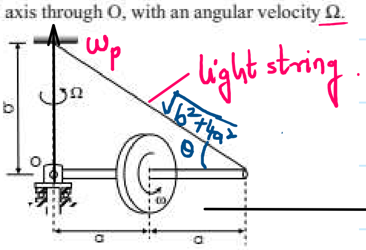
06. A thin disc of radius 'r' and mass 'm' is mounted on a light rod of length 2a which is freely hinged at O. The other end A of rod being supported by a light string. The disc spins with an angular velocity ω as shown and the whole assembly rotates about a vertical axis through O, with an angular velocity Ω.



$\hat{\omega}_{spin}$

Determine

(a) The tension in the string.

(b) What will be the string tension if the system rotates with a velocity Ω in the opposite directions ?

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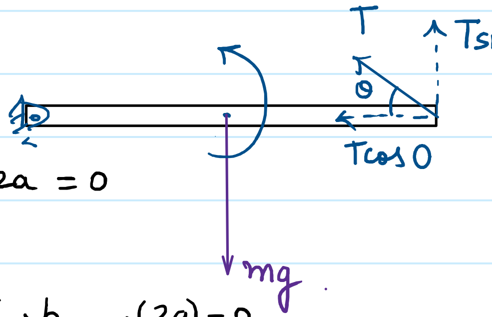
$$\sin\theta = \frac{b}{\sqrt{b^2+4a^2}}$$

$$\cos\theta = \frac{2a}{\sqrt{b^2+4a^2}}$$

$$\hat{\omega}_{spin} = \hat{i} \qquad \hat{\omega}_p = \hat{j}$$

Active gyro. $= \hat{\omega}_p \times \hat{\omega}_s = \hat{j} \times \hat{i} = -\hat{k}$

Reactive gyro. $= \hat{\omega}_s \times \hat{\omega}_p = \hat{i} \times \hat{j} = \hat{k}$ c.cw



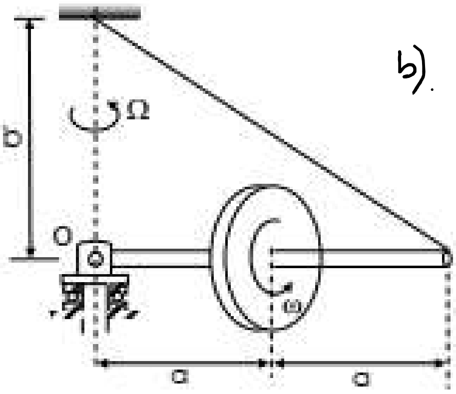
a) $\Sigma M_{Hinge} = 0$

$$-C + mg(a) - T\sin\theta \times 2a = 0$$

$$C = I \cdot \omega \cdot \omega_p = \frac{mr^2}{2} \cdot \omega \cdot \Omega$$

$$-\frac{mr^2}{2} \cdot \omega \cdot \Omega + mg \cdot (a) - T \cdot \frac{b}{\sqrt{b^2+4a^2}} \cdot (2a) = 0$$

$$T = \left[mg\,a - \frac{mr^2 \cdot \omega\,\Omega}{2}\right] \times \frac{\sqrt{b^2+4a^2}}{2ab}$$

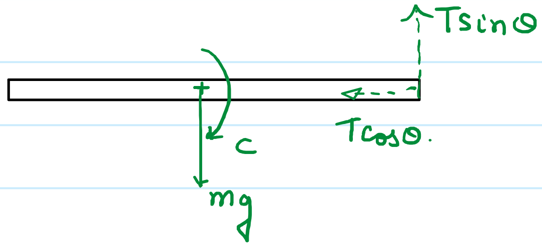


b) $\hat{\omega}_{spin} = \hat{i}$

$\hat{\omega}_p = -\hat{j}$

Active gyro. $= \hat{\omega}_p \times \hat{\omega}_s = -\hat{j} \times \hat{i} = +\hat{k}$

Reactive gyro $= \hat{\omega}_s \times \hat{\omega}_p = \hat{i} \times -\hat{j} = -\hat{k}$ (c-w)



$$T = \left[mg\,a + \frac{mr^2 \cdot \omega\,\Omega}{2}\right] \frac{\sqrt{b^2+4a^2}}{2ab}$$

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Cam and Follower

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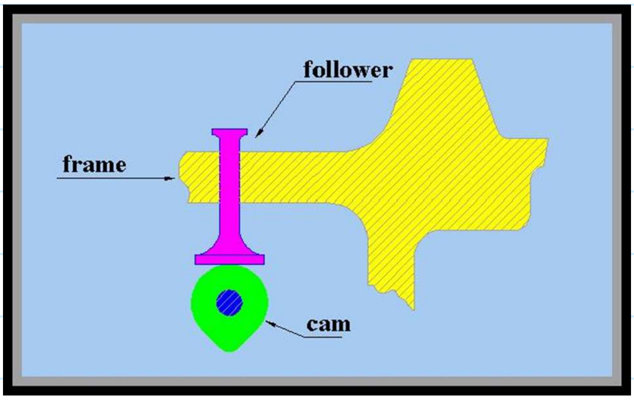
- A Cam and follower mechanism consist of
  1. Cam –
  2. Follower–
  3. Frame –

DoF = 1

- This mechanism is an example of Higher Pair, Force Closed, Constrained Pair , Open Pair.

- In it the cam is main driving element and follower follows its motion. → driven.
  Generally the Cam rotates and follower translates or oscillates.



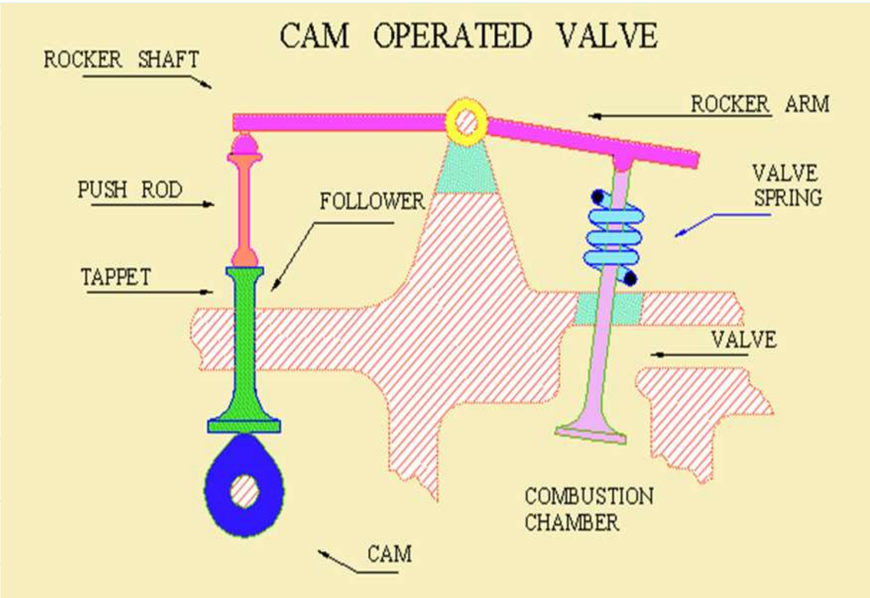
y – follower displacement
θ – Cam Angular displace-ment.

→ Type of motion impart to the follower is dependent on nature of cam profile
$y = f(\theta)$

- Cam and Follower mechanism is an exact function generator mechanism.

- For ex. In the case of moving the valves of an automobile, First in IC Engine the valves have to be kept open then keep it open then close it and keep it closed.

- All these timing operations can be easily incorporated by having Cam and Follower mechanism.



