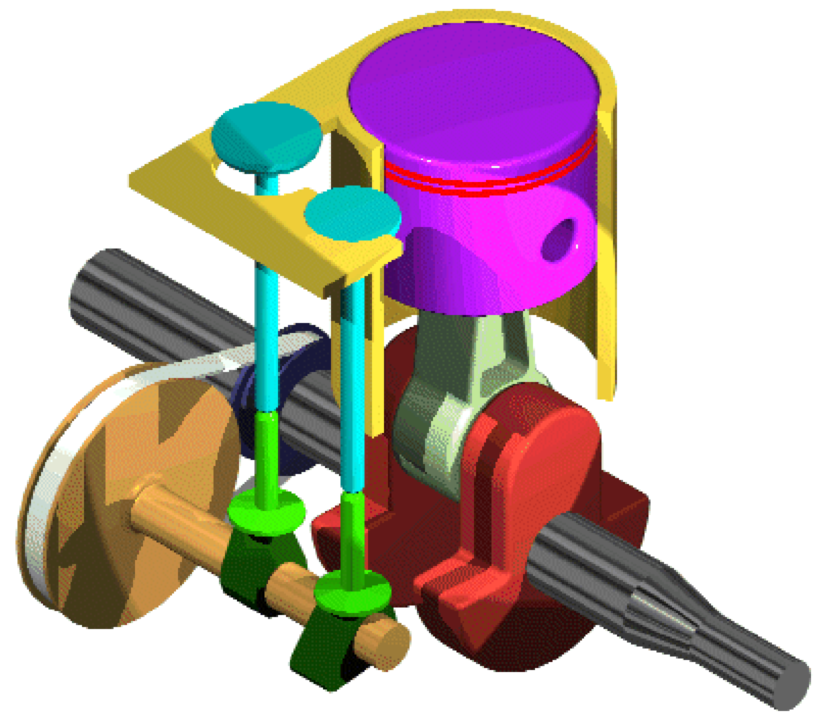


CAM OPERATED VALVE



Examples for cam

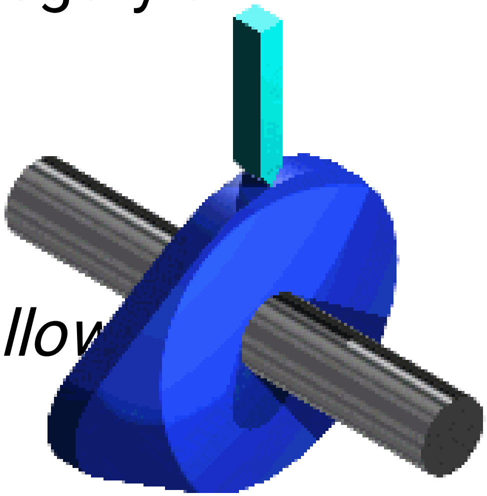




- In IC engines to operate the inlet and exhaust valves

Introduction

- A cam is a mechanical member used to impart desired motion to a follower by direct contact.
- The cam may be rotating or reciprocating whereas the follower may be rotating, reciprocating or oscillating.
- Complicated output motions which are otherwise difficult to achieve can easily be produced with the help of cams.
- Cams are widely used in automatic machines, internal combustion engines, machine tools, printing control mechanisms, and so on.
- They are manufactured usually by die-casting, milling or by punch-presses.
- A cam and the follower combination belong to the category of higher pairs.
- Necessary elements of a cam mechanism are
  - A driver member known as the *cam*
  - A driven member called *the follower*
  - *A frame which supports the cam and guides the follow*



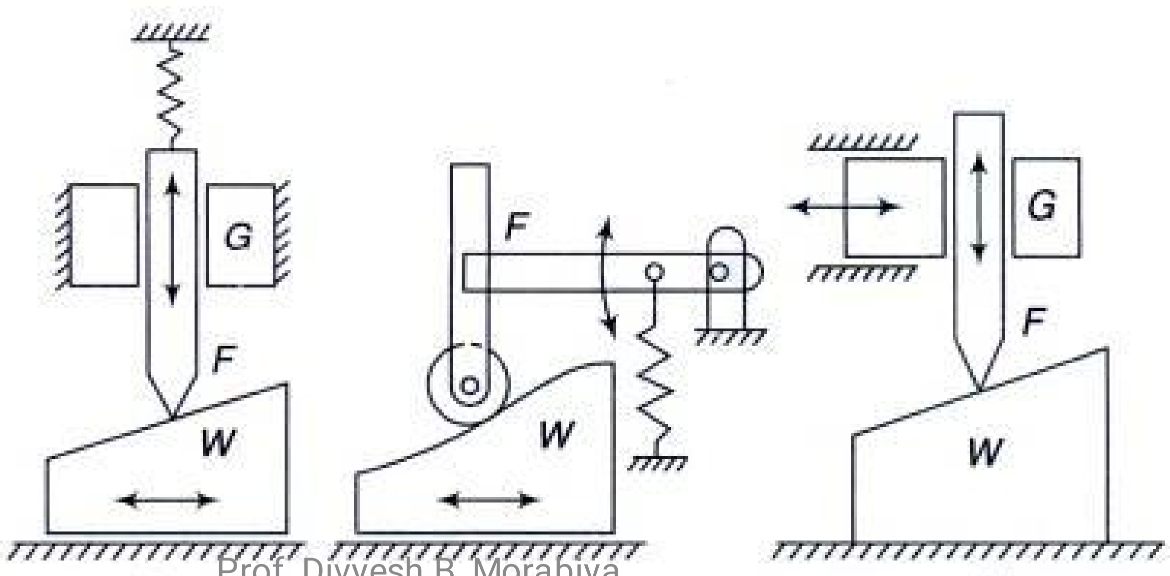
TYPES OF CAMS

- Cams are classified according to
    1. Shape,
    2. Follower movement, and
    3. Manner of constraint of the follower.

I. According to Shape

1) Wedge and Flat Cams

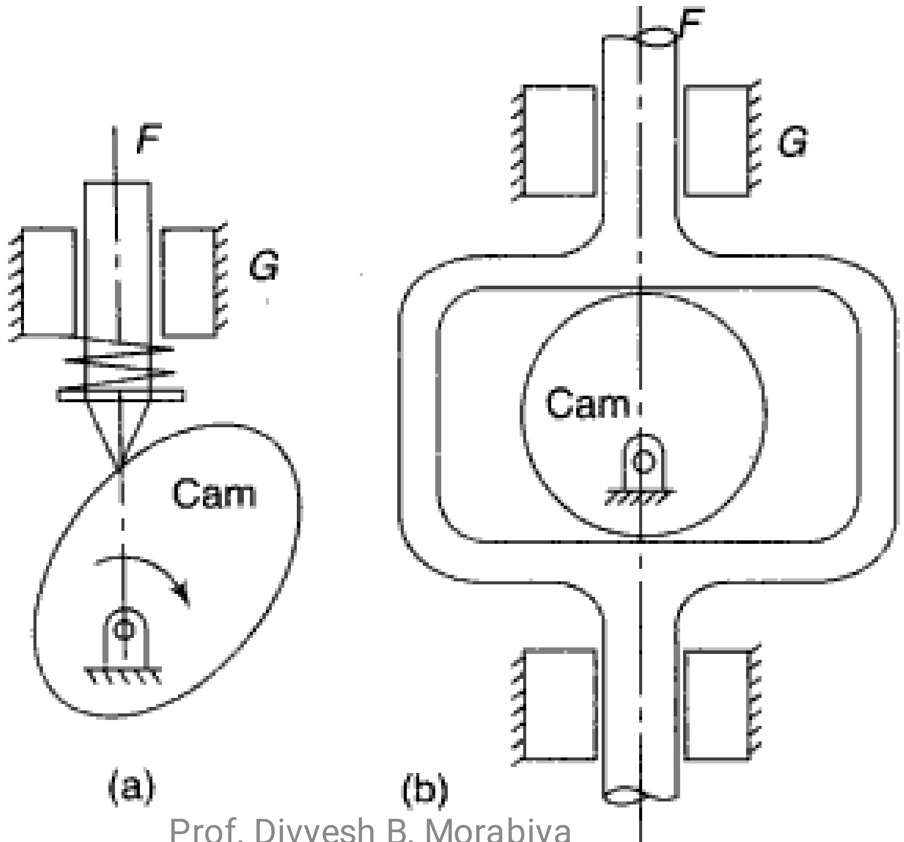
- *A wedge cam has a wedge W which, in general, has a translational motion.*
- *The follower F can either translate [Fig.(a)] or oscillate [Fig.(b)].*
- *A spring is, usually, used to maintain the contact between the cam and the follower.*
- In Fig.(c), the cam is stationary and the follower constraint or guide *G causes the relative motion of the cam and the follower.*



(a) (b) (c)

2. *Radial or Disc Cams*

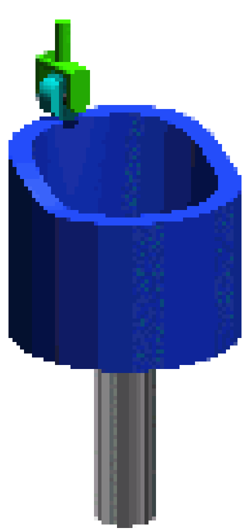
- *A cam in which the follower moves radially from the centre of rotation of the cam is known as a radial or a disc cam (Fig. (a) and (b)].*
- *Radial cams are very popular due to their simplicity and compactness.*

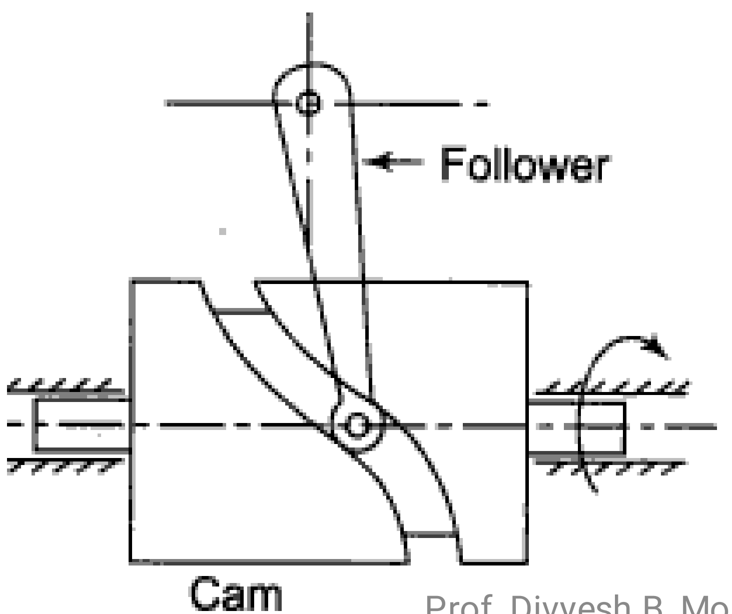


(a) (b)

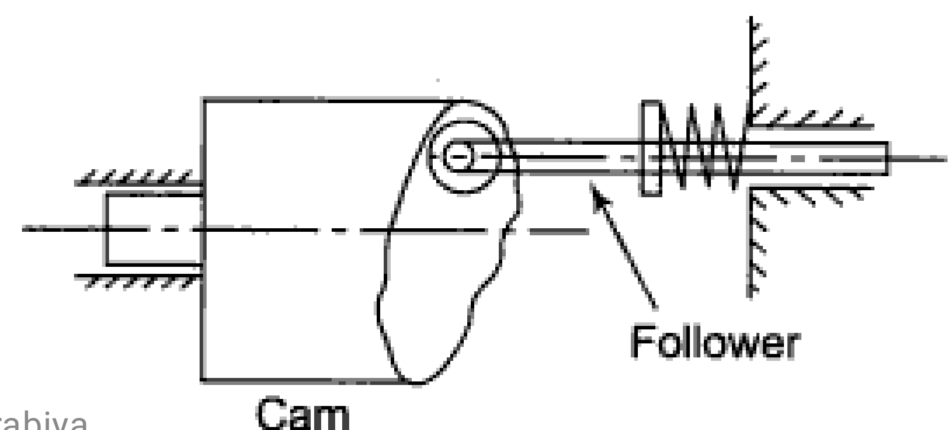
3. *Cylindrical Cams*

- *In a cylindrical cam, a cylinder which has a circumferential contour cut in the surface, rotates about its axis.*
- *The follower motion can be of two types as follows:* In the first type, a groove is cut on the surface of the cam and a roller follower has a constrained (or positive) oscillating motion [Fig.(a)].
- Another type is an end cam in which the end of the cylinder is the working surface (b).
- A spring-loaded follower translates along or parallel to the axis of the rotating cylinder.





