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DEPARTMENT OF MECHANICAL ENGINEERING

ME3491 THEORY OF MACHINES

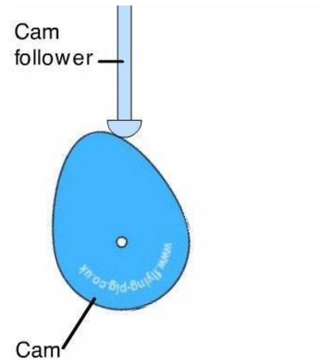
COURSE MATERIAL

1.3INTRODUCTION

A cam is a mechanical device used to transmit motion to a follower by direct contact. The driver is called the cam and the driven member is called the follower. In a cam follower pair, the cam normally rotates while the follower may translate or oscillate.

Cams:

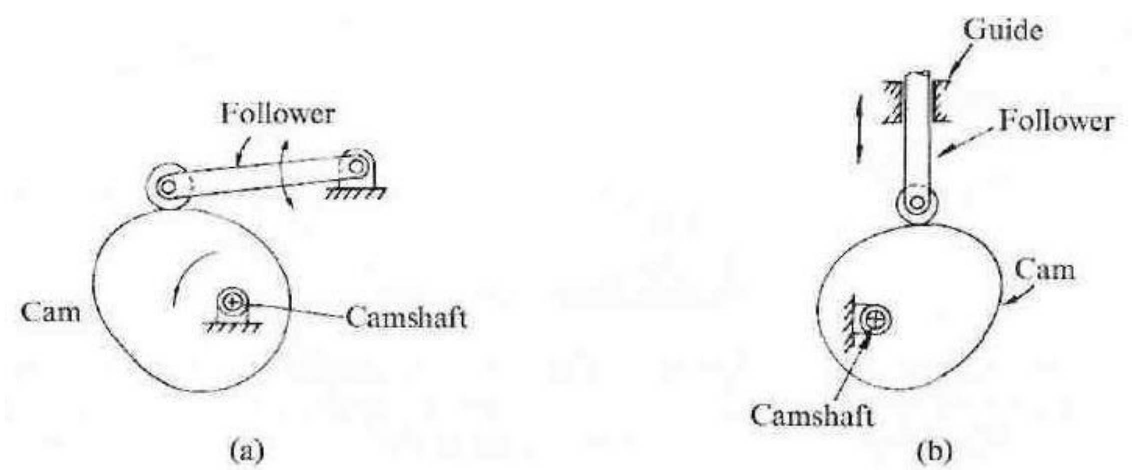
Type of cams, Type of followers, Displacement, Velocity and acceleration time curves for cam profiles, Disc cam with reciprocating follower having knife edge, roller follower, Follower motions including SHM, Uniform velocity, Uniform acceleration and retardation and Cycloidal motion.



1.1.1Types of cams

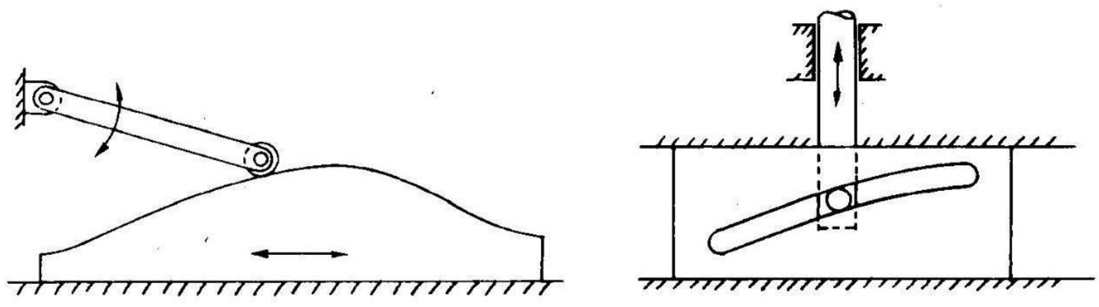
Cams can be classified based on their physical shape.

a) Disk or plate cam The disk (or plate) cam has an irregular contour to impart a specific motion to the follower. The follower moves in a plane perpendicular to the axis of rotation of the cam shaft and is held in contact with the cam by springs or gravity.



b) Cylindrical cam: The cylindrical cam has a groove cut along its cylindrical surface. The roller follows the groove, and the follower moves in a plane parallel to the axis of rotation of the cylinder.

c) Translating cam. The translating cam is a contoured or grooved plate sliding on a guiding surface(s). The follower may oscillate (Fig.3.3a) or reciprocate (Fig.3.3b). The contour or the shape of the groove is determined by the specified motion of the follower.

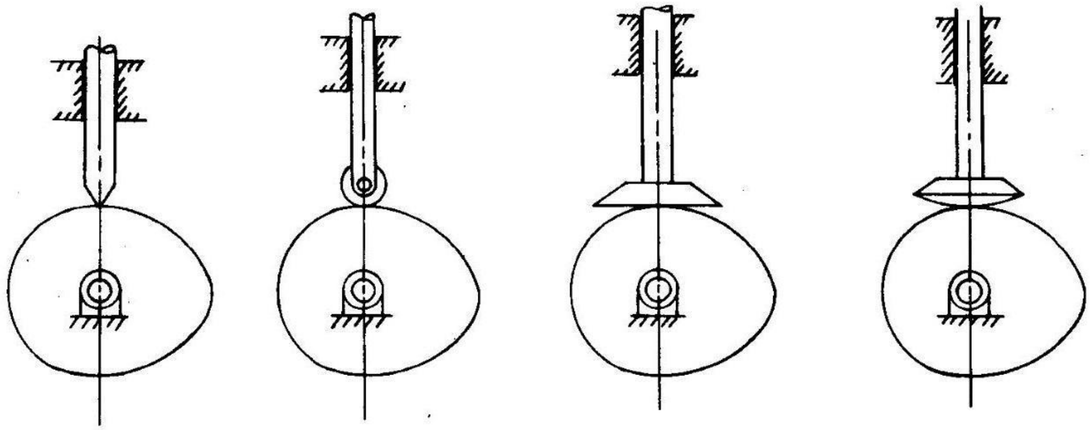


(a) (b)

Types of followers (Fig3.4):

(i) Based on surface in contact.