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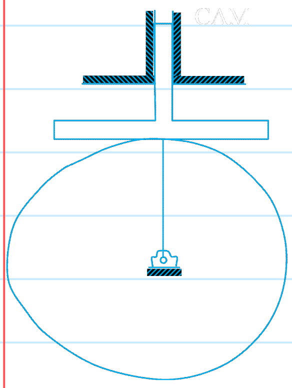
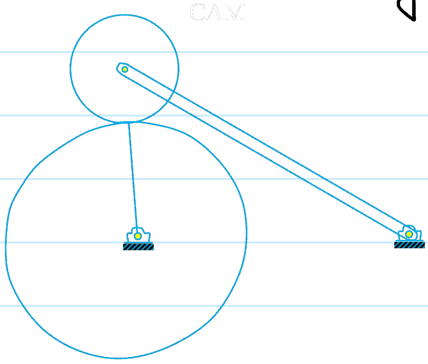
Classification of follower based on motion

(1) Reciprocating follower.



(2) oscillating follower.

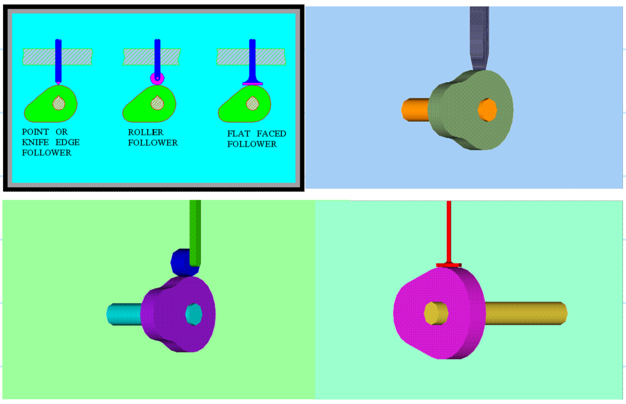


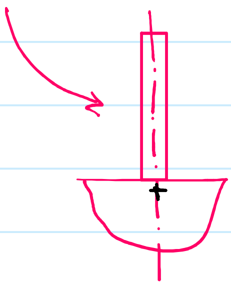
Applications of Cam and Follower

- Cam and follower are widely used for operating inlet and exhaust valve of IC Engine
- In Wall Clock
- In feed mechanism of Automatic Lathe Machine
- In Paper Cutting Machine
- In Weaving Textile Machine
- In Food processing machines

Classification of Followers

- Knife edge follower
- Roller follower
- Flat face follower
- Spherical end follower or Mushroom follower





Knife edge Follower

- It is the simplest follower
- The contacting end is a sharp knife edge, it is called a knife edge follower
- In it a considerable side thrust exists between the follower and guide
- It causes infinitely large contacting stresses and results in high rate of wear, therefore it is of very little practical use

Roller Follower

- When the contacting end of the follower is a roller, it is called a roller follower.
- Since the rolling motion takes place between the contacting surfaces therefore the rate of wear is greatly reduced but the side thrust exists.
- In case of steep cam roller follower has a tendency to jam the cam, therefore it is not preferred in this situation.
  → Mechanism is getting locked.
- It is used in gas and oil engines.
- Roller followers are extensively used where more space is available such as in stationary gas and oil engines.

Flat face follower

- When the contacting end is perfectly flat face normal to the stem of follower, it is called as flat face follower.
- The side thrust in it gets reduced w.r.t. roller follower.
- The relative motion is sliding in nature due to which there is more wear of cam surface in it.
- It causes high surface stresses.
- It is used where limited space is available such as in cams which operate the valves of automobile engines.

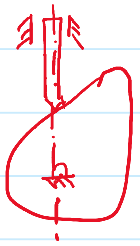
Spherical/Mushroom faced follower

- When the contacting end of the follower is of spherical shape, it is called spherical faced follower.
- The centre of spherical surface is provided on the centre line of follower.
- It is used for relatively steep cam and is useful where space may not be adequate.
- It minimises the surface stresses.
- It is used in automobile engines, aircraft engines.

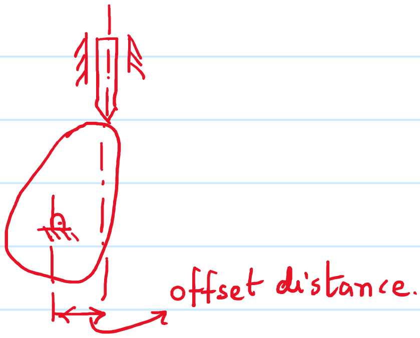
Classification of Cam (On the basis of line of movement of the follower)

- Radial Cam - Line of stroke of follower pass through the centre of rotation of CAM
- Offset Cam - Line of stroke of follower does not pass through the centre of rotation of CAM.
  It is offset by some distance.

Radial Cam.



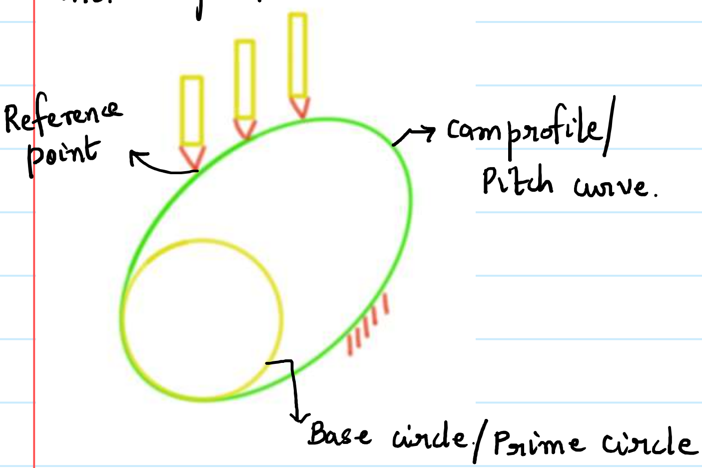
Offset cam.



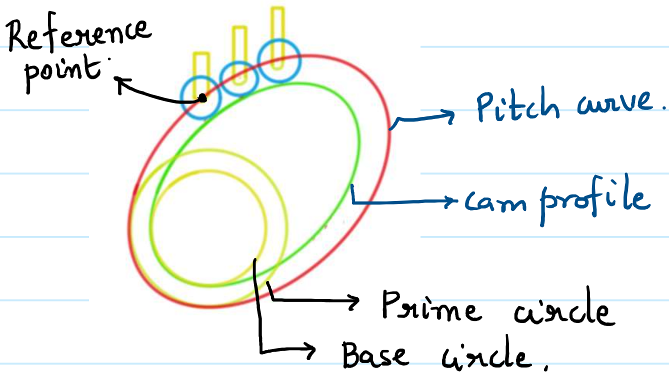
Cam and Follower Terminology:
In order to discuss the terminology we have to consider the inversion of mechanism that is we shall assume Cam as fixed element and follower as moving element.

- Base Circle - It is the smallest circle tangential to the cam profile
- Trace Point - It is the reference on the follower which along the cam as the cam rotates. For knife follower the trace point is point of contact and for roller follower the centre of roller is trace point.
- Pitch Curve - Locus of trace point is called pitch curve.
- Prime Circle - The circle which is tangential to pitch curve is called prime circle.
- Lift or Stroke - Distance between the extreme position of follower.
- Angle of ascent - Angular displacement of Cam for which follower moves from bottom most position to top most top most position.
- Angle of descent - Angular displacement of Cam for which follower moves from top most pos'n to bottom most pos'n
- Angle of dwell - Angular displacement of Cam for which follower does not move.

Knife edge follower



Roller Follower.



for knife edge. $R_{Roller} \rightarrow 0$.

$R_{prime} = R_{base} + R_{Roller}$.