(a)



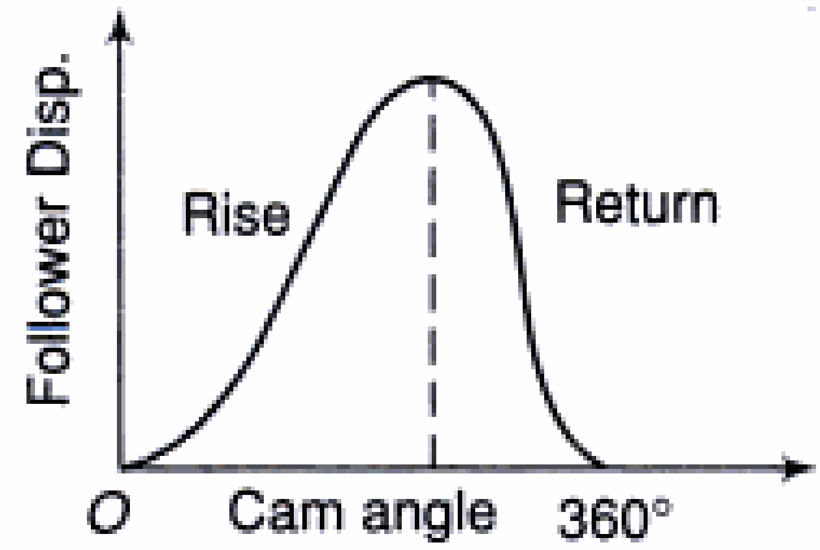
(b)

II. According to Follower Movement

- The motions of the followers are distinguished from each other by the dwells they have.
- A dwell is the zero displacement or the absence of motion of the follower during the motion of the cam.
- Cams are classified according to the motions of the followers in the following ways:

1. *Rise-Return-Rise (R-R-R)*

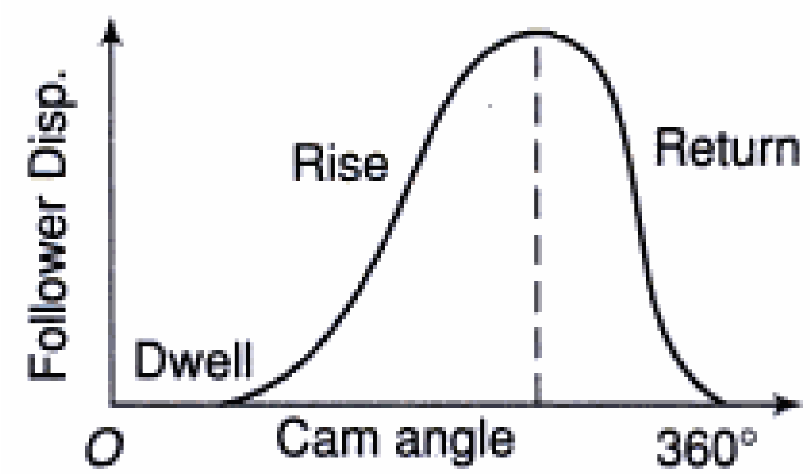
- In this, there is alternate rise and return of the follower with no periods of dwells (Fig. a).
- Its use is very limited in the industry.
- The follower has a linear or an angular displacement.



(a)

2. Dwell-Rise-Return-Dwell(D-R-R-D)

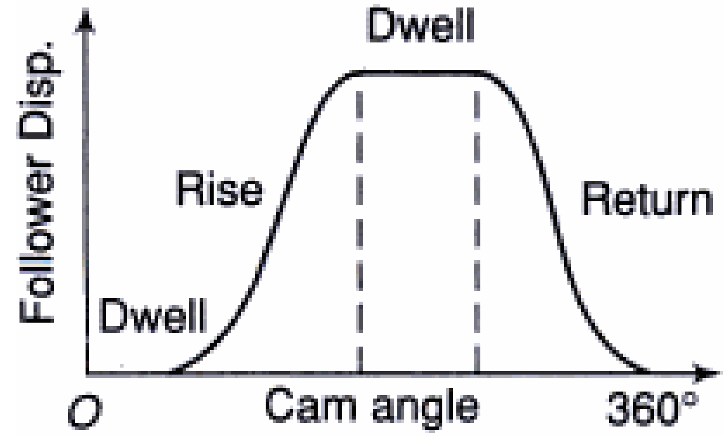
- In such a type of cam, there is rise and return of the follower after a dwell Fig.(b).
- This type is used more frequently than the R-R-R type of cam.



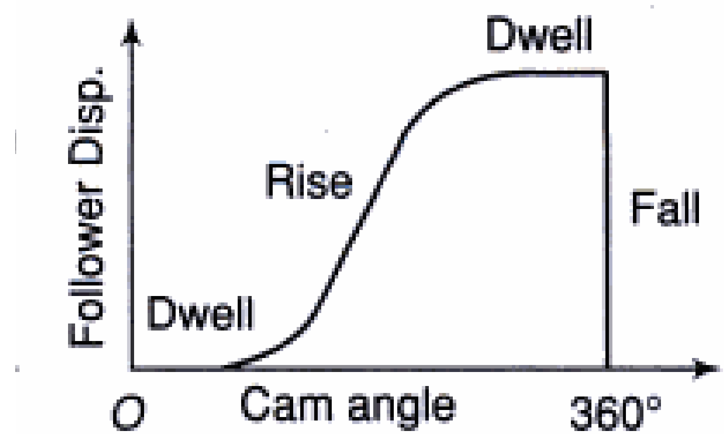
(b)

3. *Dwell-Rise-Dwell-Return-Dwell (D-R-D-R-D)*

- *It is the most widely used type of cam.*
- *The dwelling of the cam is followed by* rise and dwell and subsequently by return and dwell as shown in rig. (c).
- In case the return of the follower is by a fall [Fig.(d)], the motion may be known as Dwell-Rise-Dwell (D-R-D).



(c)



(d)

III. According to Manner of Constraint of the Follower

- To reproduce exactly the motion transmitted by the cam to the follower, it is necessary that the two remain in touch at all speeds and at all times.
- The cams can be classified according to the manner in which this is achieved.

1. ***Pre-loaded Spring Cam***

   A pre-loaded compression spring is used for the purpose of keeping the contact between the cam and the follower.

2. ***Positive-drive Cam***

   In this type, constant touch between the cam and the follower is maintained by a roller follower operating in the groove of a cam.

   The follower cannot go out of this groove under the normal working operations.

   A constrained or positive drive is also obtained by the use of a conjugate cam

3. ***Gravity Cam***

   If the rise of the cam is achieved by the rising surface of the cam and the return by the force of gravity or due to the weight of the cam, the cam is known as a gravity cam.

   However, these cams are not preferred due to their uncertain behavior.

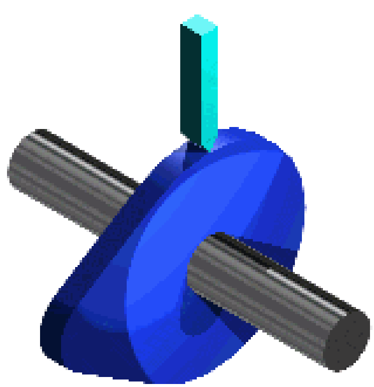
Classification of Followers

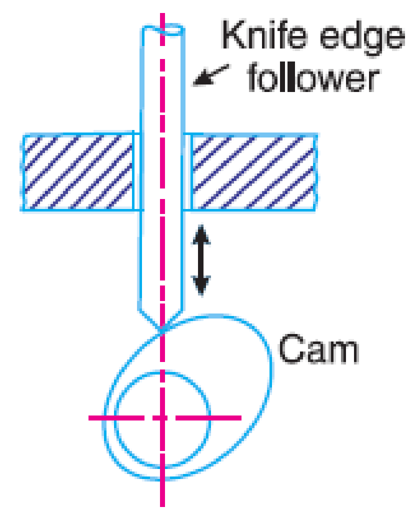
1. ***According to the surface in contact.***

a) ***Knife edge follower.***

When the contacting end of the follower has a sharp knife edge, it is called a knife edge follower, as shown in Fig.(a).

- The sliding motion takes place between the contacting surfaces (i.e. the knife edge and the cam surface).
- It is seldom used in practice because the small area of contacting surface results in excessive wear.
- In knife edge followers, a considerable side thrust exists between the follower and the guide.

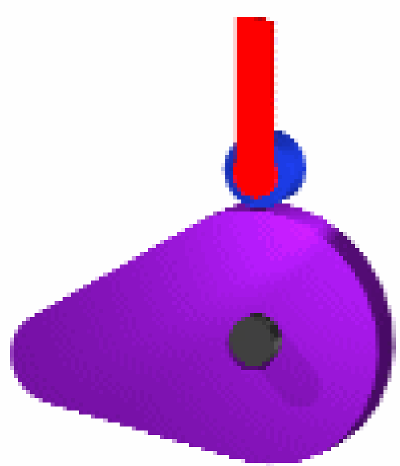


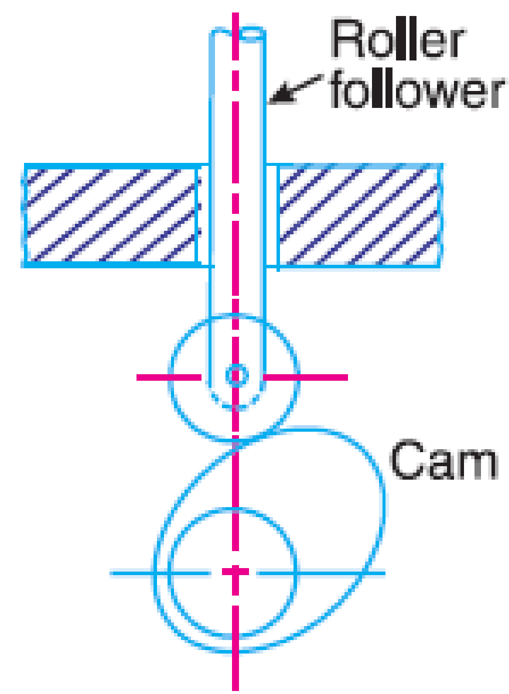


(*a*) Cam with knife edge follower.

(b) Roller follower.