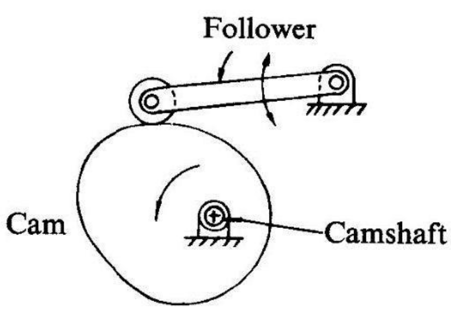
(a)Knife edge follower
(b)Roller follower
(c)Flat faced follower
(d)Spherical follower



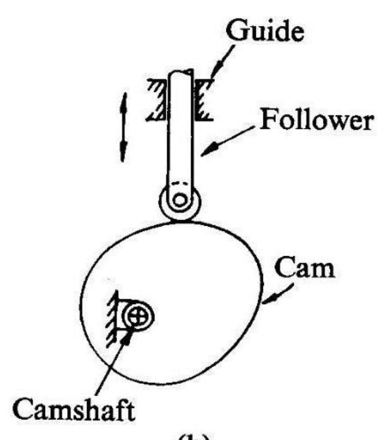
(a) (b) (c) (d)

(ii) **Based on type of motion**

(a)Oscillating follower
(b)Translating follower



(a)



(b)

(a) Radial follower: The lines of movement of in-line cam followers pass through the centre of the camshafts

(b) Off-set follower: For this type the lines of movement are offset from the centres of the camshafts

Cam Nomenclature (Fig.3.7):

Cam Profile The contour of the working surface of the cam.

Tracer Point The point at the knife edge of a follower, or the centre of a roller, or the centre of a spherical face.

Pitch Curve The path of the tracer point.

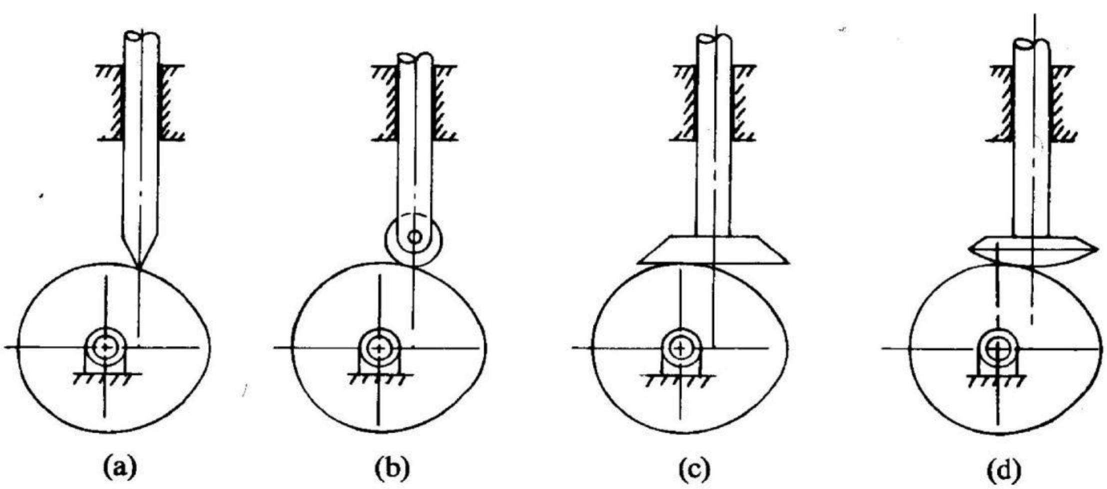
Base Circle The smallest circle drawn, tangential to the cam profile, with its centre on the axis of the camshaft. The size of the base circle determines the size of the cam.

Prime Circle The smallest circle drawn, tangential to the pitch curve, with its centre on the axis of the cam shaft.

Pressure Angle The angle between the normal to the pitch curve and the direction of motion of the follower at the point of contact

3.2 Types of follower motion:

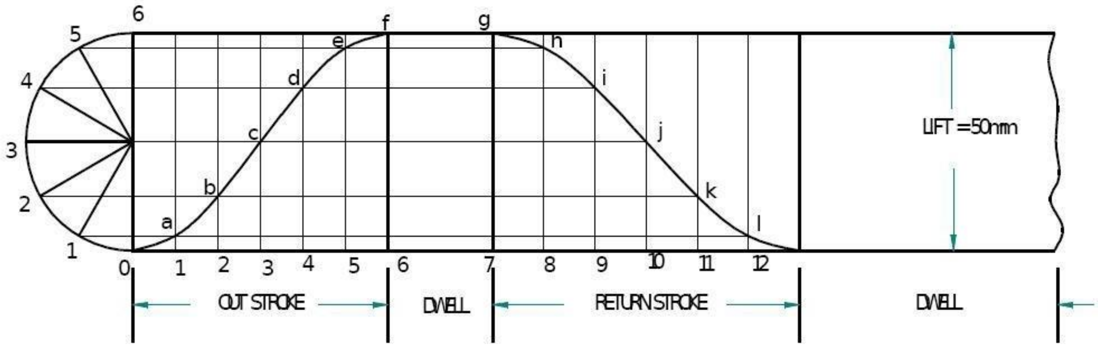
(a)Uniform velocity
(b)Modified uniform velocity
(c) Uniform acceleration and deceleration
(d)Simple harmonic motion
(e)Cycloidal motion



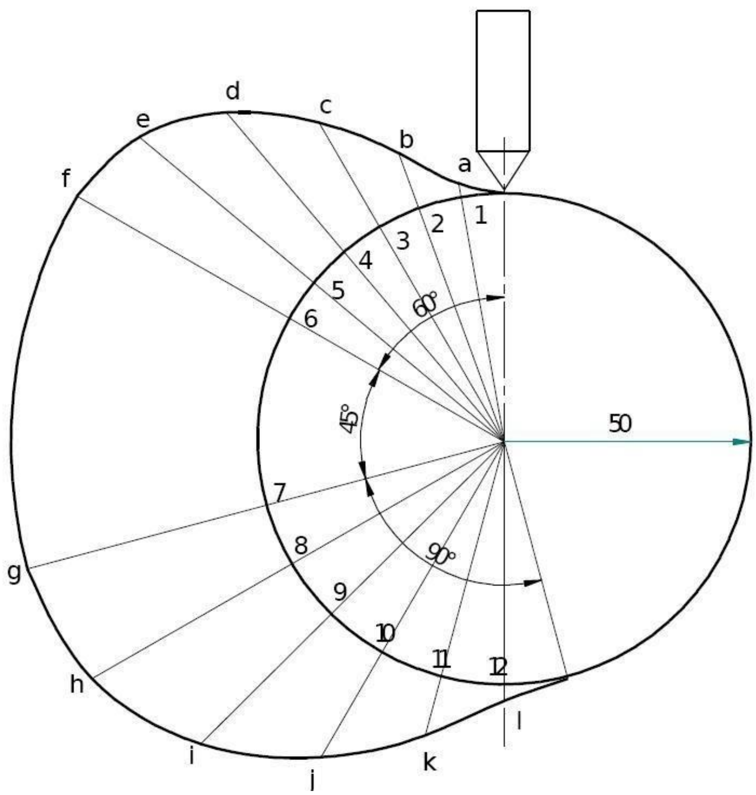
1. Draw the cam profile for following conditions:

Follower type=Knife edged in-line; lift=50mm; base circle radius =50mm; outstroke with SHM,for60^0 Cam rotation; dwellfor45^0camrotation; return stroke with SHM, for90^ocam rotation; dwell for the remaining period. Draw the cam profile for the same operating condition so f with the follower offset by 10mm to the left of cam centre.