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Pressure Angle / Deviation Angle

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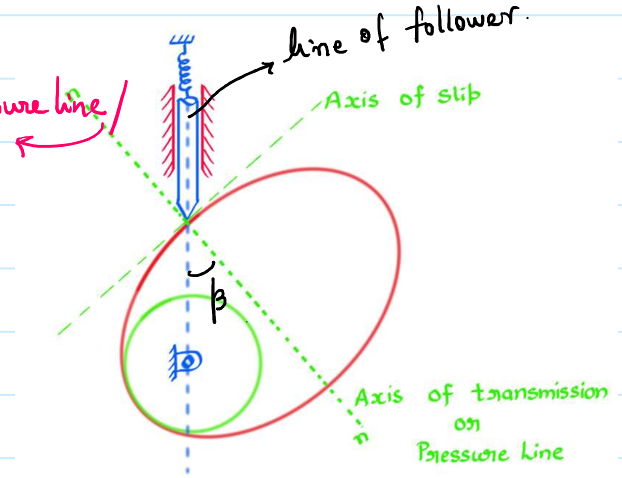
higher pair.

- It is the angle included between common normal to the pitch curve through trace point and the line of action of follower motion.
- It is compliment of transmission angle and it is an index of merit of the mechanism. $\beta + \gamma = 90^\circ$

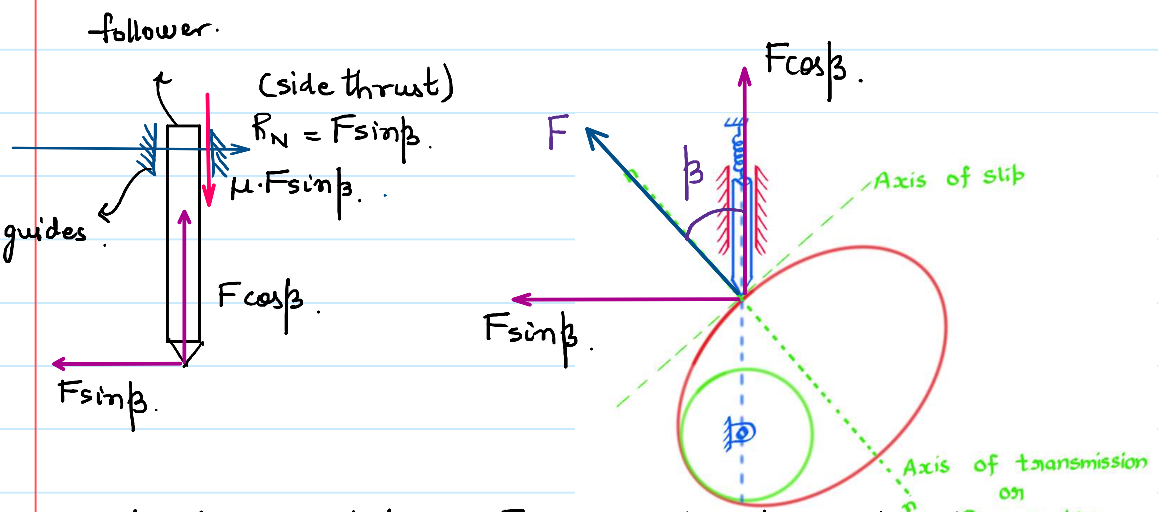
β – Pressure Angle.

- It measures the steepness of the cam profile.
- Pressure angle varies in magnitude at all instants of the follower motion. The point where it is maximum is known as Pitch Point.
- The locus of pitch point is known as Pitch Circle.

common normal / Pressure line / line of transmission.



Force Angle of Cam and follower.



As $\beta \uparrow$. $F\sin\beta \uparrow$, $F\sin\beta$ will try to bend the follower.

$\mu F\sin\beta \uparrow$. friction b/w follower and guides increases. Cam and follower mechanism get locked.

As. $\beta \uparrow$ $F\cos\beta \downarrow$. the contact b/w cam and follower may lost.

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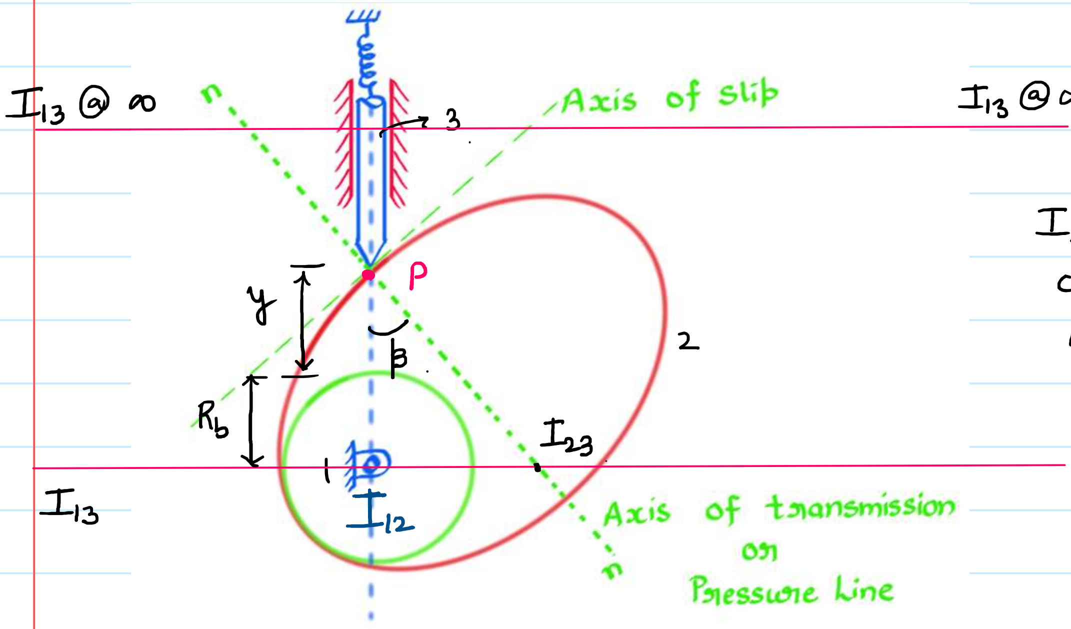


I_{23} must lie on common normal and it must be colinear with I_{12} & I_{13}.

In Δ^{le} $I_{12}.P.I_{23}$

$$\tan\beta = \frac{I_{12}.I_{23}}{(R_b+y)}$$

$$I_{12}I_{23}\cdot\omega_2 = I_{13}\cdot I_{23}\cdot\omega_3 \rightarrow V_{follower}$$

$$V_{follower} = I_{12}\cdot I_{23}\cdot\omega_2.$$

$$\omega_2 = \frac{d\theta}{dt}.$$

$$V_{follower} = (R_b+y)\tan\beta\cdot\frac{d\theta}{dt}.$$

$$y = f(\theta)$$

$$V_f = \frac{dy}{dt} = \frac{dy}{d\theta}\cdot\frac{d\theta}{dt}$$

$$V_f. = \omega\cdot\frac{dy}{d\theta}$$

$$V_f. = \frac{d\theta}{dt}\cdot\frac{dy}{d\theta} = (R_b+y)\tan\beta\cdot\frac{d\theta}{dt}.$$

$$\tan\beta = \frac{\frac{dy}{d\theta}}{(R_b+y)} = \frac{V_{follower}}{(R_b+y)\,\omega_{cam}}.$$

R_b - Radius of Base circle, y - follower displacement.

Effect of various parameters on Pressure Angle

1. Size of Cam

$$\tan\beta. = \frac{V_f}{(R_b+y)\omega} \Rightarrow \tan\beta \propto \frac{1}{R_b}$$

As $R_b\uparrow$ $\tan\beta\downarrow$. $\beta\downarrow$.

2. Type of follower

$$\tan\beta = \frac{V_f}{(R_b + R_{roller} + y)\cdot\omega_2}$$

$\tan\beta \propto \frac{1}{R_{Roller}}$ $R_{Roller}\uparrow \; \tan\beta\downarrow \; \beta\downarrow$.