- ***When the contacting end of the follower is a roller, it is called a roller*** follower, as shown in Fig. (*b).*
- *Since the rolling motion takes place between the* contacting surfaces (*i.e. the roller and the cam), therefore the rate of wear is greatly reduced.*
- In roller followers also the side thrust exists between the follower and the guide.
- The roller followers are extensively used where more space is available such as in stationary gas and oil engines and aircr





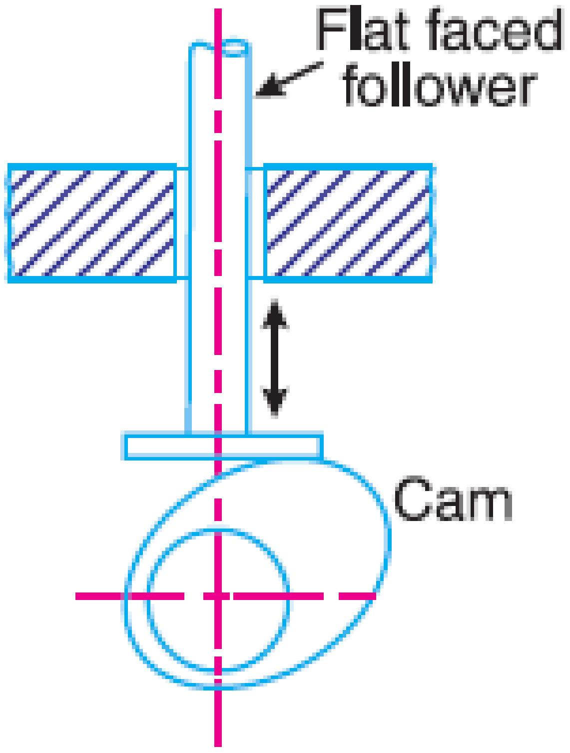
(*b*) Cam with roller follower.

(c) Flat faced or mushroom follower.

- *When the contacting end of the follower is a perfectly* flat face, it is called a flat-faced follower, as shown in Fig. 20.1 (*c*).
- *It may be noted that* the side thrust between the follower and the guide is much reduced in case of flat faced followers.
- The only side thrust is due to friction between the contact surfaces of the follower and the cam.

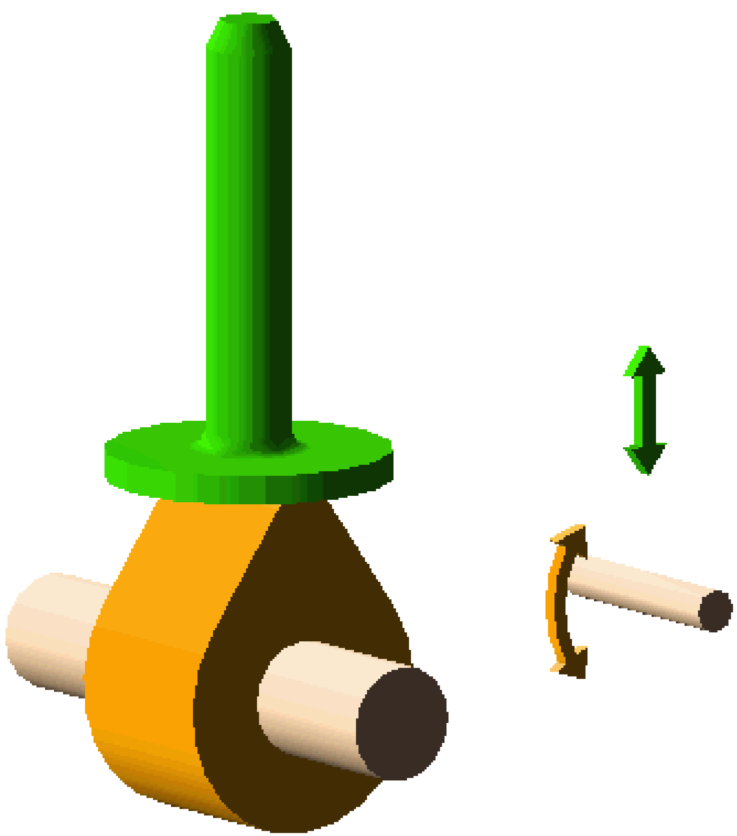
- The flat faced followers are generally used where space is limited such as in cams which operate the valves of automobile engines.

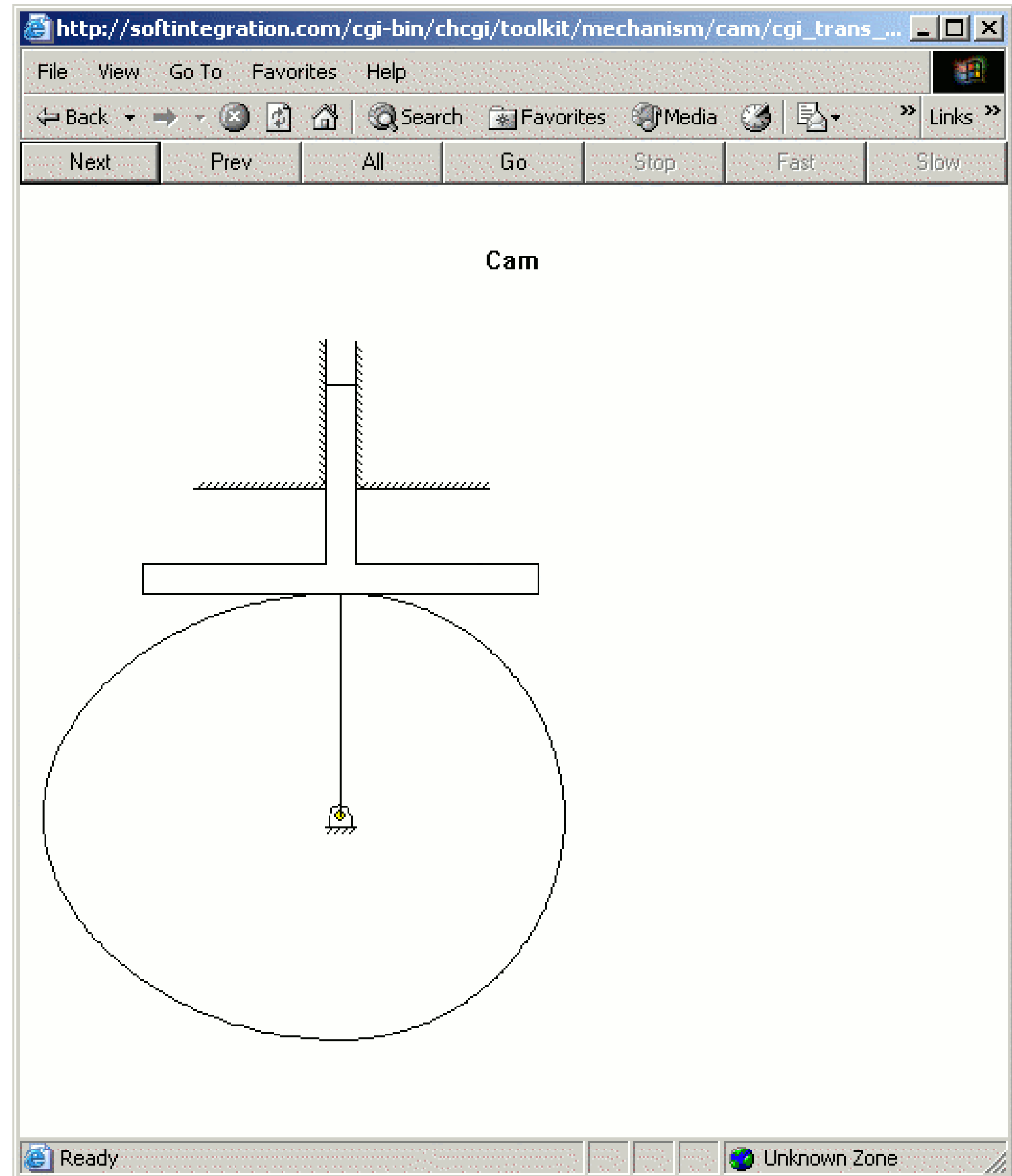
- Note : When the flat faced follower is circular, it is then called a mushroom follower.



(*c*) Cam with flat faced follower.

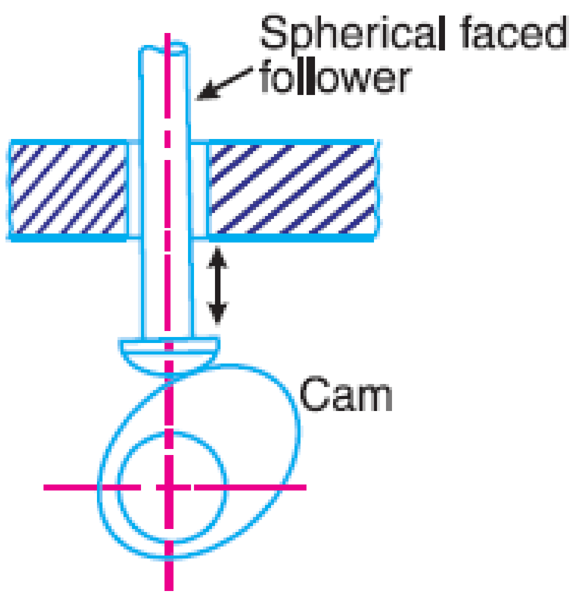
C) Flat faced or mushroom follower.



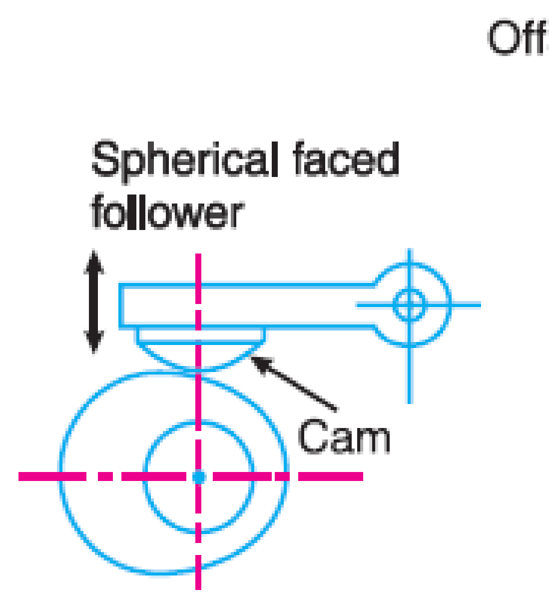


(d) Spherical faced follower.

- When the contacting end of the follower is of spherical shape, it is called a spherical faced follower, as shown in Fig. (d).
- It may be noted that when a flat-faced follower is used in automobile engines, high surface stresses are produced.
- In order to minimise these stresses, the flat end of the follower is machined to a spherical shape.



(*d*) Cam with spherical faced follower.

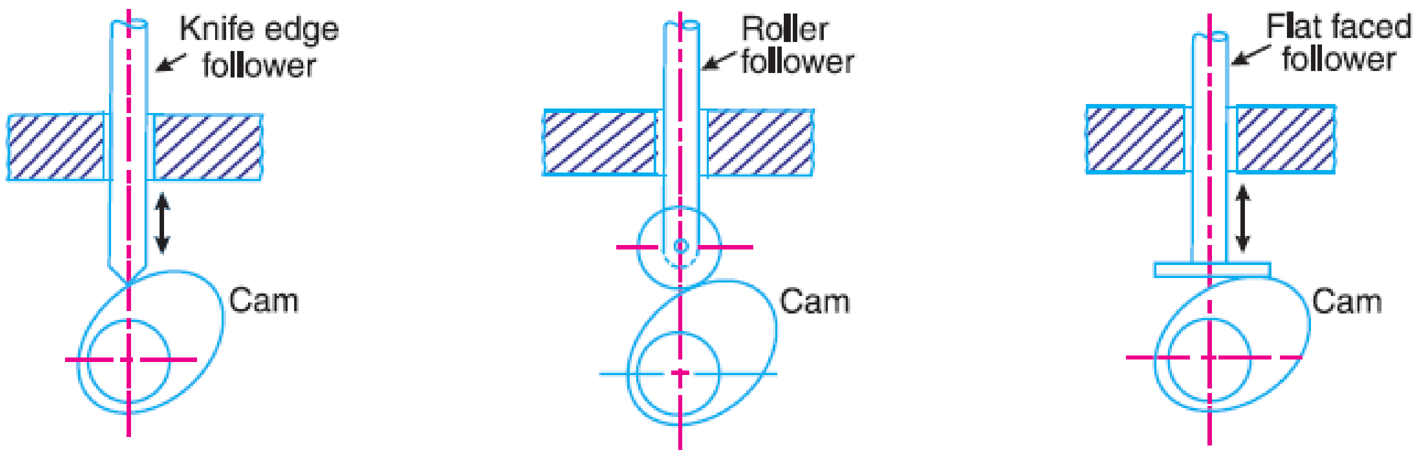


(*e*) Cam with spherical faced follower.