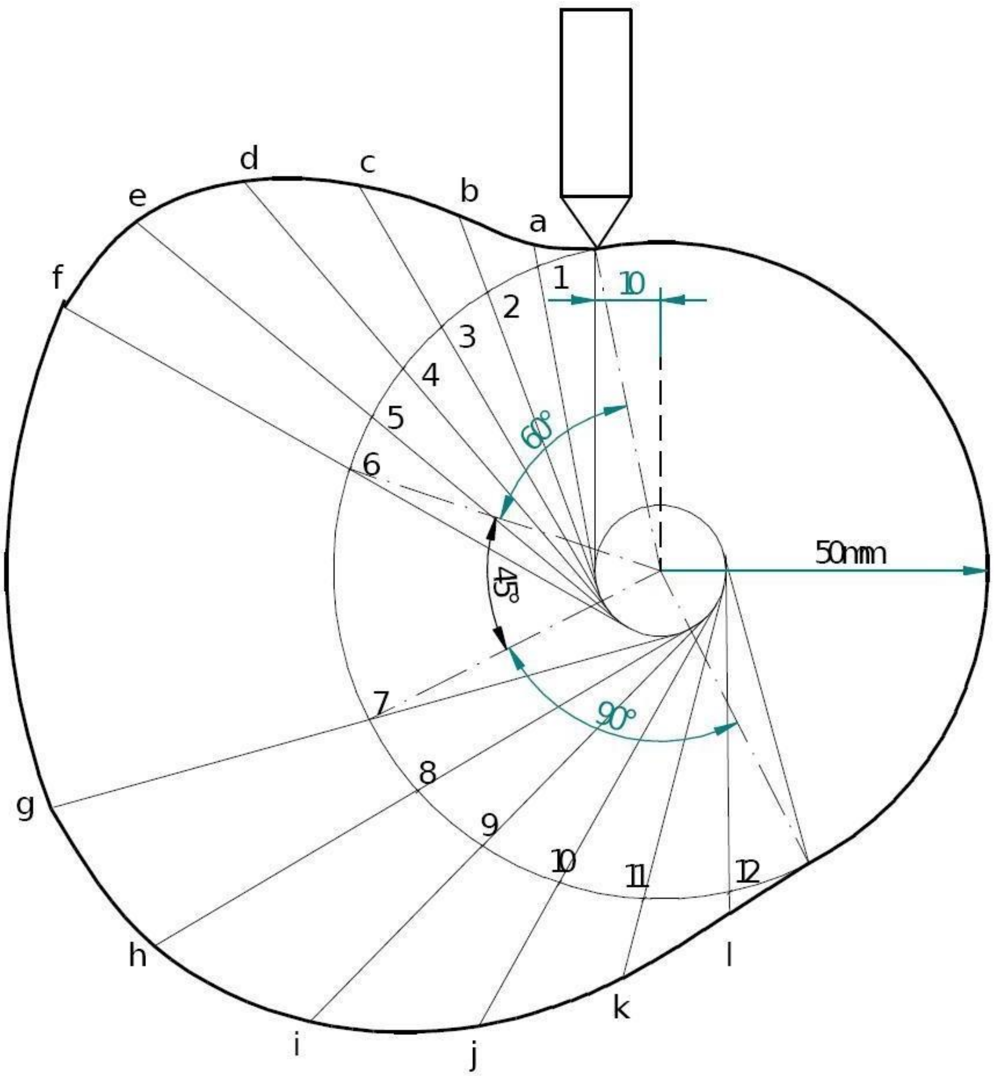
Displacement diagram:



Cam profile:



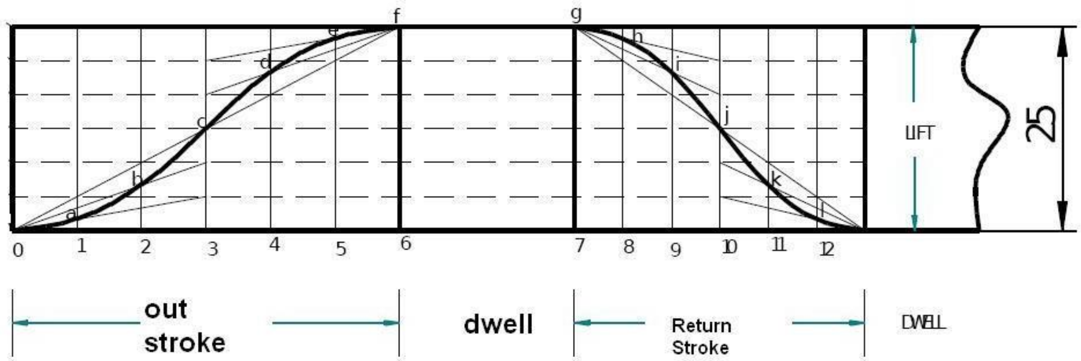
Cam profile with 10 mm offset:



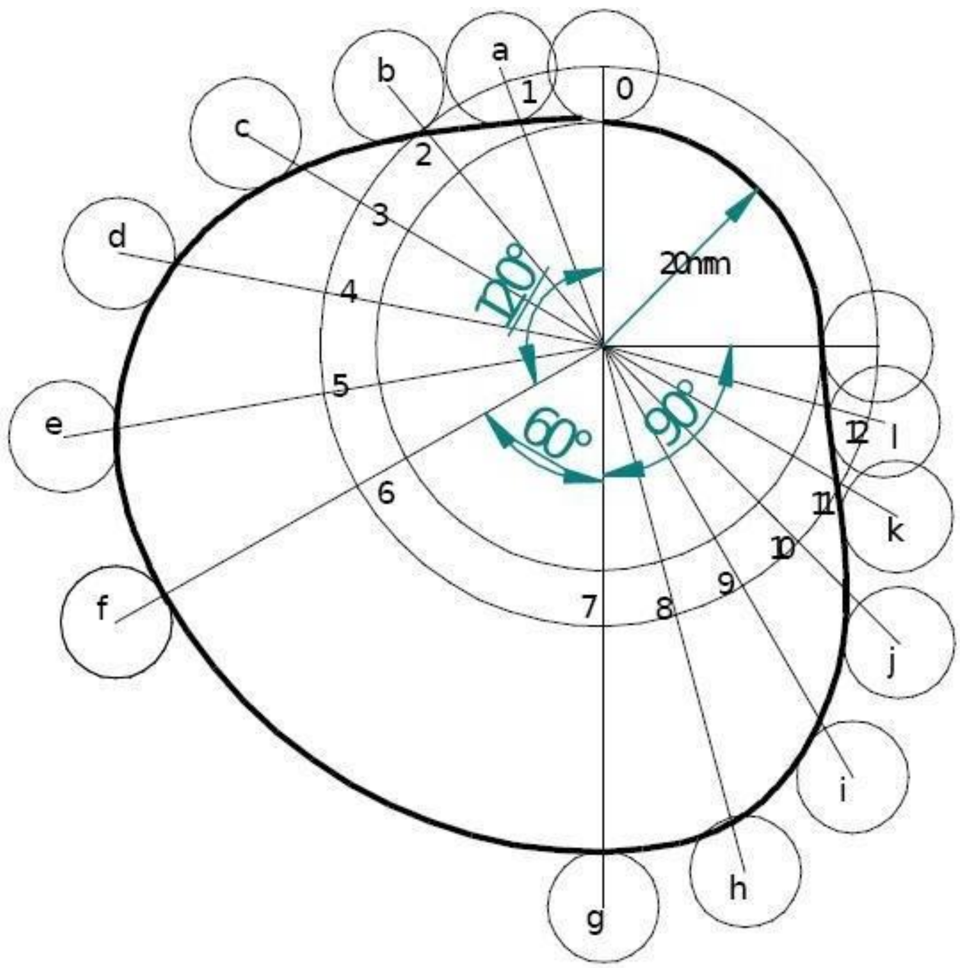
2. Draw the cam profile for following conditions:

Follower type=roller follower, in-line; lift=25mm; base circle radius=20mm; roller radius= 5mm; out stroke with Uniform acceleration and retardation, for 120^0 cam rotation; dwell for 60^0 cam rotation; return stroke with Uniform acceleration and retardation, for90^0 cam rotation; dwell for the remaining period (4) Draw the cam profile for conditions same with follower off set to right of cam centre by 5mm and cam rotating counter clockwise.

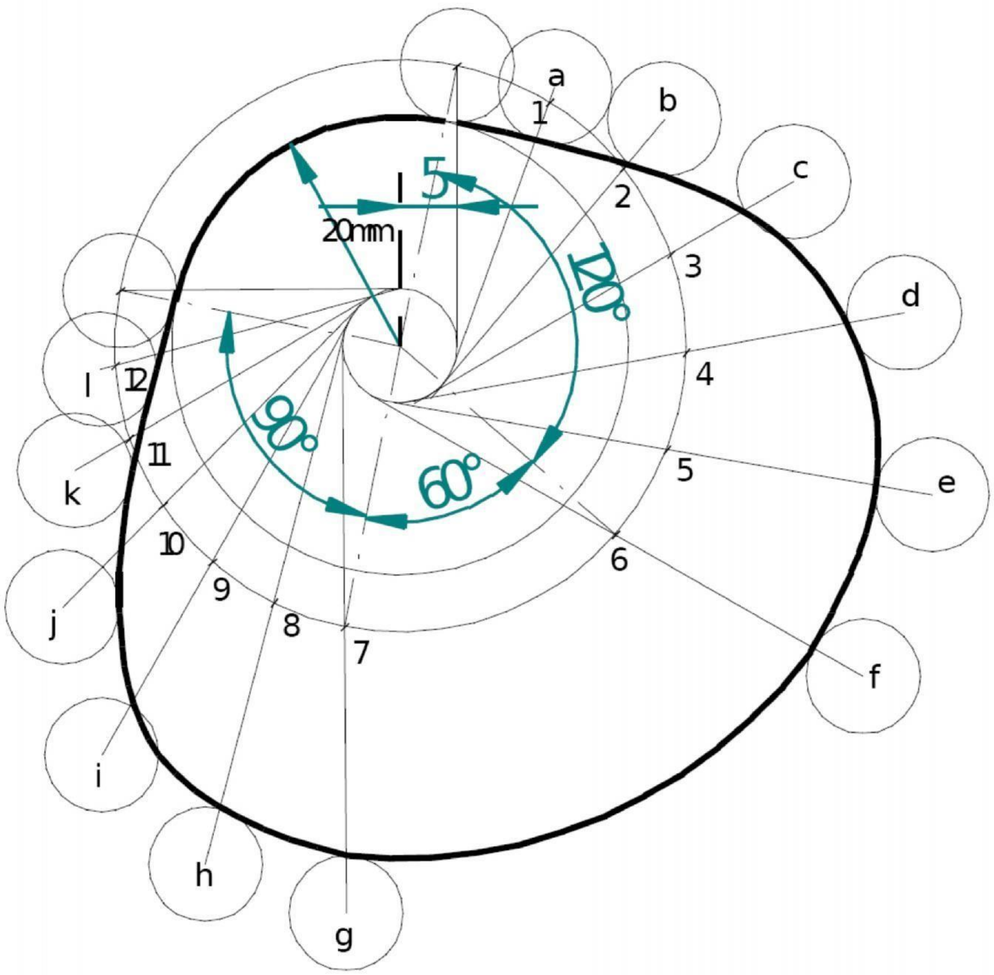
Displacement Diagram:



Cam profile;