3. Velocity of follower

$\boxed{\tan\beta \propto V_{follower}}$. $V_f\uparrow \; \tan\beta\uparrow \; \beta\uparrow$.

$$\boxed{V_{cycloidal} = V_{uniform\ acc^n} > V_{S.H.M.} > V_{uniform\ velocity}}$$

Cycloidal cams are mostly preferred.

V_f is more in cycloidal cams. $\tan\beta\downarrow$, $R_b\uparrow$.

$R_b\uparrow$. These cams are large in size.

Cycloidal motion is found in High speed cams. The high speed cams are large in size.

4. **Effect of slope of displacement curve.**

$$\tan\beta = \frac{dy/d\theta}{(R_b + y)}$$

It signifies about the steepness of cam.

$y \rightarrow$ follower displacement

$\theta \rightarrow$ Angular displacement of cam.

Cam – 1 . θ 30° $\longrightarrow$ $y = 40$ mm.

Cam – 2 θ – 30° $\longrightarrow$ $y = 50$ mm $\longrightarrow$ cam 2 is steeper compared with cam 1.

For small rotation of cam if the follower experience more displacement then the cam is steeper.

5. Effect of Offset distance.

$$\tan\beta = \frac{\left[\frac{dy}{d\theta} - e\right]}{\sqrt{R_b^2 - e^2} + y}$$

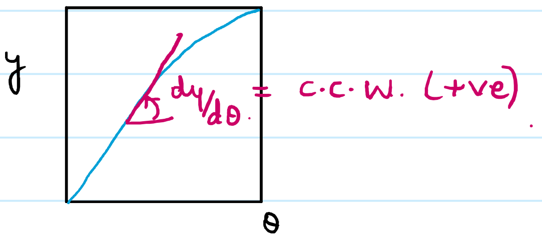
$$\tan\beta \propto \left[\frac{dy}{d\theta} - e\right]$$

$R_b >>> e$. $\sqrt{R_b^2 - e^2} \approx R_b$.

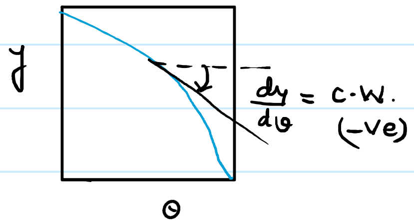
As $e \uparrow$ $\left[\frac{dy}{d\theta} - e\right]\downarrow$ $\tan\beta \downarrow$. $\beta \downarrow$.

6. Effect of stroke

Forward stroke



Return stroke



$$\tan\beta \propto \left[\frac{dy}{d\theta} - e\right].$$

$$\tan\beta \propto \left[-\frac{dy}{d\theta} - e\right]$$

$$(\beta)_{Return} > (\beta)_{forward}.$$

Physical derivates.

y – displacement of follower.

$y = f(\theta)$.

Velocity $\Rightarrow$ $v = \frac{dy}{dt} = \frac{dy}{d\theta}\cdot\frac{d\theta}{dt} = \omega\cdot\frac{dy}{d\theta}$. $v = f(\theta)$

$\frac{dy}{d\theta} \rightarrow$ slope of displacement curve

Acceleration $\Rightarrow$ $a = \frac{dv}{dt} = \frac{dv}{d\theta}\cdot\frac{d\theta}{dt} = \omega\cdot\frac{d}{d\theta}\left[\omega\cdot\frac{dy}{d\theta}\right]$

$= \omega^2\cdot\frac{d^2y}{d\theta^2}$ $\rightarrow$ convex . or concave.

$a = f(\theta)$

Jerk $\Rightarrow$ $J = \frac{da}{dt} = \frac{da}{d\theta}\cdot\frac{d\theta}{dt} = \omega\cdot\frac{d}{d\theta}\left[\omega^2\cdot\frac{d^2y}{d\theta^2}\right] = \omega^3\cdot\frac{d^3y}{d\theta^3}$

Types of motion

1. Uniform Velocity
2. Uniform Acceleration and Uniform Retardation
3. Simple Harmonic Motion
4. Cycloidal Motion

h – stroke of follower.
θ_a – Angular disp. of cam.

1. Uniform Velocity.

$$V = \text{constant}$$

$$V = \omega \cdot \frac{dy}{d\theta} \qquad \omega = \text{constant}.$$

$$\frac{dy}{d\theta} = \text{constant}.$$

$$y = c\theta'.$$

$$y = h \quad \theta = \theta_a \qquad c = \frac{h}{\theta_a}.$$

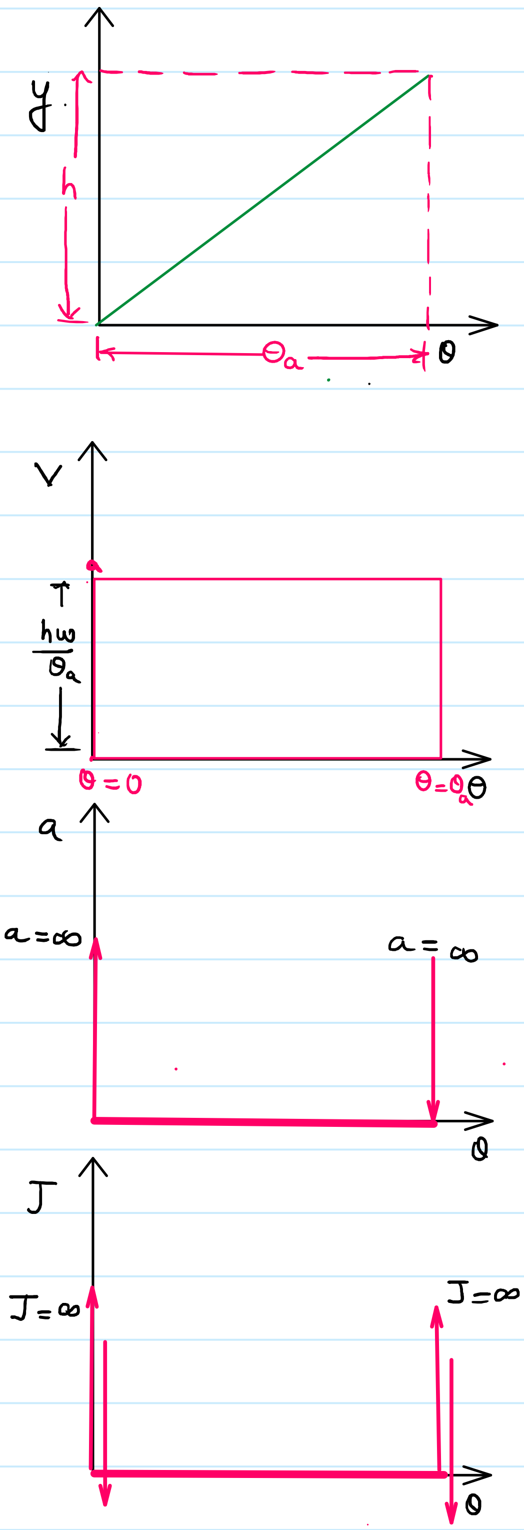
$$y = \frac{h}{\theta_a} \cdot \theta$$

Velocity $\quad V = \frac{dy}{dt} = \omega \cdot \frac{dy}{d\theta} = \frac{\omega h}{\theta_a} \theta^0.$

$$V = f(\theta^0) = \text{const}.$$

Acceleration $\quad a = \frac{dv}{dt} = 0$

Jerk $\quad J = \frac{da}{dt} = 0$



2. Uniform Acceleration and Uniform Retardation

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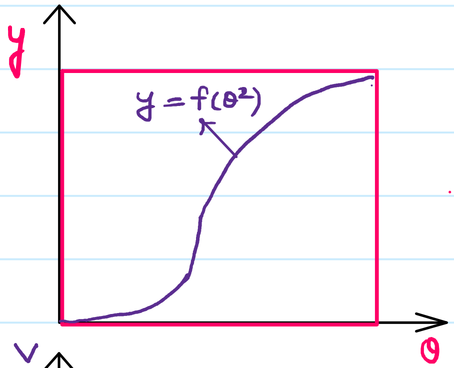
acceleration $a = \text{const}$