2. *According to the motion of the follower*

(*a*) *Reciprocating or translating follower.*

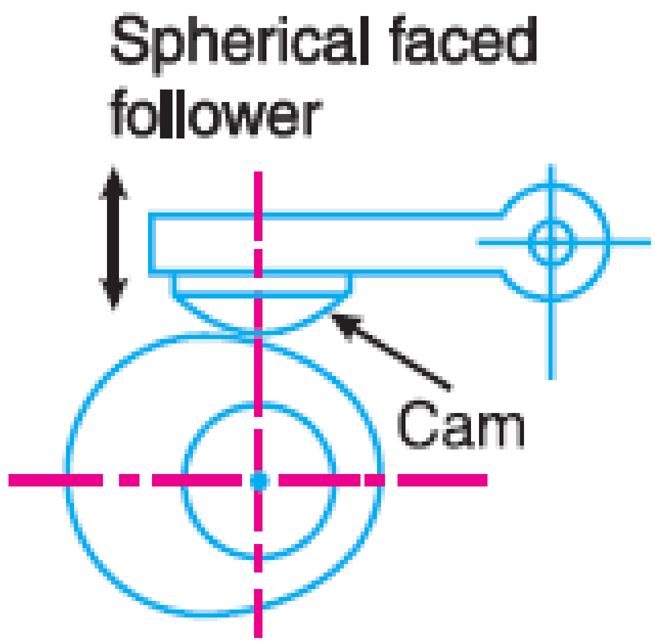
- *When the follower reciprocates in guides as the* cam rotates uniformly, it is known as reciprocating or translating follower.
- The followers as shown in Fig. (*a*) *to* (*d*) *are all reciprocating or translating followers.*



(*a*) Cam with knife edge follower. (*b*) Cam with roller follower. (*c*) Cam with flat faced follower.

(*b*) *Oscillating or rotating follower.*

- When the uniform rotary motion of the cam is converted into predetermined oscillatory motion of the follower, it is called oscillating or rotating follower.
- The follower, as shown in (e), is an oscillating or rotating follower.

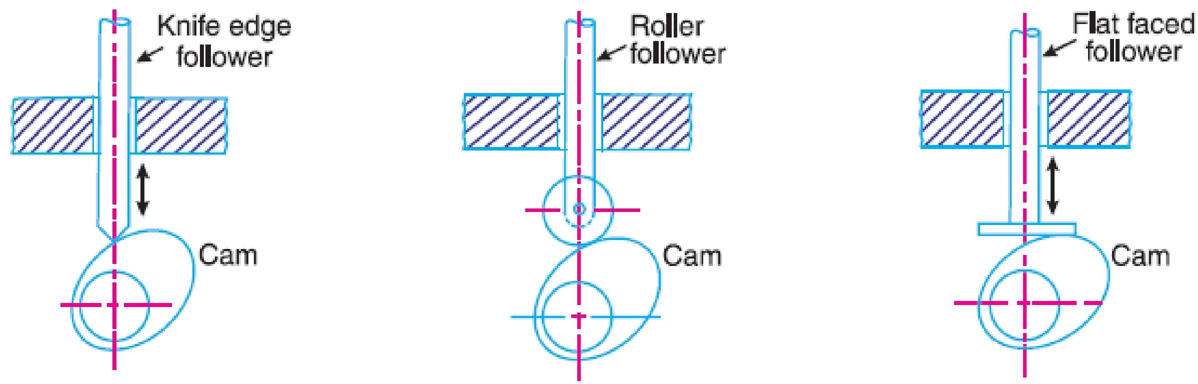


(*e*) Cam with spherical faced follower.

3. *According to the path of motion of the follower.*

(*a)* Radial follower. When the motion of the follower is along an axis passing through the centre of the cam, it is known as radial follower.

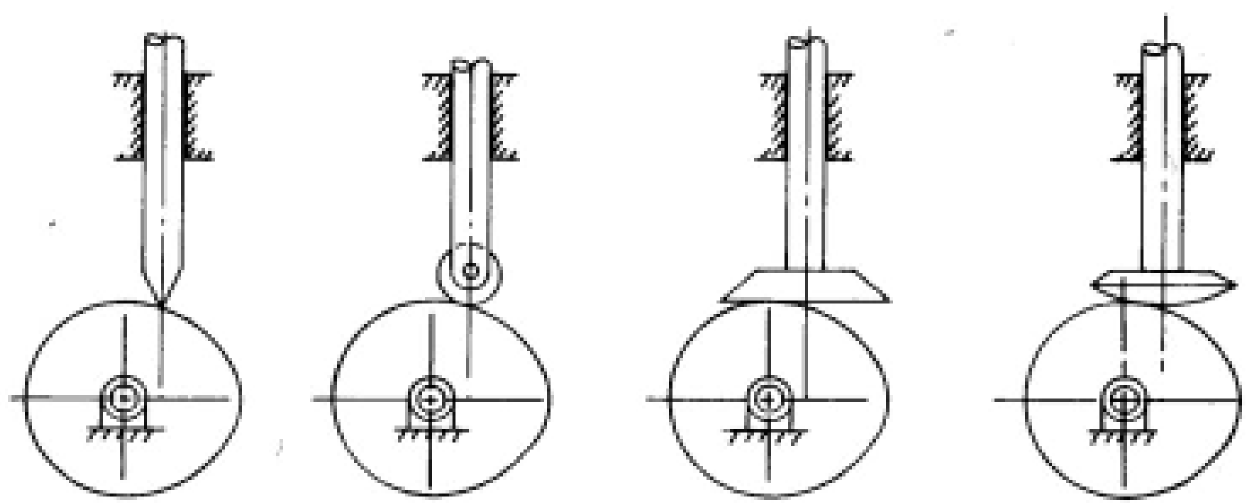
The followers, as shown in Fig. (a) to (c), are all radial followers.



(*a*) Cam with knife edge follower. (*b*) Cam with roller follower. (*c*) Cam with flat faced follower.

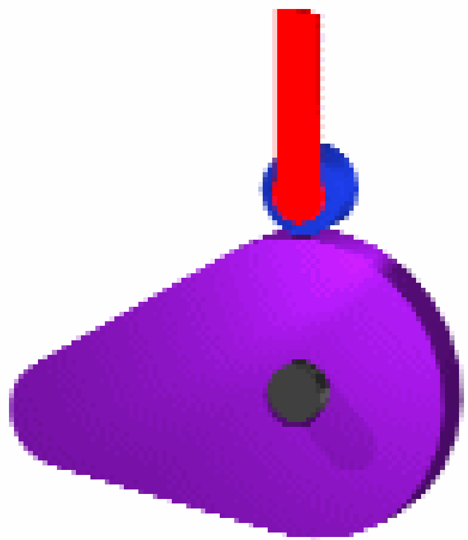
(b) Off-set follower.

- When the motion of the follower is along an axis away from the axis of the cam centre, it is called off-set follower. The follower, as shown in Fig. (f), is an off-set follower.