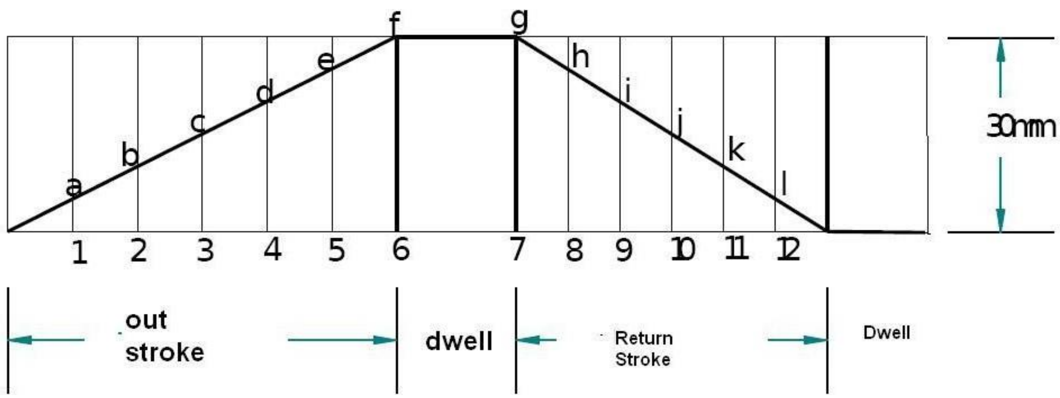


Cam profile with 5 mm offset

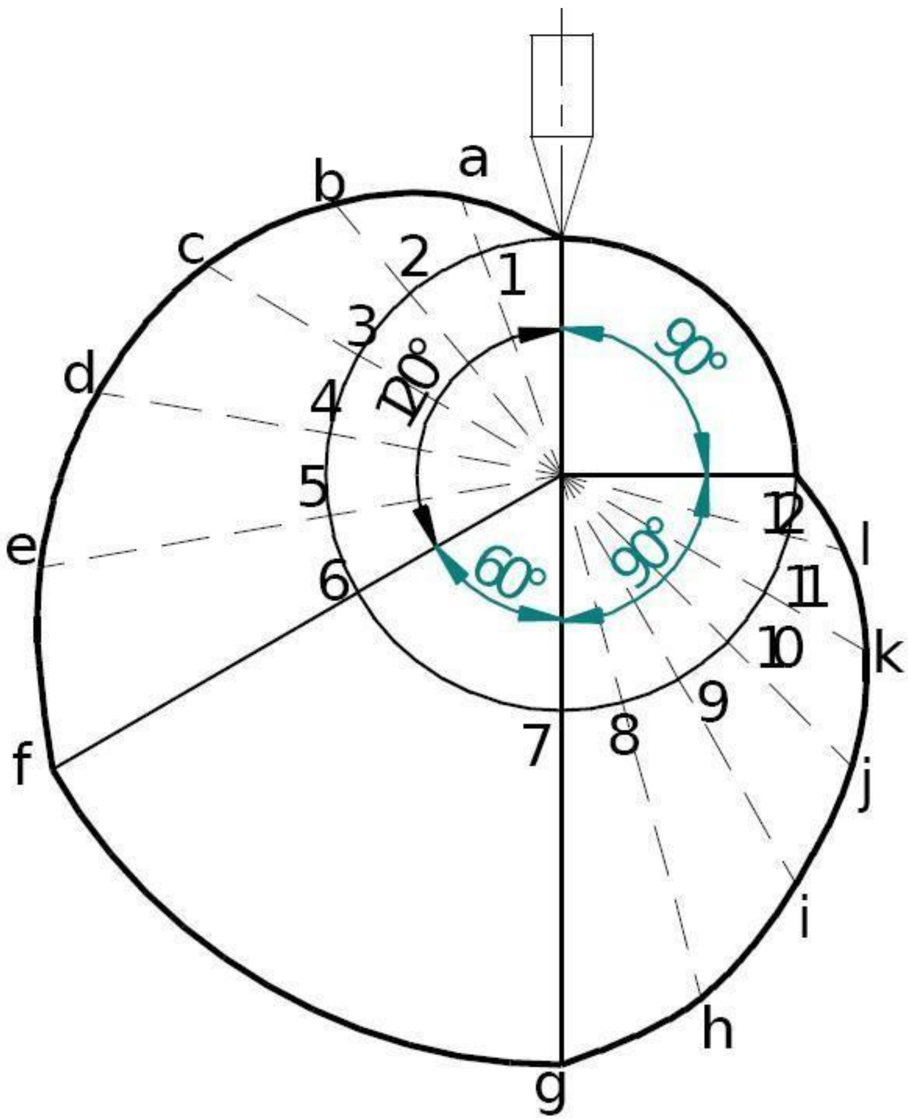


(3) Draw the cam profile for following conditions:
Follower type=knife edge d follower, in line; lift=30mm; base circle radius =20mm; outstroke with uniform velocity in120^{0}of cam rotation; dwell for 60^0; return stroke with uniform velocity, during90^{0}ofcam rotation; dwell for the remaining period.