$$a = \omega^2 \cdot \frac{d^2y}{d\theta^2} \qquad \omega = \text{const.}$$

$$\frac{d^2y}{d\theta^2} = \text{const.}$$

$$y = c_1\theta^2 + c_2\theta + c_3.$$

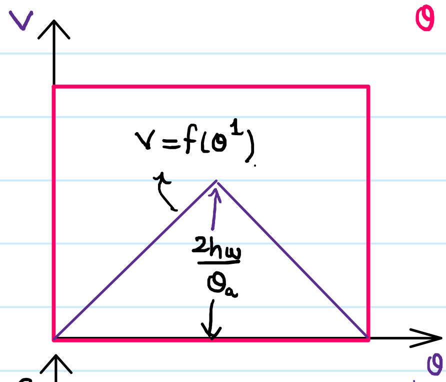


initial conditions. @ $\theta = 0$ $\quad y = 0 \Rightarrow c_3 = 0$

@ $\theta = 0$ $\quad V = 0$ or $\frac{dy}{d\theta} = 0 \Rightarrow c_2 = 0$

$$V = \omega \cdot \frac{dy}{d\theta} \Rightarrow \frac{dy}{d\theta} = 0.$$

$$y = c_1\theta^2 \Rightarrow y = f(\theta^2)$$



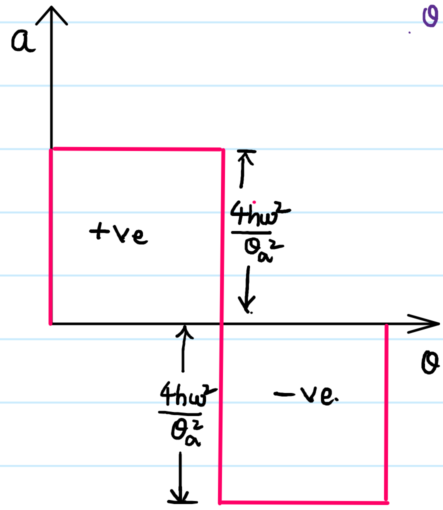
$\theta = \frac{\theta_a}{2}$, $y = \frac{h}{2}$, $V = \text{Max.}$ $\quad c_1 = \dfrac{(h/2)}{\theta_a^2/4} = \dfrac{2h}{\theta_a^2}$

Velocity of follower $\quad V = \omega \cdot \frac{dy}{d\theta} = \omega \cdot \frac{d}{d\theta}\left(\frac{2h}{\theta_a^2}\theta^2\right)$

$$V = \frac{4h\omega}{\theta_a^2} \cdot \theta^1 \qquad V = f(\theta^1)$$

$$V_{max} = \frac{4h\omega}{\theta_a^2} \cdot \frac{\theta_a}{2}$$

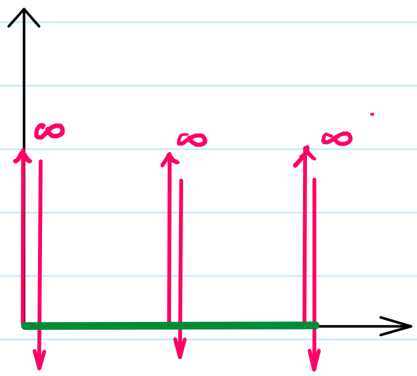
$$V_{max} = \frac{2h\omega}{\theta_a}$$



Acceleration $\quad a = \omega^2 \cdot \frac{d^2y}{d\theta^2} = \omega^2 \cdot \frac{d^2}{d\theta^2}\left(\frac{2h}{\theta_a^2} \cdot \theta^2\right)$

$$a = \frac{4h\omega^2}{\theta_a^2}$$

Jerk. $\quad J = \frac{da}{dt} = 0.$



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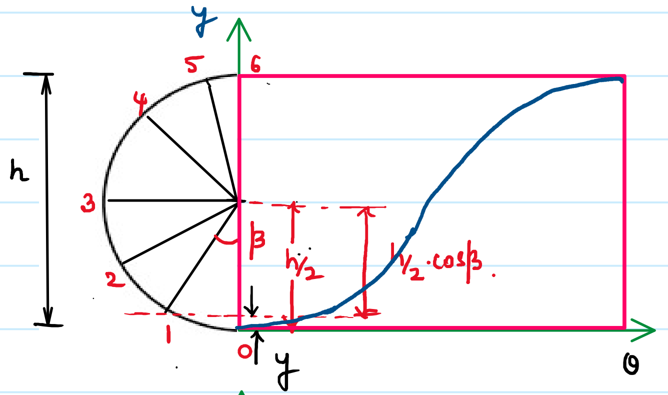
3. Simple Harmonic Motion



$$y = \frac{h}{2}\left[1-\cos\beta\right].$$

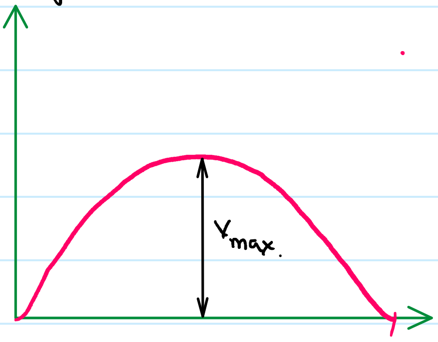
$\beta \rightarrow \pi \quad y \rightarrow h. \quad \theta \rightarrow \theta_a.$

$\beta \longrightarrow \pi$
$\theta \longrightarrow \theta_a.$

$$\beta = \frac{\pi\theta}{\theta_a}$$

$$y = h/_2.\left[1-\cos\frac{\pi\theta}{\theta_a}\right].$$

Velocity $\quad v = \omega.\frac{dy}{d\theta}$

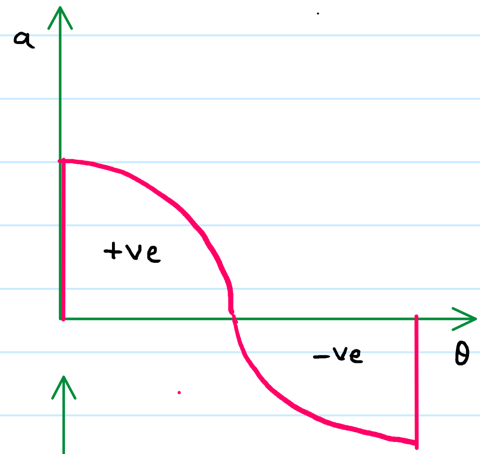


$$v = \omega.\frac{d}{d\theta}\left[1-\cos\frac{\pi\theta}{\theta_a}\right]\times\frac{h}{2}$$

$$= \omega.\left[0-\left(-\sin\frac{\pi\theta}{\theta_a}\times\frac{\pi}{\theta_a}\right)\right]\times\frac{h}{2} \rightarrow \frac{dy}{d\theta}.$$

$$= \frac{\pi h.\omega}{2\theta_a}\ \sin\left(\frac{\pi\theta}{\theta_a}\right)$$

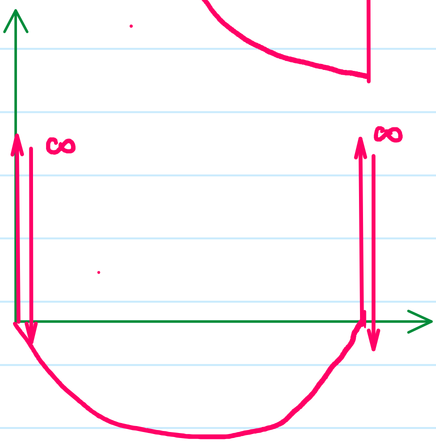
$$V_{max} = \frac{\pi h\omega}{2\theta_a}$$