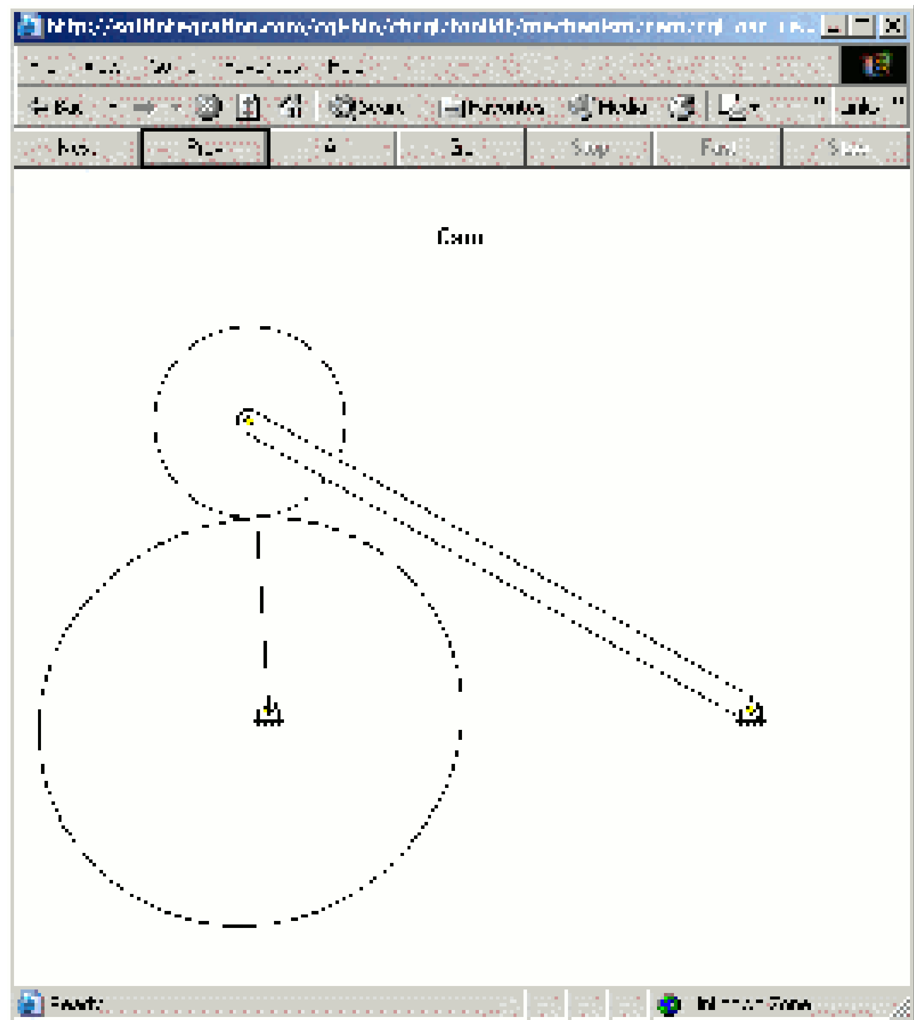
Based on modes of Input / Output motion

Rotating cam – Translating follower



Based on modes of Input / Output motion

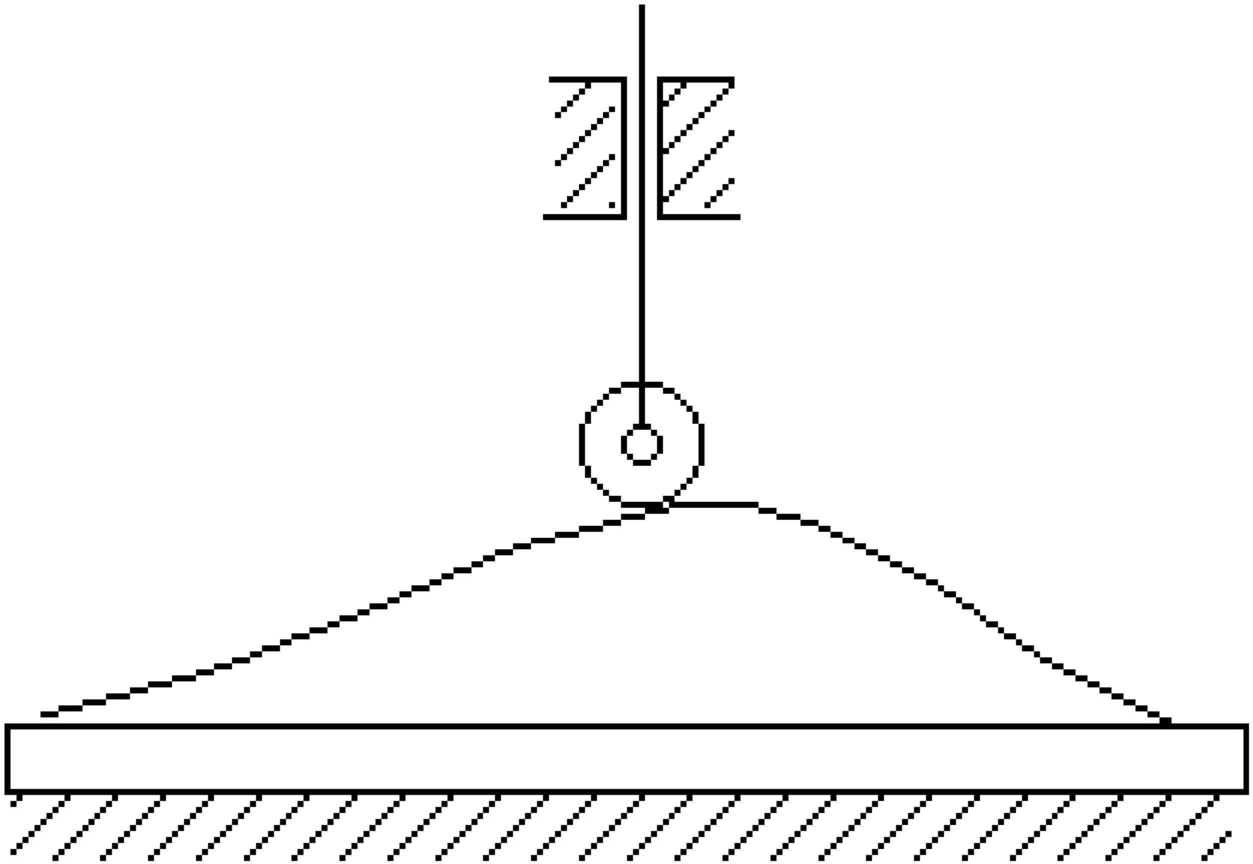
Rotating cam – Oscillating follower



Prof. Divyesh B. Morabiya
Prof. Rahul L. Patel

Based on modes of Input / Output motion

Translating cam – Translating follower

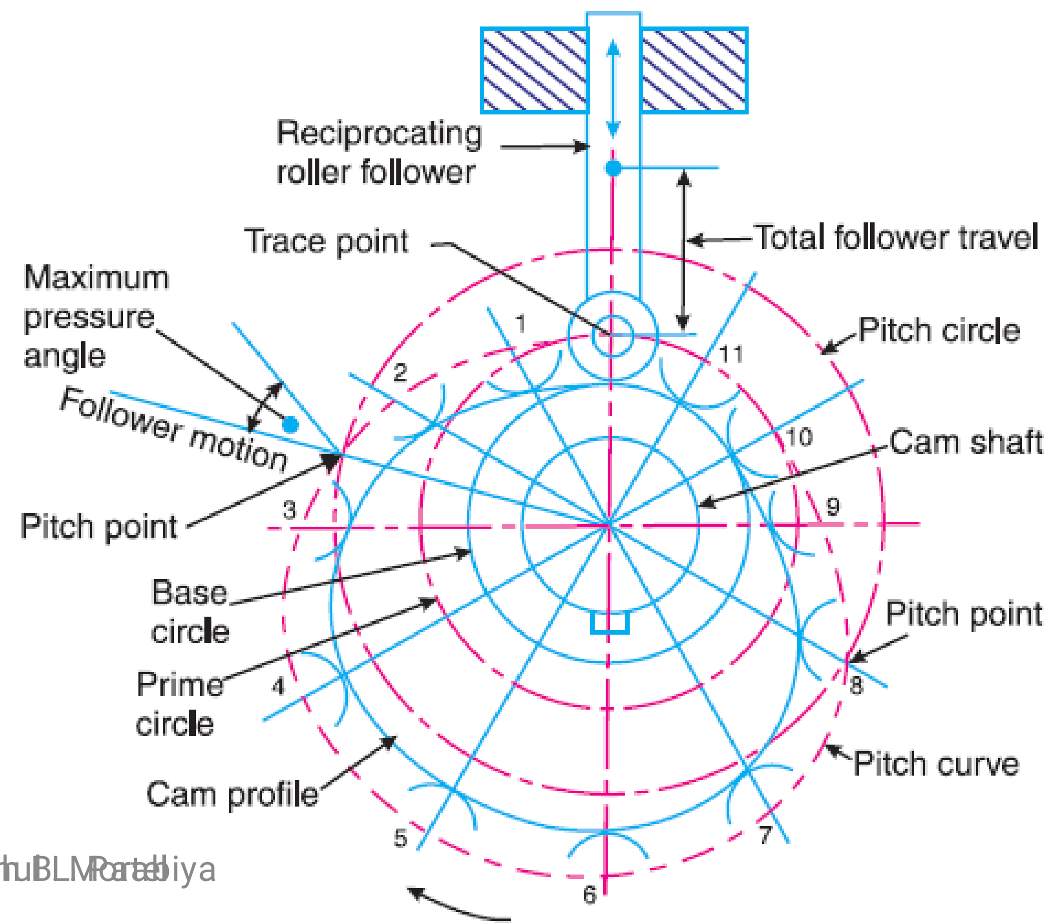


Terms Used in Radial Cams

- Fig. shows a radial cam with reciprocating roller follower. The following terms are important in order to draw the cam profile.

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

2. ***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.



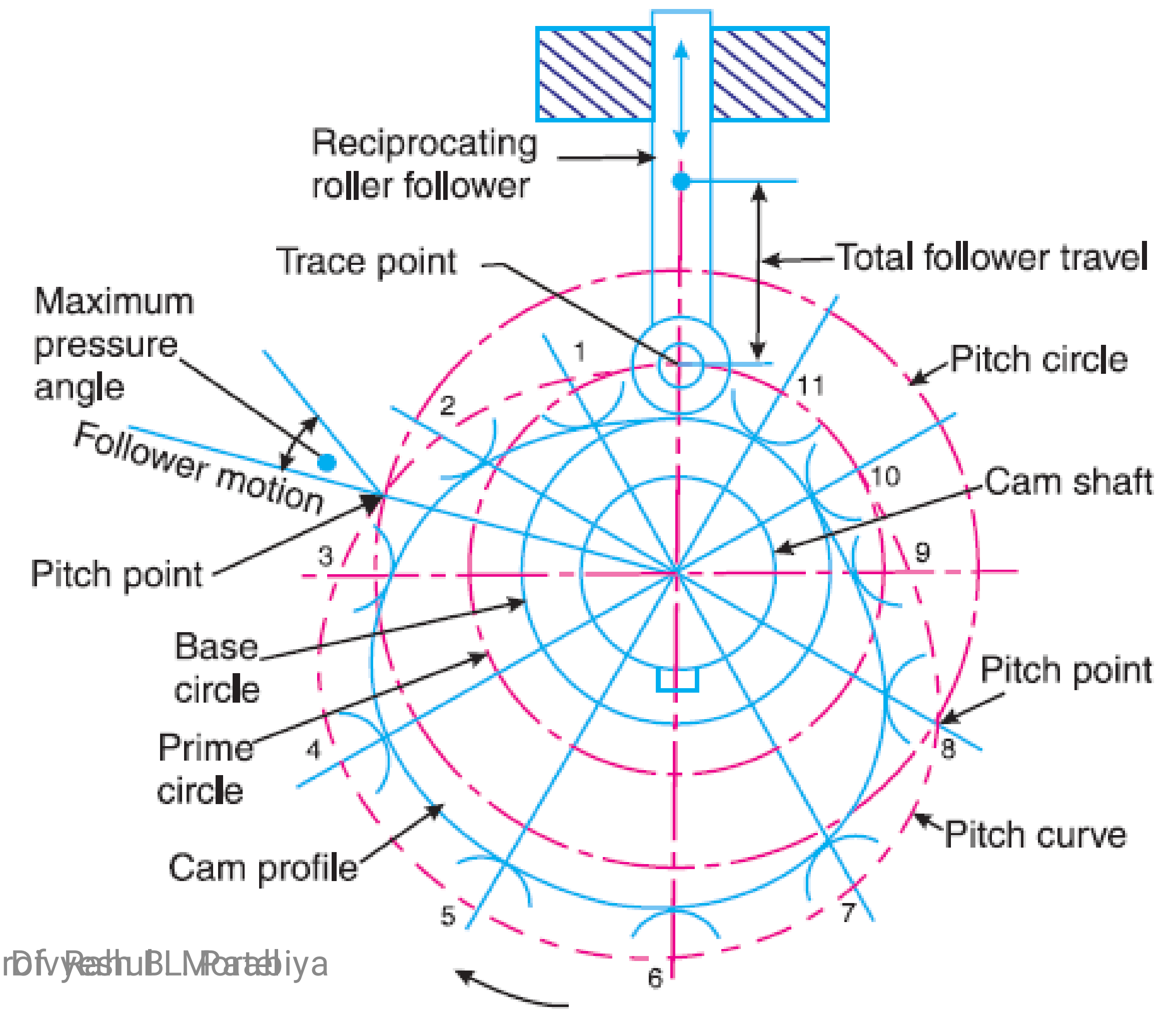
Terms Used in Radial Cams

3. Pressure angle. It is the angle between the direction of the follower motion and a normal to the pitch curve. This angle is very important in designing a cam profile. If the pressure angle is too large, a reciprocating follower will jam in its bearings.

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

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

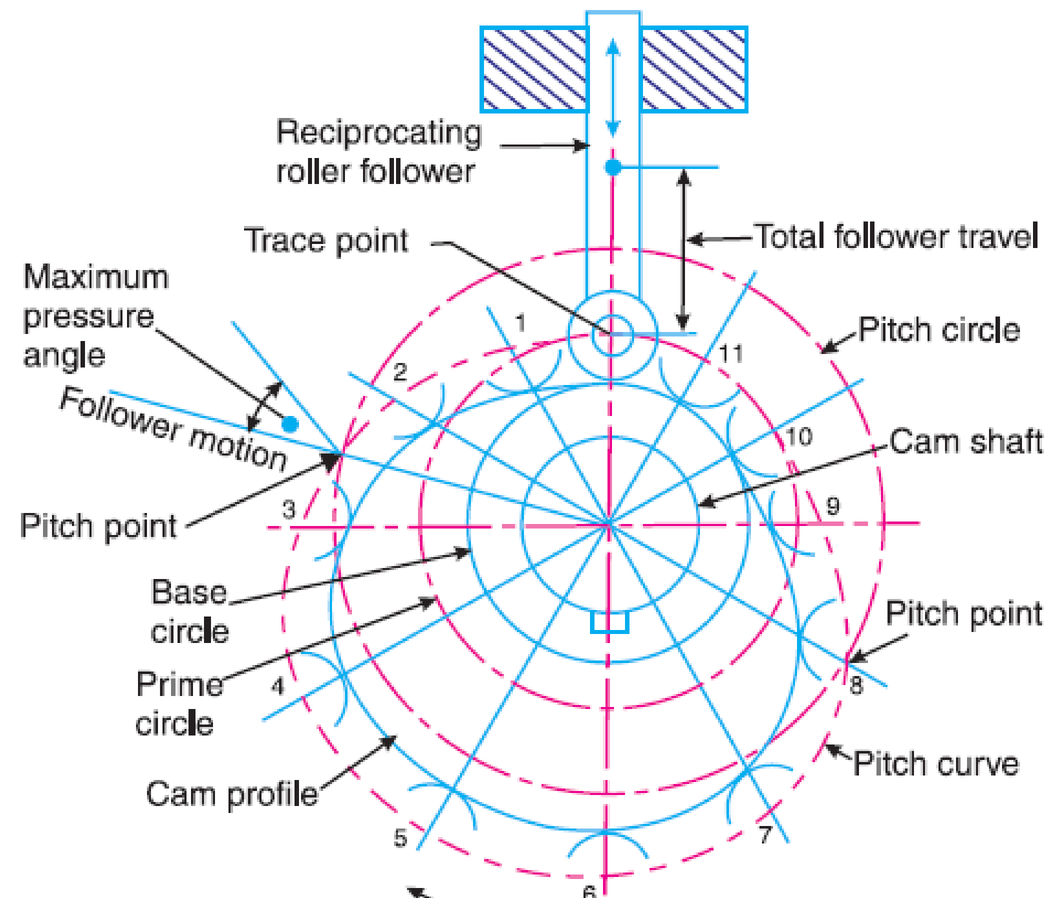
6. Pitch curve. It is the curve generated by the trace point as the follower moves relative to the cam. For a knife edge follower, the pitch curve and the cam profile are same whereas for a roller follower, they are separated by the radius of the roller.