Displacement Diagram

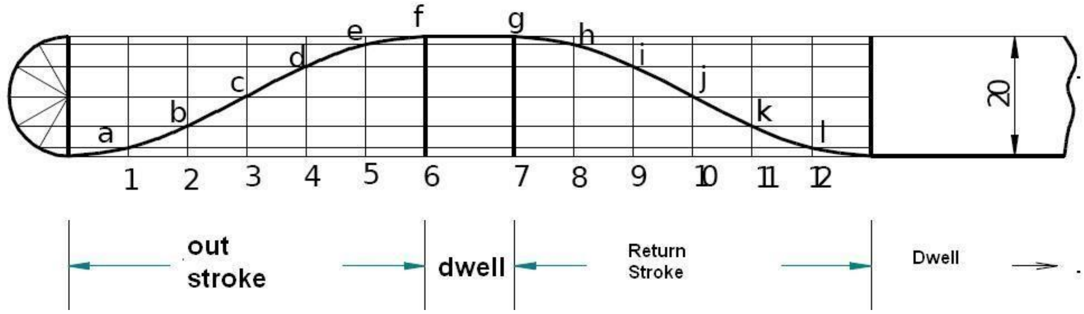


Cam profile

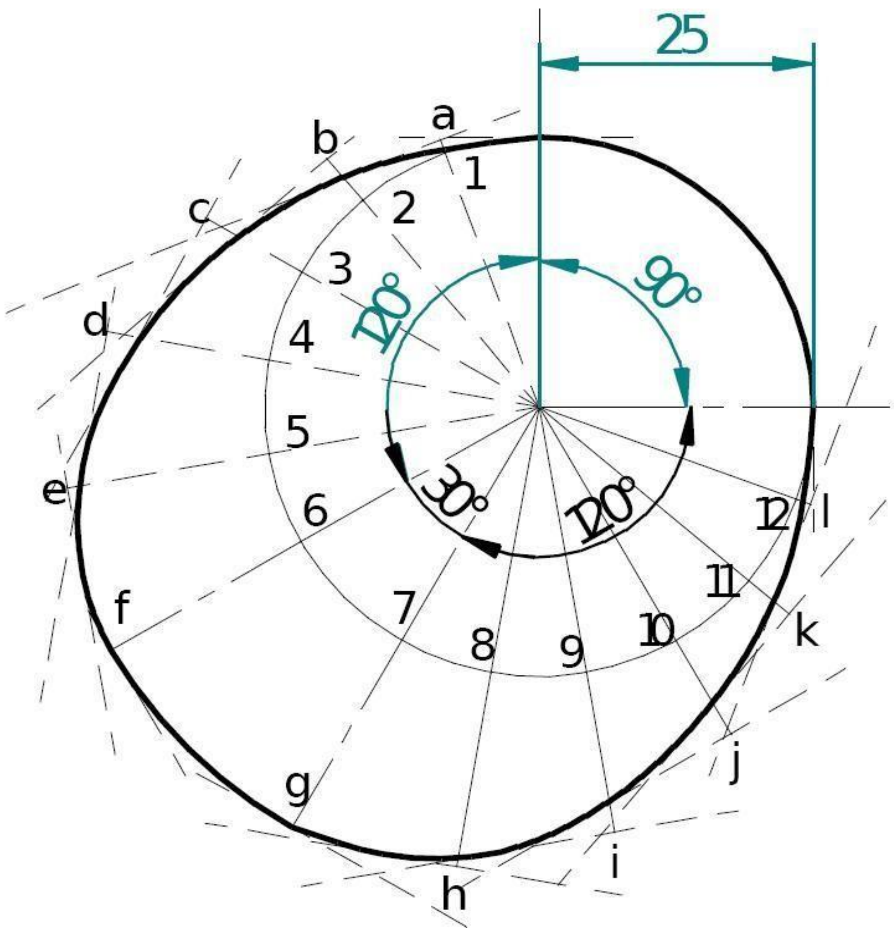


(4) Draw the cam profile for following conditions: Follower type = flat faced follower, inline; follower rises by 20mm with SHM in 120⁰of cam rotation, dwells for 30⁰ of cam rotation; returns with SHM in 120⁰ of cam rotation and dwells during the remaining period. Base circle radius =25mm.

Displacement Diagram:



Cam profile



3.5 Layout of plate cam profiles:

- Drawing the displacement diagrams for the different kinds of the motions and the plate cam profiles for these different motions and different followers.
- SHM, Uniform velocity, Uniform acceleration and retardation and Cycloidal motions
- Knife-edge, Roller, Flat-faced and Mushroom followers.

3.6Derivatives of Follower motion:

- Velocity and acceleration of the followers for various types of motions.
- Calculation of Velocity and acceleration of the followers for various types of motions.

3.7Circular arc and Tangent cam s:

- Circular arc
- Tangent cam

Standard cam motion:

- Simple Harmonic Motion
- Uniform velocity motion
- Uniform acceleration and retardation motion
- Cycloidal motion

3.8 Pressure angle and undercutting:

- Pressure angle
- Undercutting

. A cam, with a minimum radius of 25 mm, rotating clockwise at a uniform speed is to be designed to give a roller follower, at the end of a valve rod, motion described below :

1. *To raise the valve through 50 mm during 120° rotation of the cam ;*
2. *To keep the valve fully raised through next 30°;*
3. *To lower the valve during next 60°; and*
4. *To keep the valve closed during rest of the revolution i.e. 150° ;*

The diameter of the roller is 20 mm and the diameter of the cam shaft is 25 mm.

Draw the profile of the cam when (a) the line of stroke of the valve rod passes through the axis of the cam shaft, and (b) the line of the stroke is offset 15 mm from the axis of the cam shaft.

The displacement of the valve, while being raised and lowered, is to take place with simple harmonic motion. Determine the maximum acceleration of the valve rod when the cam shaft rotates at 100 r.p.m.

Draw the displacement, the velocity and the acceleration diagrams for one complete revolution of the cam.

Solution. Given : S = 50 mm = 0.05 m ; θ_O = 120° = 2 π/3 rad = 2.1 rad ; θ_R = 60° = π/3 rad = 1.047 rad ; N = 100 r.p.m.

(a) *Profile of the cam when the line of stroke of the valve rod passes through the axis of the cam shaft*

The profile of the cam, as shown in Fig. 20.17, is drawn as discussed in the following steps :

1. Draw a base circle with centre O and radius equal to the minimum radius of the cam (*i.e.* 25 mm).
2. Draw a prime circle with centre O and radius,

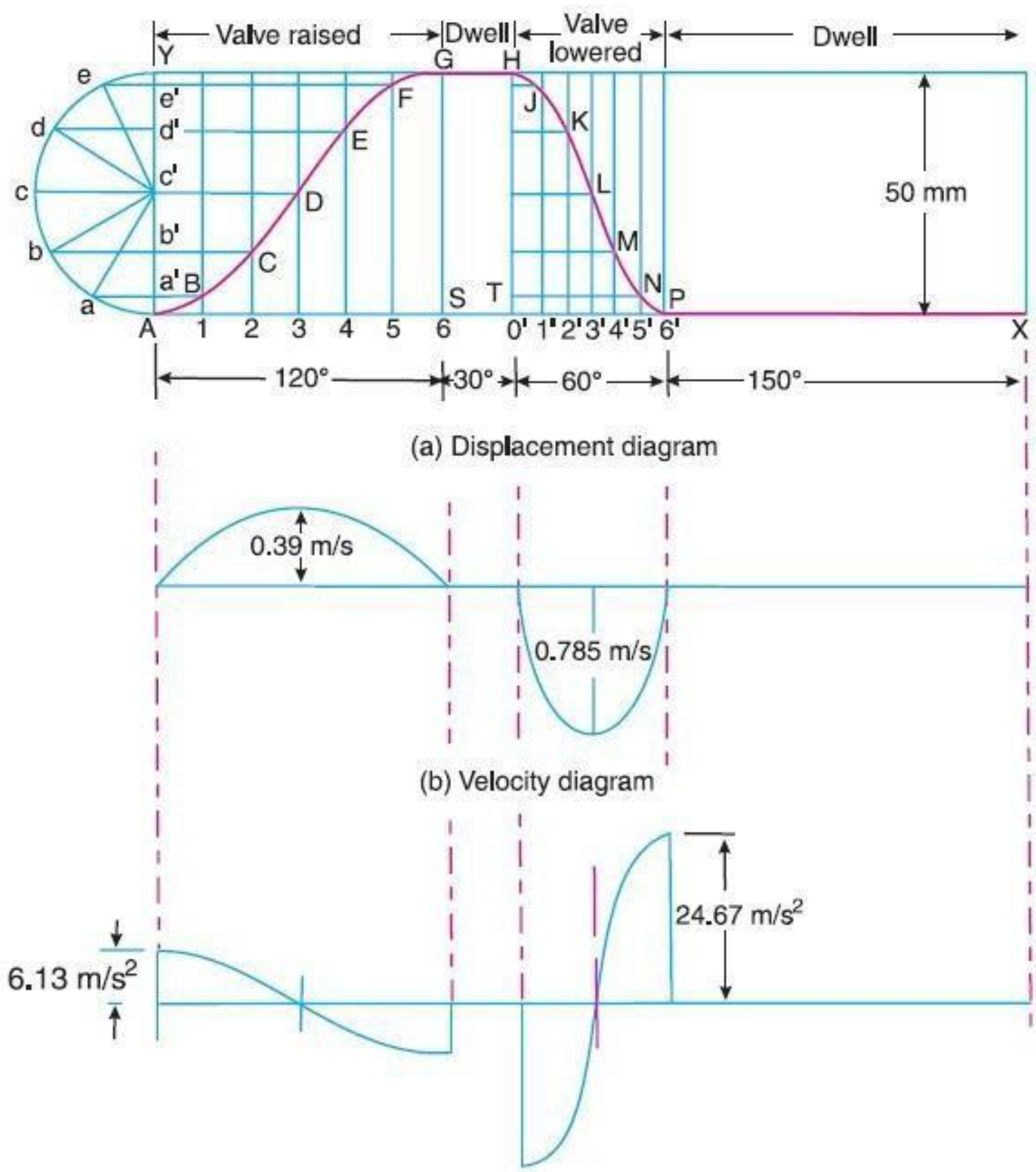
$$OA = \text{Min. radius of cam} + \frac{1}{2}\text{ Dia. of roller} = 25+\frac{1}{2}\times 20 = 35 \text{ mm}$$