Acceleration $\quad a = \omega^2.\frac{d^2y}{d\theta^2}$

$$a = \omega^2.\frac{d}{d\theta}\left[\frac{\pi h}{2\theta_a}.\sin\left(\frac{\pi\theta}{\theta_a}\right)\right]$$

$$a = \frac{\omega^2.h}{2}.\cos\left(\frac{\pi\theta}{\theta_a}\right).\left(\frac{\pi}{\theta_a}\right)^2 \rightarrow \frac{d^2y}{d\theta^2}$$



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

$$a_{max} = \frac{\pi^2.h\omega^2}{2\theta_a^2}$$

Jerk. $\quad J = \frac{da}{dt} = \omega^3.\frac{d^3y}{d\theta^3}$

$$= \omega^3.\frac{d}{d\theta}\left[\frac{h}{2}.\cos\left(\frac{\pi\theta}{\theta_a}\right)\left(\frac{\pi}{\theta_a}\right)^2\right]$$

$$= \frac{\pi^3.h\omega^3}{2\theta_a^3}.\left[-\sin\left(\frac{\pi\theta}{\theta_a}\right)\right].$$

$$J_{max} = \frac{-\pi^3.h\omega^3}{2\theta_a^3}$$

4. Cycloidal Motion

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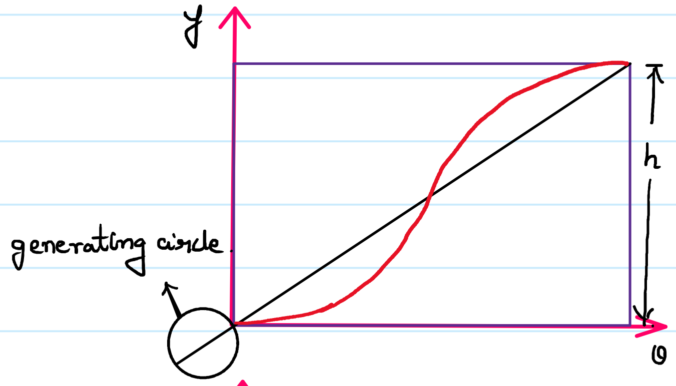
Displacement of follower.

$$y = \frac{h}{\pi}\left[\frac{\pi\theta}{\theta_a} - \frac{1}{2}\cdot\sin\left(\frac{2\pi\theta}{\theta_a}\right)\right]$$

Radius of generating circle $= \frac{h}{2\pi}$.

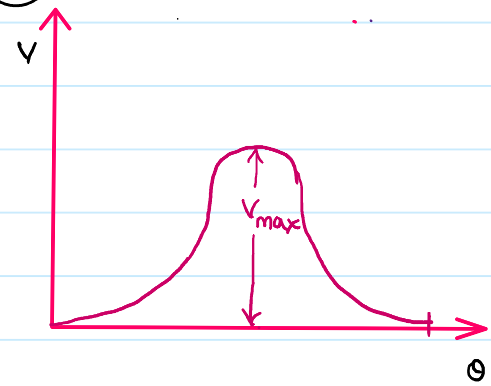


Velocity of follower.

$$V = \omega\cdot\frac{dy}{d\theta} = \omega\cdot\frac{d}{d\theta}\left[\frac{h}{\pi}\left(\frac{\pi\theta}{\theta_a} - \frac{1}{2}\sin\left(\frac{2\pi\theta}{\theta_a}\right)\right)\right]$$

$$V = \underbrace{\frac{\omega\cdot h}{\pi}\left[\frac{\pi}{\theta_a} - \frac{1}{2}\left(\frac{2\pi}{\theta_a}\right)\cdot\cos\left(\frac{2\pi\theta}{\theta_a}\right)\right]}_{\frac{dy}{d\theta}}$$

$$V = \frac{h\omega}{\theta_a}\left[1 - \cos\left(\frac{2\pi\theta}{\theta_a}\right)\right]$$



θ	0°	$\frac{\theta_a}{4}$	$\frac{\theta_a}{2}$	$\frac{3\theta_a}{4}$	θ_a
V	0	$\frac{h\omega}{\theta_a}$	$\frac{2h\omega}{\theta_a}$	$\frac{h\omega}{\theta_a}$	0

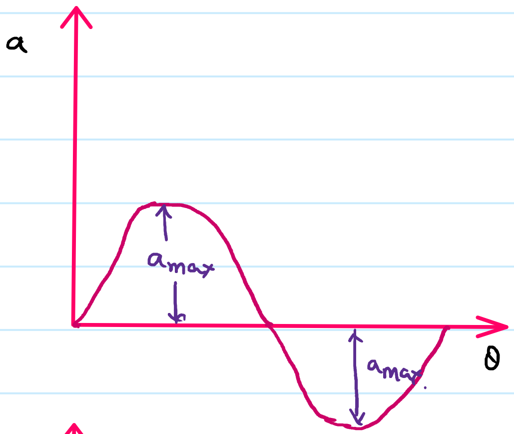
$\hookrightarrow V_{max}$.

Acceleration.

$$a = \omega^2\cdot\frac{d^2y}{d\theta^2} = \omega^2\cdot\frac{d}{d\theta}\left[\frac{h}{\theta_a}\left(1 - \cos\left(\frac{2\pi\theta}{\theta_a}\right)\right)\right]$$

$$= \underbrace{\frac{\omega^2 h}{\theta_a}\cdot\left[0 + \sin\left(\frac{2\pi\theta}{\theta_a}\right)\cdot\frac{2\pi}{\theta_a}\right]}_{\frac{d^2y}{d\theta^2}}$$

$$a = \frac{2\pi\cdot h\omega^2}{\theta_a^2}\cdot\sin\left(\frac{2\pi\theta}{\theta_a}\right).$$

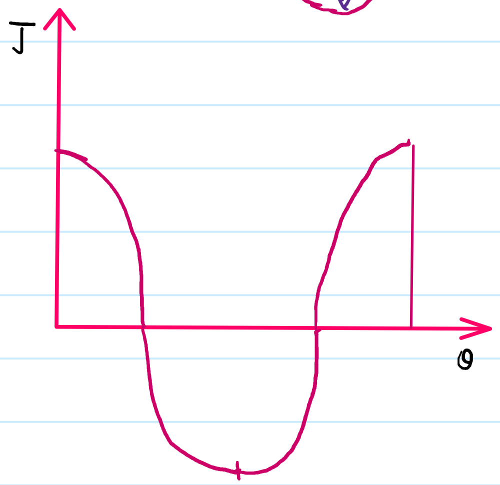


θ	0°	$\frac{\theta_a}{4}$	$\frac{\theta_a}{2}$	$\frac{3\theta_a}{4}$	θ_a
a	0	$\frac{2\pi h\omega^2}{\theta_a^2}$	0	$-\frac{2\pi h\omega^2}{\theta_a^2}$	0

Jerk.

$$J = \omega^3\cdot\frac{d^3y}{d\theta^3} = \omega^3\cdot\frac{d}{d\theta}\left[\frac{h}{\theta_a}\cdot\sin\left(\frac{2\pi\theta}{\theta_a}\right)\cdot\frac{2\pi}{\theta_a}\right]$$

$$J = \frac{4\pi^2\cdot h\omega^3}{\theta_a^3}\cdot\cos\left(\frac{2\pi\theta}{\theta_a}\right).$$



θ	0°	$\frac{\theta_a}{4}$	$\frac{\theta_a}{2}$	$\frac{3\theta_a}{4}$	θ_a
J	$\frac{4\pi^2 h\omega^3}{\theta_a^3}$	0	$-\frac{4\pi^2 h\omega^3}{\theta_a^3}$	0	$\frac{4\pi^2 h\omega^3}{\theta_a^3}$

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In Cycloidal motion the Jerk is finite at all the instances of motion.
This type of motion is preferred for High speed Cams.