Terms Used in Radial Cams

7. **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.

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

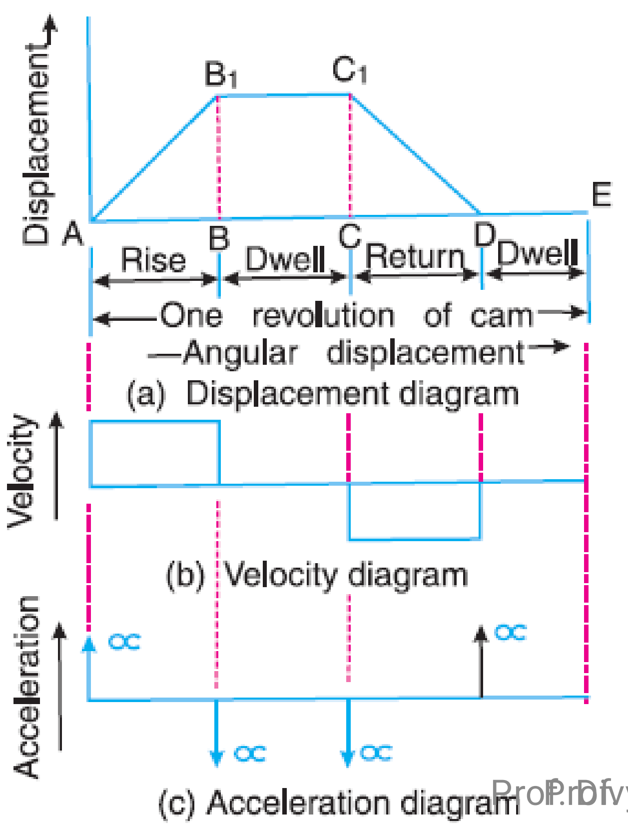


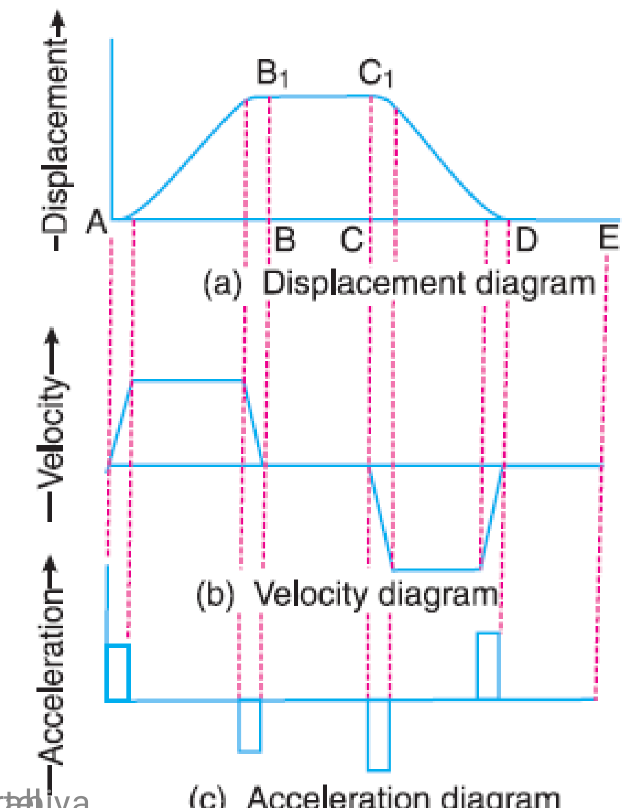
Motion of the Follower

- The follower, during its travel, may have one of the following motions.
  - **Uniform velocity**
  - **Simple harmonic motion**
  - **Uniform acceleration and retardation**
  - **Cycloidal motion**

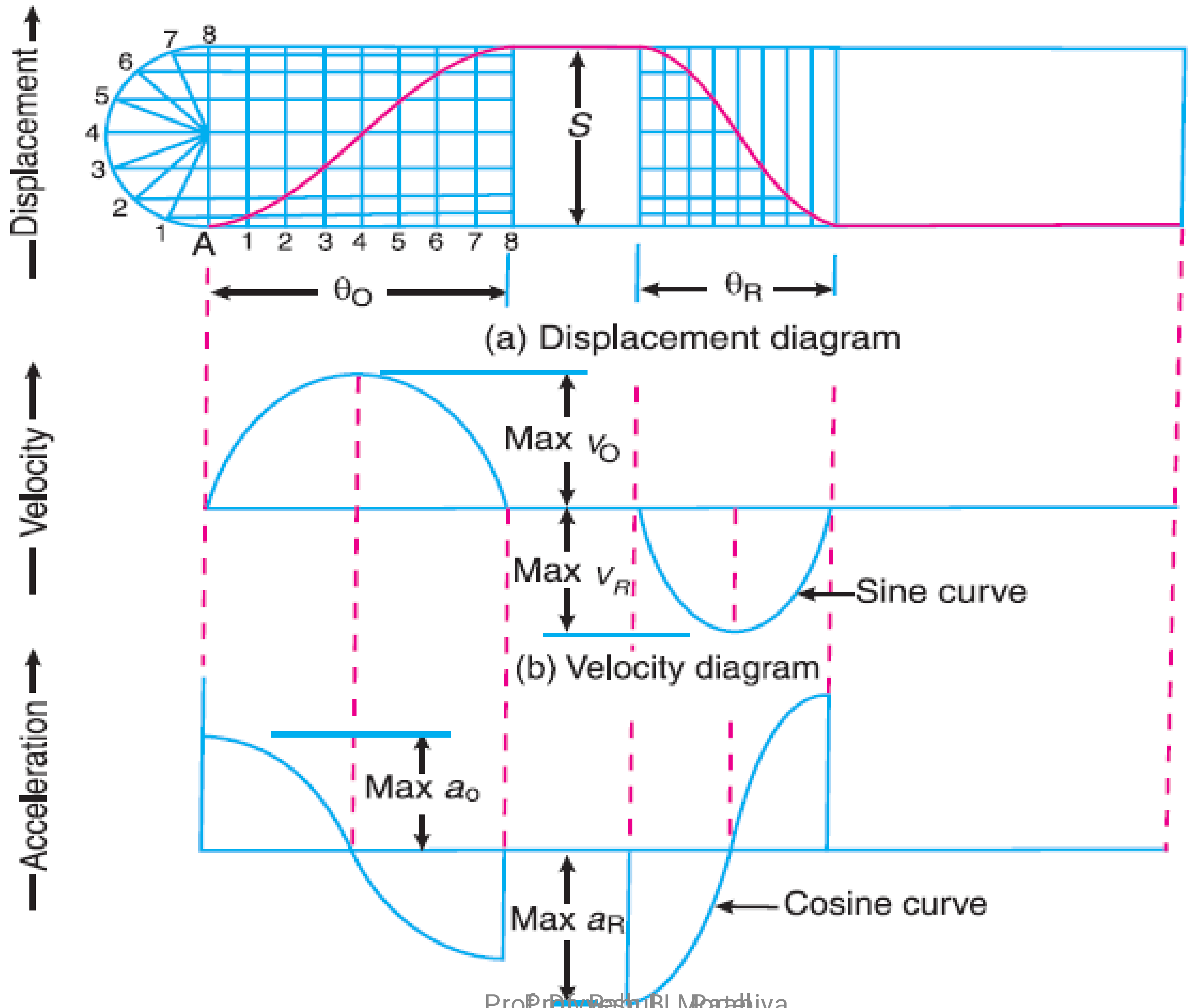
Displacement, Velocity and Acceleration Diagrams when the Follower Moves with Uniform Velocity

- The displacement, velocity and acceleration diagrams when a knife-edged follower moves with uniform velocity are shown in Fig. (*a), (b) and (c) respectively.*
- The abscissa (base) represents the time (*i.e. the number of seconds required for the cam to complete one revolution) or* it may represent the angular displacement of the cam in degrees. The ordinate represents the displacement, or velocity or acceleration of the follower.





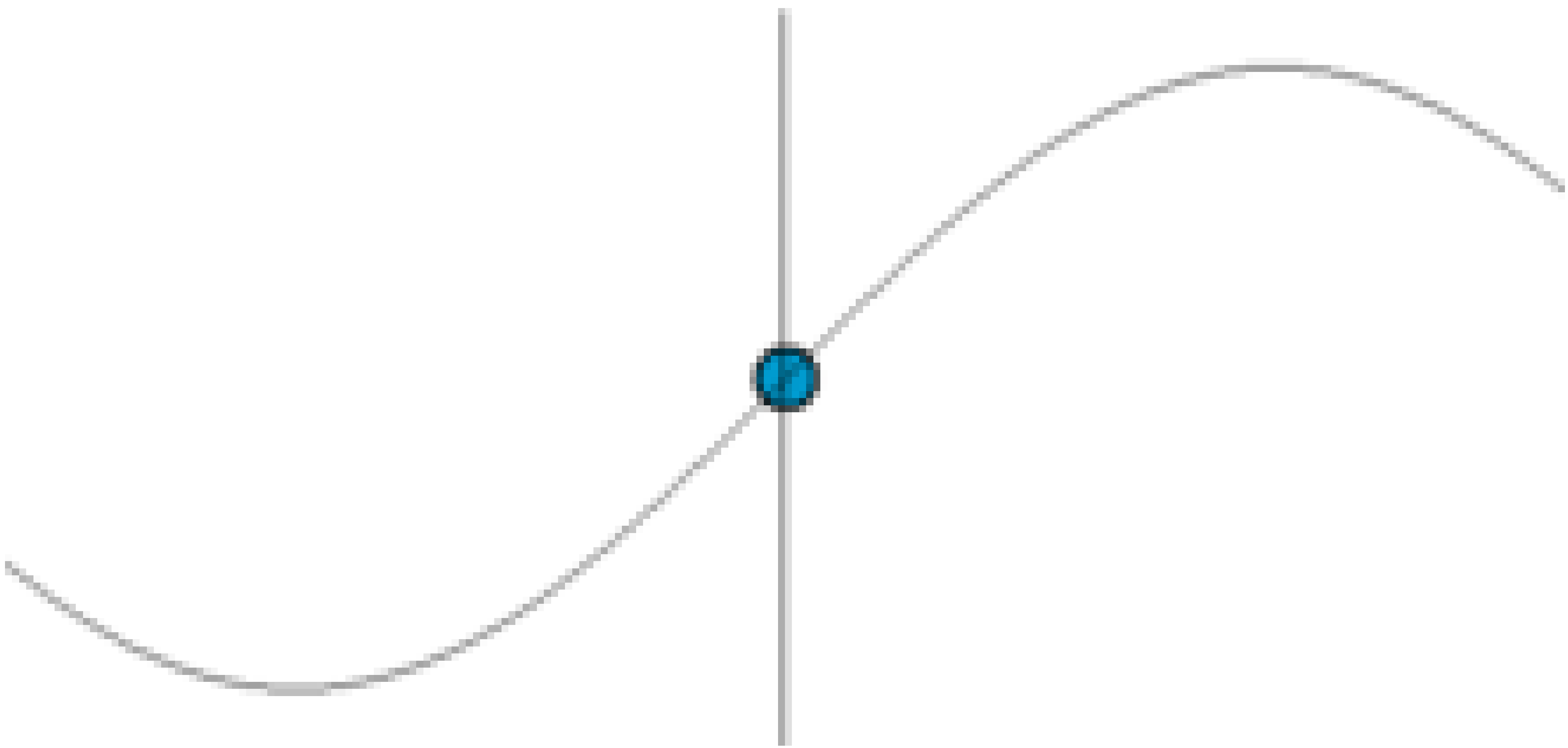
Displacement, Velocity and Acceleration Diagrams when the Follower Moves with Simple Harmonic Motion