3. Draw angle AOS = 120° to represent raising or out stroke of the valve, angle SOT = 30° to represent dwell and angle TOP = 60° to represent lowering or return stroke of the valve.
4. Divide the angular displacements of the cam during raising and lowering of the valve (*i.e.* angle AOS and TOP) into the same number of equal even parts as in displacement diagram.
5. Join the points 1, 2, 3, etc. with the centre O and produce the lines beyond prime circle as shown in Fig. 20.17.
6. Set off $1B$, $2C$, $3D$ etc. equal to the displacements from displacement diagram.
7. Join the points A, B, C ... N, P, A. The curve drawn through these points is known as ***pitch curve.***

2. Draw a prime circle with centre O and radius,

$$OA = \text{Min. radius of cam} + \frac{1}{2}\ \text{Dia. of roller} = 25 + \frac{1}{2} \times 20 = 35\ \text{mm}$$

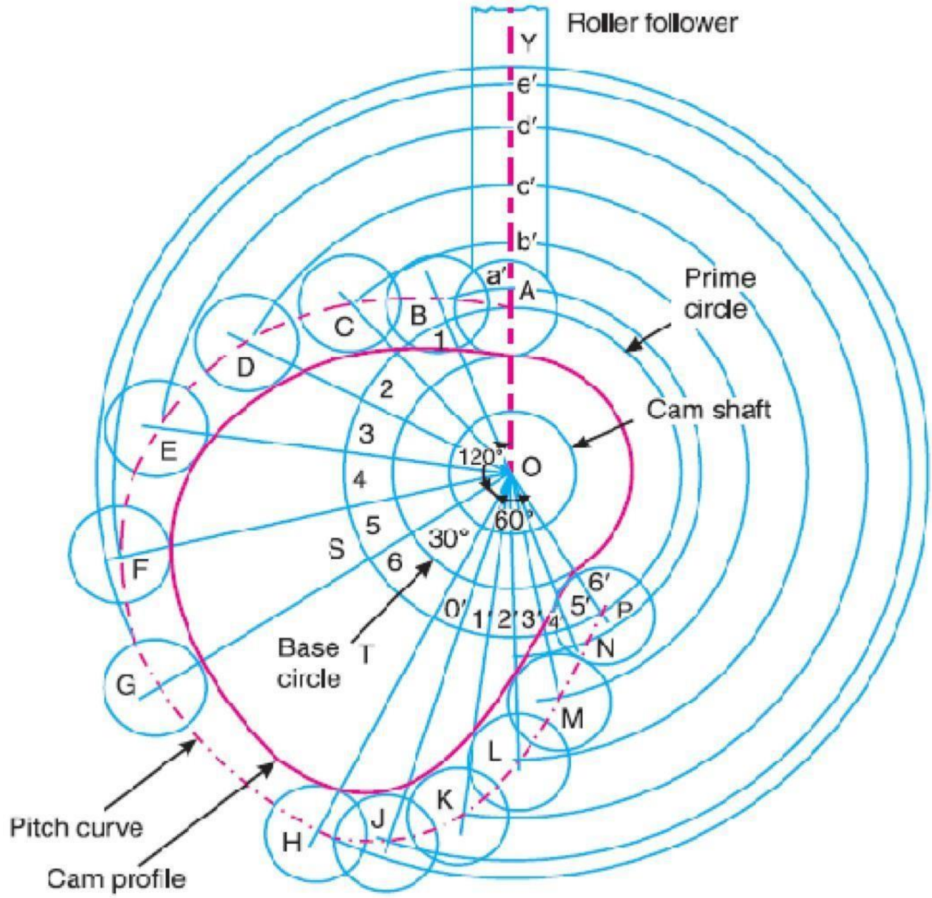
3. Draw angle $AOS = 120°$ to represent raising or out stroke of the valve, angle $SOT = 30°$ to represent dwell and angle $TOP = 60°$ to represent lowering or return stroke of the valve.
4. Divide the angular displacements of the cam during raising and lowering of the valve (*i.e.* angle AOS and TOP) into the same number of equal even parts as in displacement diagram.
5. Join the points 1, 2, 3, etc. with the centre O and produce the lines beyond prime circle as shown in Fig. 20.17.
6. Set off $1B$, $2C$, $3D$ etc. equal to the displacements from displacement diagram.
7. Join the points $A, B, C \ldots N, P, A$. The curve drawn through these points is known as *pitch curve.*