S.No.	Motion	Velocity	Acceleration	Jerk.
1.	Uniform velocity.	$1\frac{h\omega}{\theta_a}$	$0\frac{h\omega^2}{\theta_a^2}$	$0\frac{h\omega^3}{\theta_a^3}$
2.	Uniform Acceleration.	$2\frac{h\omega}{\theta_a}$	$4\frac{h\omega^2}{\theta_a^2}$	$0\frac{h\omega^3}{\theta_a^3}$
3.	Simple Harmonic Motion	$\frac{\pi}{2}\frac{h\omega}{\theta_a}$	$\frac{\pi^2}{2}\frac{h\omega^2}{\theta_a^2}$	$\frac{\pi^3}{2}\frac{h\omega^3}{\theta_a^3}$
4.	Cycloidal Motion.	$2\frac{h\omega}{\theta_a}$	$2\pi\frac{h\omega^2}{\theta_a^2}$	$(2\pi)^2\frac{h\omega^3}{\theta_a^3}$

01. The pressure angle in a cam depends on
1. Follower type
2. Displacement profile
3. Angle of action of cam
4. Offset between cam centre and follower

(a) 2, 4
(b) 1, 2, 3
(c) 2, 3, 4
(d) 1, 2, 3, 4

$\tan\beta \propto \frac{1}{R_{Roller}}$

$\tan\beta \propto \frac{dy}{d\theta}$ ⇝ cam profile.

$\tan\beta \propto \frac{1}{d\theta}$ ⇝ cam angle.

$\tan\beta \propto \left[\frac{dy}{d\theta} - e\right]$

02. In a radial cam follower system with same lift and angle of action the maximum velocity during rise with the following profiles
I. Uniform velocity profile
II. Simple Harmonic motion profile
III. Cycloidal motion profile

(a) I > II > III (b) II > III > I
(c) III > I > II (d) III > II > I

$V_{cycloid} = V_{uni.accn} > V_{S.H.M.} > V_{uniform\ velo.}$

III > II > I

03. The pressure angle of a cam during lift can be reduced by increase
(a) ~~Decreasing~~ the base circle radius
(b) Increasing the angle of action
(c) ~~Reducing~~ increasing the roller radius
(d) By reducing the offset distance

$\tan\beta \propto \frac{1}{R_{base}}$.

$\tan\beta \propto \frac{1}{d\theta}$ ⇝ cam angle / Angle of action.

$\tan\beta \propto \frac{1}{R_{Roller}}$

$\tan\beta \propto \left[\frac{dy}{d\theta} - e\right]$ As $e\uparrow$ $\left[\frac{dy}{d\theta} - e\right]\downarrow$ $\tan\beta\downarrow$.

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04. A cam follower rises by 4cm during 90° rotation of the cam with SHM. The cam is rotating at an uniform angular velocity of 2 rad/sec. The displacement, velocity and acceleration of the follower after 2/3 of the rotation of the cam during rise is

(a) 2cm, 8 cm/sec, 16 cm/sec²
(b) 3cm, 7 cm/sec, 16 cm/sec² ✓
(c) 2cm, 8 cm/sec, 32 cm/sec²
(d) 2.67cm, 6 cm/sec, 23.86 cm/sec²

$h = 4cm.$

$\theta_a = 90^\circ = \pi/2.$

$\omega_{cam} = 2 rad/s.$

@ $\theta = 2/3 \cdot \theta_a.$

$y, v, a = ?$

Disp. $y = \frac{h}{2}\left[1-\cos\frac{\pi\theta}{\theta_a}\right] \Rightarrow y = 4/2\left[1-\cos\frac{2\pi}{3}\right] = 2\left[1-(-0.5)\right] = 3cm.$

Velocity. $v = \frac{\pi h\omega}{2\theta_a}\cdot\sin\left(\frac{\pi\theta}{\theta_a}\right) = \frac{\pi\times4\times2}{2\times\pi/2}\cdot\sin\left(\frac{2\pi}{3}\right) = 7cm/s.$

Acceleration $a = \frac{\pi^2 h\omega^2}{2\theta_a^2}\cdot\cos\left(\frac{\pi\theta}{\theta_a}\right) = \frac{\pi^2\cdot(4)\cdot(2)^2}{2\cdot(\pi/2)^2}\cdot\cos\left(2\pi/3\right) = 16cm/s^2.$

05. The profile of a radial cam is specified as

$x = 15\cos\theta$

and $y = 10 + 5\sin\theta$

where θ is the angle of rotation of the cam and x, y are the Cartesian coordinates of the profile for a specific range. Determine the pressure angle at an angle θ = 30°. (Assume cam center as origin)

(a) 30° (b) 16° (c) 0° (d) 45°

$x = 15\cos\theta$ $y = 10 + 5\sin\theta.$

$\theta = 30^\circ.$

$x = 0$

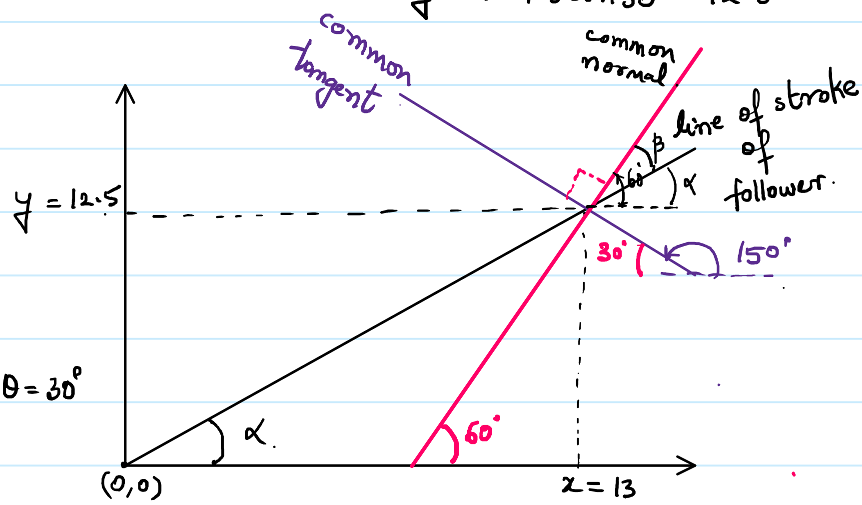
$y = 0$

$\theta = 30^\circ$

$x = 15\cos30^\circ = 12.99 \approx 13$

$y = 10 + 5\sin30 = 12.5$

$\alpha = \tan^{-1}\left(\frac{12.5}{13}\right) = 43.87.$



Common Tangent.

$\frac{dy}{dx} = \frac{\frac{dy}{d\theta}}{\frac{dx}{d\theta}} = \frac{0+5\cos\theta}{15(-\sin\theta)}$

slope of common tangent @ $\theta = 30^\circ$

$\tan\theta_1 = \frac{5\cos30^\circ}{-15\sin30^\circ}$

$\theta_1 = \tan^{-1}\left(-\frac{5\times\sqrt{3}/2}{15\times1/2}\right)$

$\theta_1 = \tan^{-1}\left(\frac{-1}{\sqrt{3}}\right) = 150^\circ$ from $+x$-axis.