(a) Displacement diagram

(b) Velocity diagram

(c) Acceleration diagram



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

Let S = Stroke of the follower,

θ_O and θ_R = Angular displacement of the cam during out stroke and return stroke of the follower respectively, in radians, and

ω = Angular velocity of the cam in rad/s.

maximum velocity of the follower on the outstroke, $\frac{\pi\omega S}{2\theta_O}$

$\therefore$ Maximum acceleration of the follower on the outstroke,

$$a_O = a_P = \frac{\pi^2\omega^2.S}{2(\theta_O)^2}$$

Similarly, maximum velocity of the follower on the return stroke,

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

and 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

velocity of the follower during outstroke,

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

maximum velocity of the follower during return

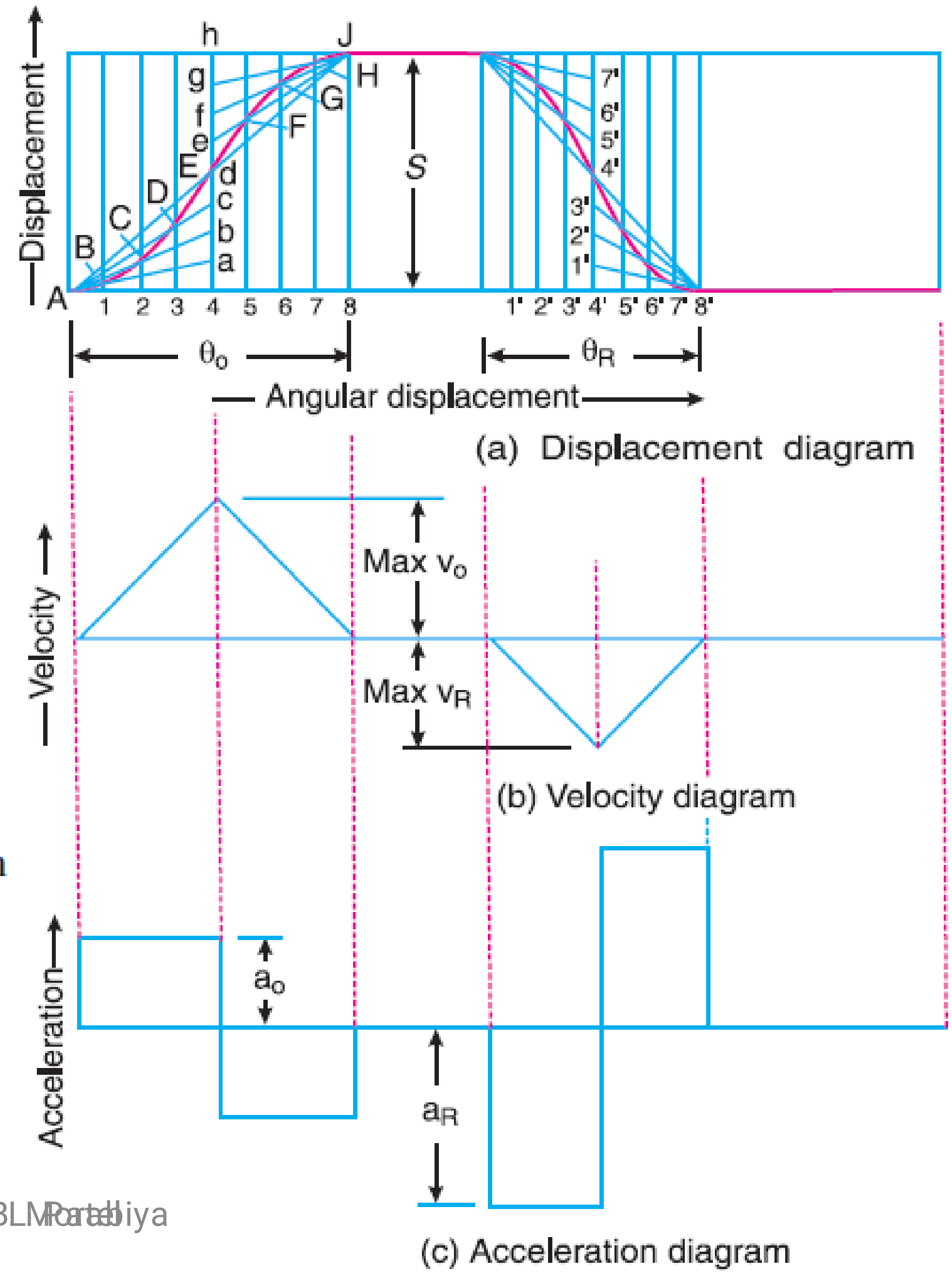
$$v_R = \frac{2\omega . S}{\theta_R}$$

Maximum acceleration of the follower during outstroke,

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

Similarly, maximum acceleration of the follower during return

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



• Cycloidal Motion

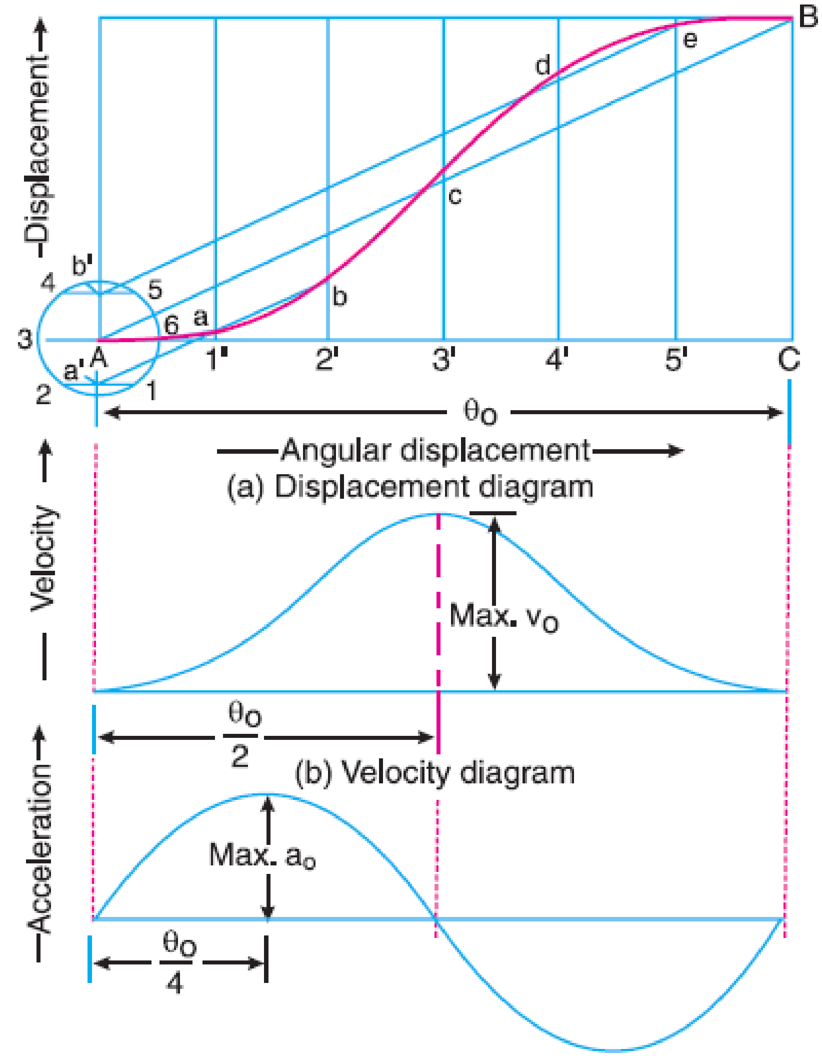
Displacement, Velocity and Acceleration Diagrams when the Follower Moves with Cycloidal Motion

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

$$a_O = \frac{2\pi\omega^2 . S}{(\theta_O)^2}$$

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

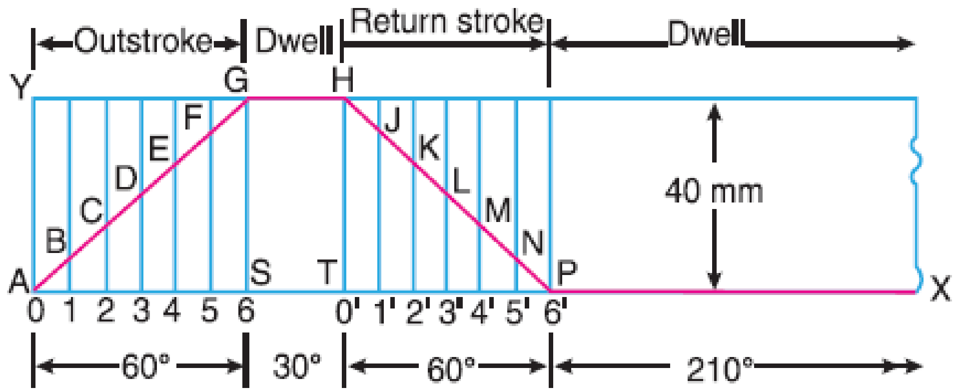
$$a_R = \frac{2\pi\omega^2 . S}{(\theta_R)^2}$$