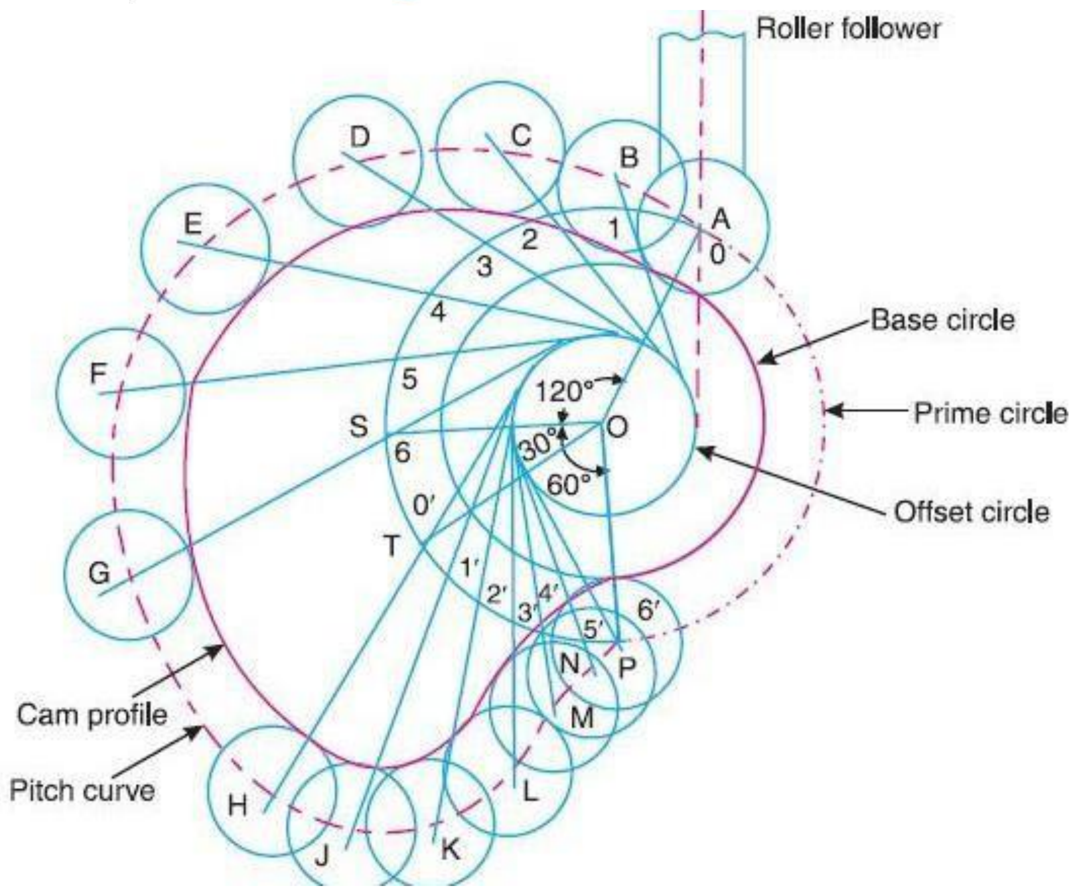
(a) Displacement diagram

(b) Velocity diagram

(c) Acceleration diagram



Roller follower
Y
e′
d′
c′
b′
a′
A
B
C
D
E
F
G
H
J
K
L
M
N
P
1
2
3
4
5
6
S
T
0′
1′
2′
3′
4′
5′
6′
120°
60°
30°
O
Prime circle
Cam shaft
Base circle
Pitch curve
Cam profile



Roller follower
A
0′
B
C
D
E
F
G
H
J
K
L
M
N
P
1
2
3
4
5
6
S
T
1′
2′
3′
4′
5′
6′
120°
30°
60°
O
Base circle
Prime circle
Offset circle
Cam profile
Pitch curve

(b) Profile of the cam when the line of stroke is offset 15 mm from the axis of the cam shaft

The profile of the cam when the line of stroke is offset from the axis of the cam shaft, as shown in Fig. 20.18, may be drawn as discussed in the following steps :

1. Draw a base circle with centre *O* and radius equal to 25 mm.
2. Draw a prime circle with centre *O* and radius *OA* = 35 mm.
3. Draw an off-set circle with centre *O* and radius equal to 15 mm.
4. Join *OA*. From *OA* draw the angular displacements of cam *i.e.* draw angle *AOS* = 120°, angle *SOT* = 30° and angle *TOP* = 60°.
5. Divide the angular displacements of the cam during raising and lowering of the valve into the same number of equal even parts (*i.e.* six parts) as in displacement diagram.
6. From points 1, 2, 3 .... etc. and $0', 1', 3'$, ...etc. on the prime circle, draw tangents to the offset circle.
7. Set off 1*B*, 2*C*, 3*D*... etc. equal to displacements as measured from displacement diagram.
8. By joining the points *A*, *B*, *C* ... *M*, *N*, *P*, with a smooth curve, we get a ***pitch curve.***
9. Now *A*, *B*, *C*...etc. as centre, draw circles with radius equal to the radius of roller.
10. Join the bottoms of the circles with a smooth curve as shown in Fig. 20.18. This is the required profile of the cam.

Maximum acceleration of the valve rod

We know that angular velocity of the cam shaft,

$$\omega = \frac{2\pi N}{60} = \frac{2\pi\times 100}{60} = 10.47 \text{ rad/s}$$

We also know that maximum velocity of the valve rod to raise valve,

$$v_O = \frac{\pi\omega S}{2\theta_O} = \frac{\pi\times 10.47\times 0.05}{2\times 2.1} = 0.39 \text{ m/s}$$

and maximum velocity of the valve rod to lower the valve,

$$v_R = \frac{\pi\omega S}{2\theta_R} = \frac{\pi\times 10.47\times 0.05}{2\times 1.047} = 0.785 \text{ m/s}$$

The velocity diagram for one complete revolution of the cam is shown in Fig. 20.16 (*b*).

We know that the maximum acceleration of the valve rod to raise the valve,

$$a_O = \frac{\pi^2\omega^2 . S}{2(\theta_0)^2} = \frac{\pi^2(10.47)^2 0.05}{2(2.1)^2} = 6.13 \text{ m/s}^2 \textbf{ Ans.}$$

and maximum acceleration of the valve rod to lower the valve,

$$a_R = \frac{\pi^2\omega^2 . S}{2(\theta_R)^2} = \frac{\pi^2(10.47)^2 0.05}{2(1.047)^2} = 24.67 \text{ m/s}^2 \textbf{ Ans.}$$

Example: A cam drives a flat reciprocating follower in the following manner: During first 120° rotation of the cam, follower moves outwards through a distance of 20 mm with simple harmonic motion. The follower dwells during next 30° of cam rotation. During next 120° of cam rotation, the follower moves inwards with simple harmonic motion. The follower dwells for the next 90° of cam rotation. The minimum radius of the cam is 25 mm. Draw the profile of the cam.