$\beta = 60^\circ - \alpha$

$= 60^\circ - 43.87^\circ$

$= 16.13^\circ$

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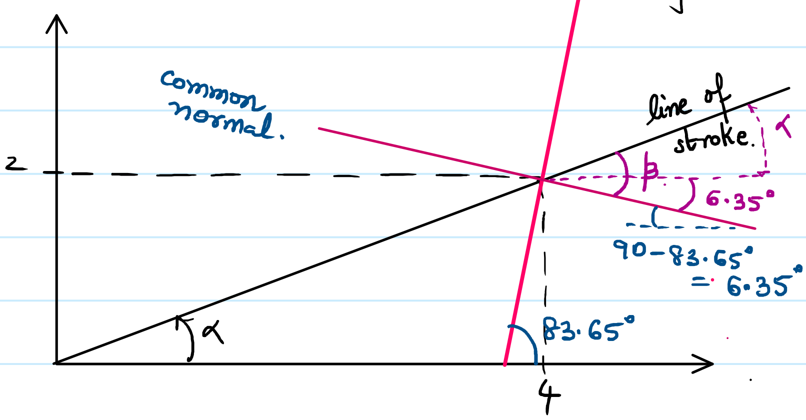
06. A segment of a radial cam profile is given by the equation in Cartesian space
$y = 2x^2 - 7x - 2$ with the origin of the coordinate frame at the centre. For the knife edge follower determine the pressure angle at a location $(x = 4, y = 2)$

(a) 32.82° (b) 63.4°
(c) 83.7° (d) 58°

$y = 2x^2 - 7x - 2$

$\beta = ?$ @ $x = 4$ $y = 2$.



$\alpha = \tan^{-1}(2/4) = 26.56°$

Common Tangent.

$\dfrac{dy}{dx} = 4x - 7$

Slope of common Tangent @ $x = 4$. $y = 2$

$\tan\theta_1 = 4(4) - 7 \Rightarrow \tan\theta_1 = 9$. $\theta_1 = \tan^{-1}(9) = 83.65°$ with $+x$-axis.

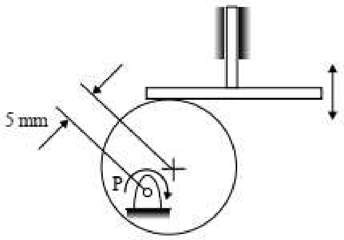
Pressure Angle

$\beta = \alpha + 6.35° = 26.56° + 6.35° = 33°$.

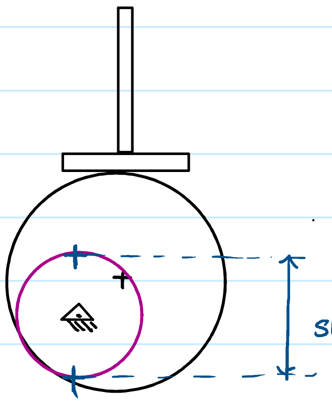
07. Consider a circular cam with a flat face follower as shown in the figure below. The cam is rotated in the plane of the paper about point P lying 5 mm away from its center. The radius of the cam is 20 mm. The distance (in mm) between the highest and the lowest positions of the flat face follower is

(GATE -16)

stroke. = ?

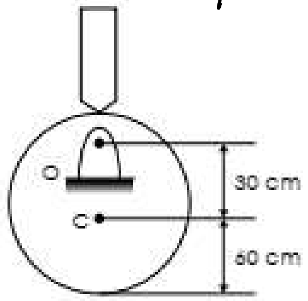


(a) 5 (b) 10
(c) 40 (d) 45

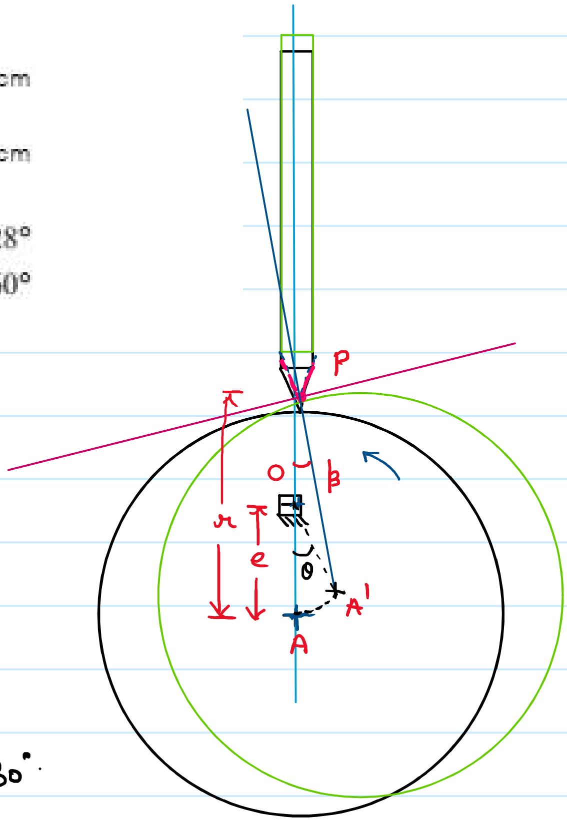


stroke = 2e.
= 2×5
= 10 mm.

08. For the eccentric circular cam and follower mechanism shown below for the pressure angle at pitch point is $\longrightarrow \beta = \text{Max.}$



(a) 30°   (b) 28°
(c) 45°   (d) 60°



$AA' = r\sin\beta = e\sin\theta.$

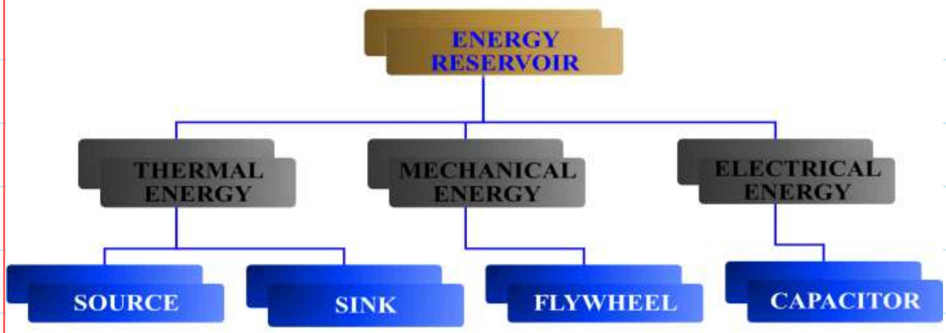
$60\sin\beta = 30\sin\theta.$

$\beta = \text{Max.} \quad \sin\theta = 1$

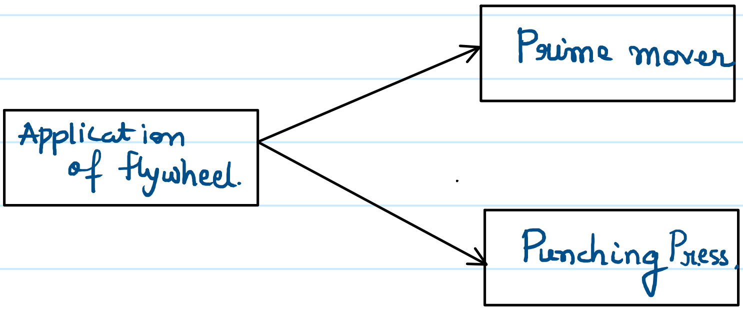
$\sin\beta = 30/60.$

$\beta = \sin^{-1}(1/2) = 30^\circ.$

Flywheel



Flywheel is the energy reservior which stores the energy when there is excess in supply of energy and it supplies the same amount of energy when there is deficiency in energy.



Prime Mover – It is a device which is used to drive some m/c or external load.

Supply Torque – Torque exerted on the shaft of prime mover is called as supply Torque.

Torque on crank shaft $\Rightarrow$ $T = \dfrac{F_P \cdot \sin(\theta+\beta)}{\cos\beta} \times r$. $\longrightarrow$ constant.

$$F_P = F_G \pm F_I \longrightarrow m r \omega^2 \cdot \left[\cos\theta + \frac{\cos 2\theta}{n}\right]$$

$$F_P = f(\theta) \qquad \beta = f(\theta)$$

$$T_{supply} = f(\theta) \longrightarrow \text{I.C. Engine}$$