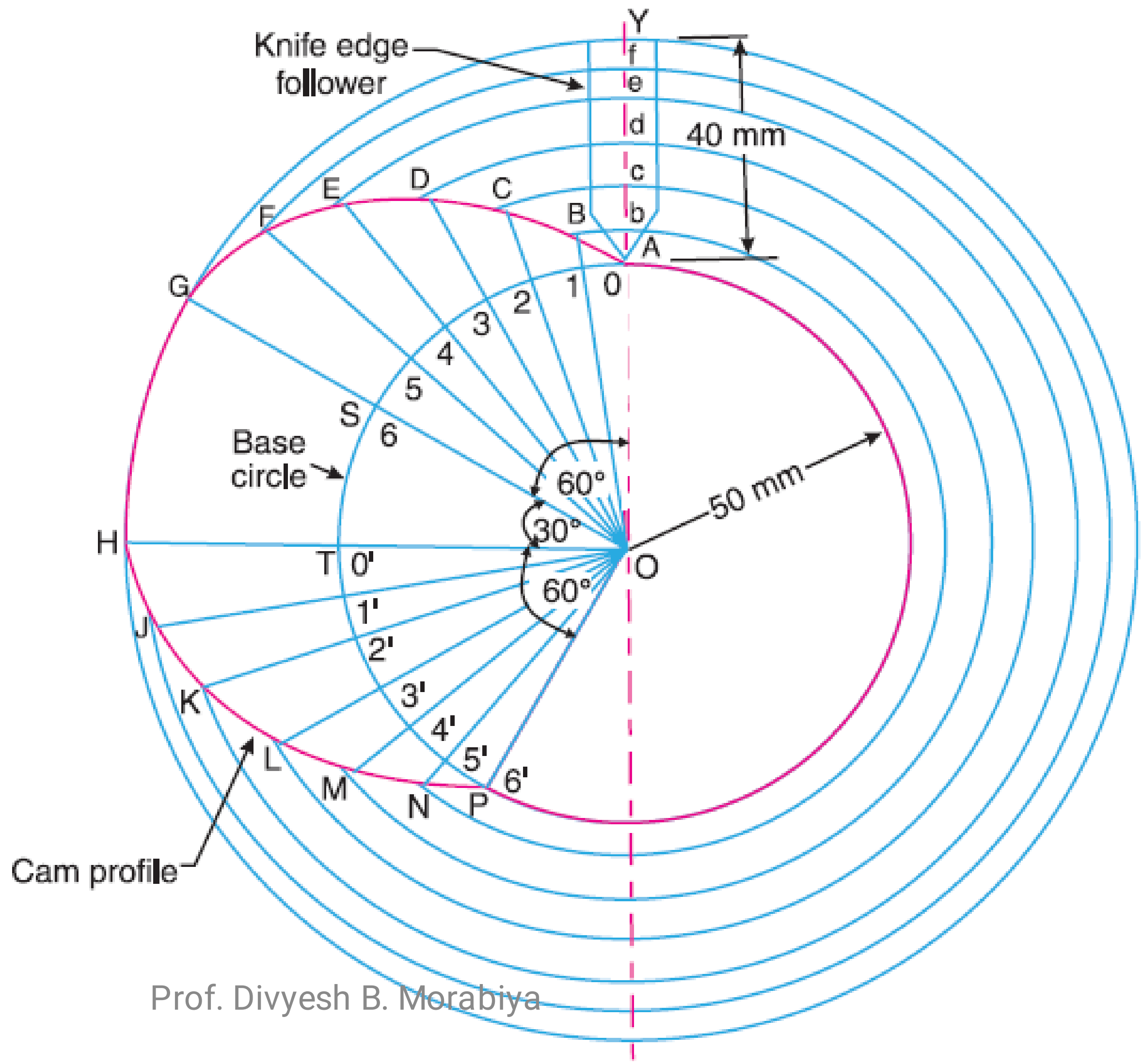


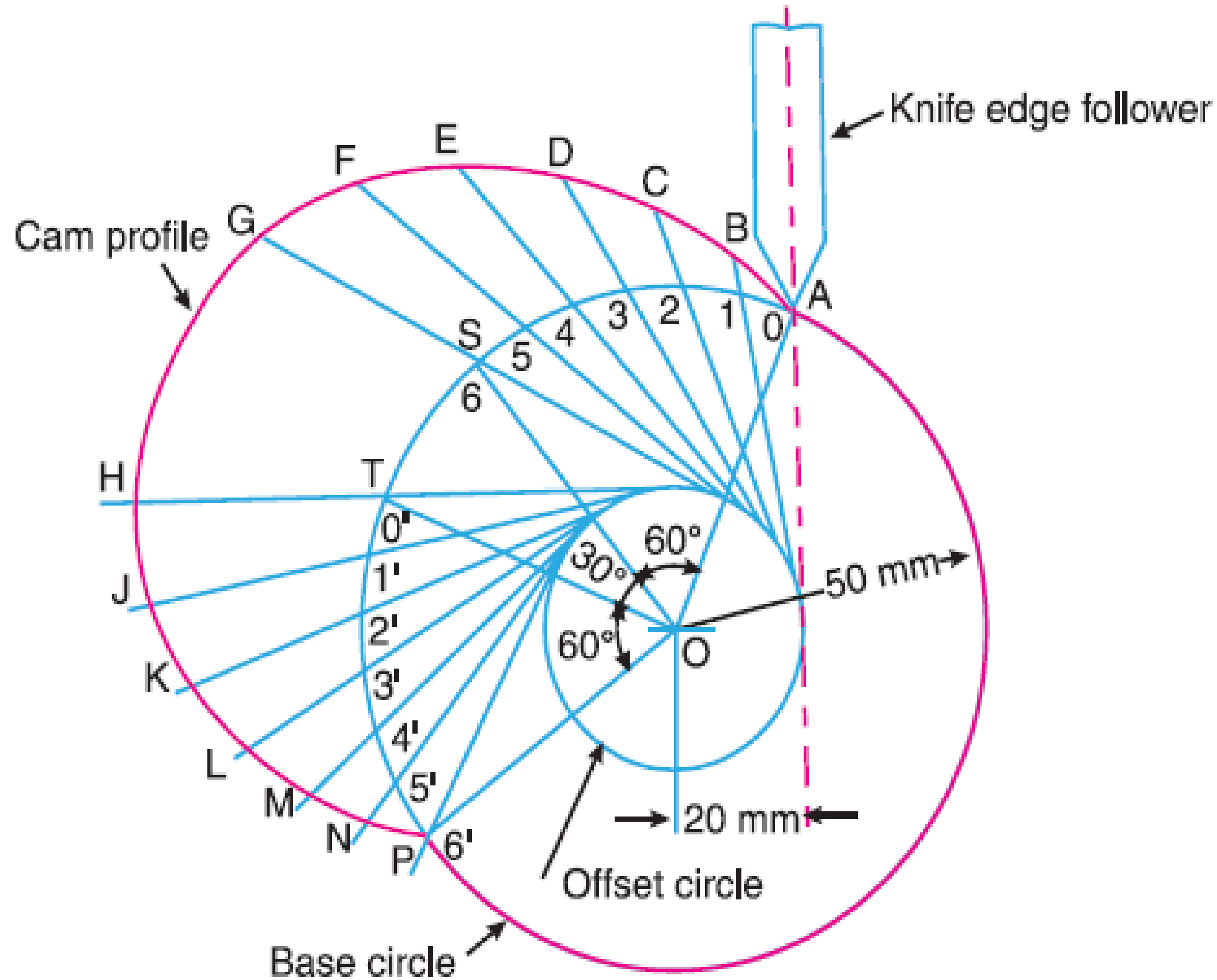
(a) Displacement diagram

(b) Velocity diagram

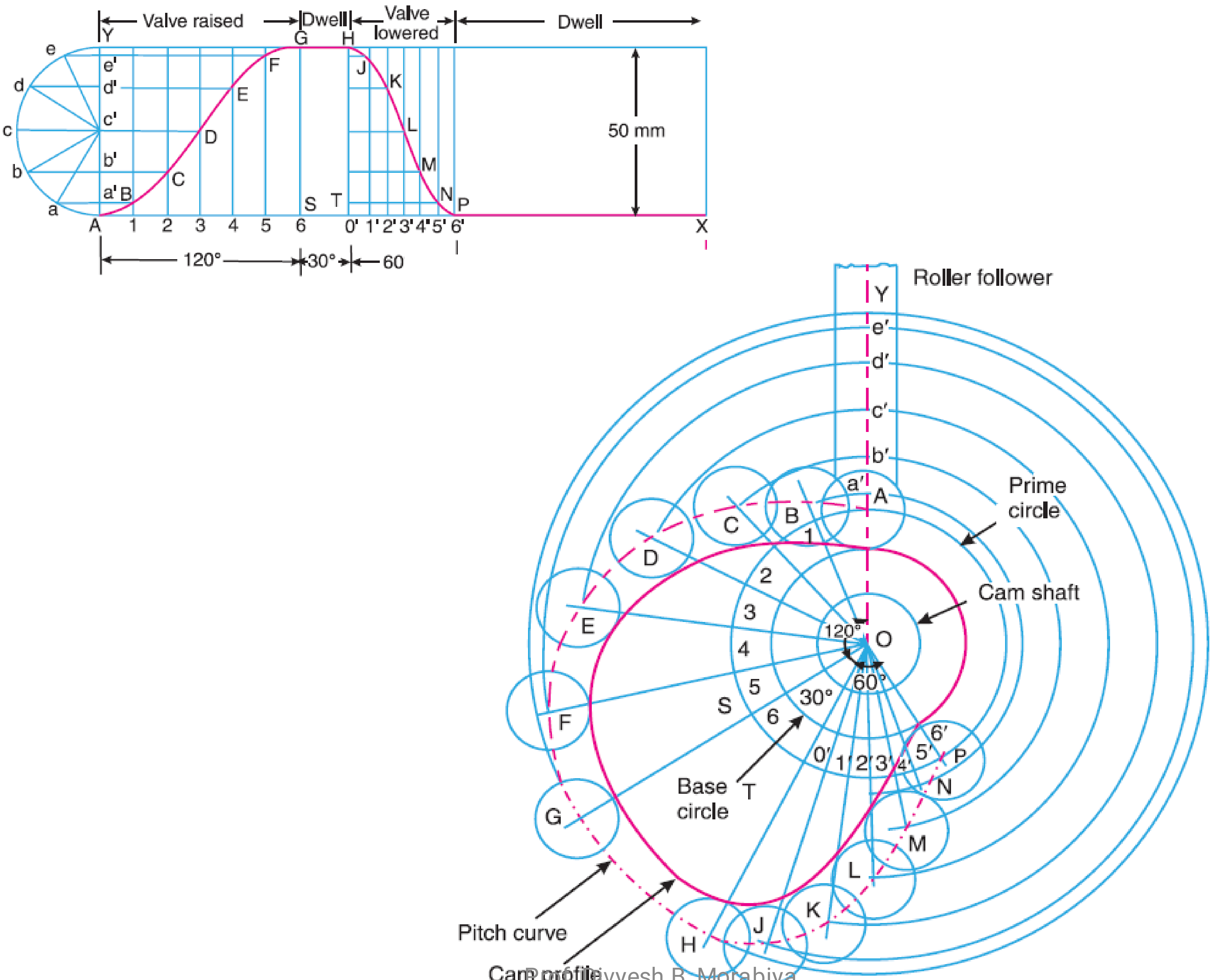
(c) Acceleration diagram


Outstroke
Dwell
Return stroke
Dwell
Y
G
H
A
B
C
D
E
F
J
K
L
M
N
P
S
T
X
40 mm
0 1 2 3 4 5 6
0' 1' 2' 3' 4' 5' 6'
60°
30°
60°
210°


Y
Knife edge follower
f
e
d
c
b
A
B
C
D
E
F
G
40 mm
1
0
2
3
4
5
6
S
Base circle
60°
30°
50 mm
H
T
0'
O
60°
1'
2'
3'
4'
5'
6'
J
K
L
M
N
P
Cam profile



Knife edge follower
Cam profile
A
B
C
D
E
F
G
H
J
K
L
M
N
P
S
T
O
0
1
2
3
4
5
6
0'
1'
2'
3'
4'
5'
6'
60°
30°
60°
50 mm
20 mm
Offset circle
Base circle



Valve raised
Dwell
Valve lowered
Dwell
Y
G
H
e
d
c
b
a
e'
d'
c'
b'
a'
A
B
C
D
E
F
J
K
L
M
N
P
S
T
50 mm
1
2
3
4
5
6
0'
1'
2'
3'
4'
5'
6'
X
120°
30°
60
Roller follower
Prime circle
Cam shaft
O
120°
60°
30°
Base circle
Pitch curve
Cam profile