Inertial frames.

$$\bar{v} = \frac{d}{dt}(\underline{r}) = \frac{dx_1}{dt}\underline{e_1} + x_1 \underbrace{\frac{de_1}{dt}}$$

0 when
coord system
does not acce.
↓
Inertial frame

$$\frac{de_r}{dt} = \dot{\theta} e_\theta$$

$$\frac{de_\theta}{dt} = -\dot{\theta} e_r$$

$$v = \underbrace{\dot{r} e_r}_{\text{Radial}} + \underbrace{r\dot{\theta} e_\theta}_{\text{tangential}}$$

$$a = \frac{dv}{dt} = \ddot{r} e_r + \dot{r} \cdot \frac{de_r}{dt} + \dot{r}\dot{\theta} e_\theta$$

$$+ r\ddot{\theta} e_\theta + r\dot{\theta} \frac{de_\theta}{dt} \quad - \dot{\theta} e_r$$

$$\Rightarrow \left[\ddot{r} - (\dot{r}^2)\right] e_r + (2\dot{r}\dot{\theta} + r\ddot{\theta}) e_\theta$$

Circular Motion:

$$v = r\omega e_\theta$$

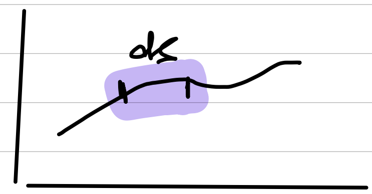
$$a = -r(\dot{\theta})^2 e_r + r\ddot{\theta} e_\theta$$

$$= -r\omega^2 e_r + \underbrace{r \cdot \alpha e_\theta}_{\text{tangential Component.}}$$

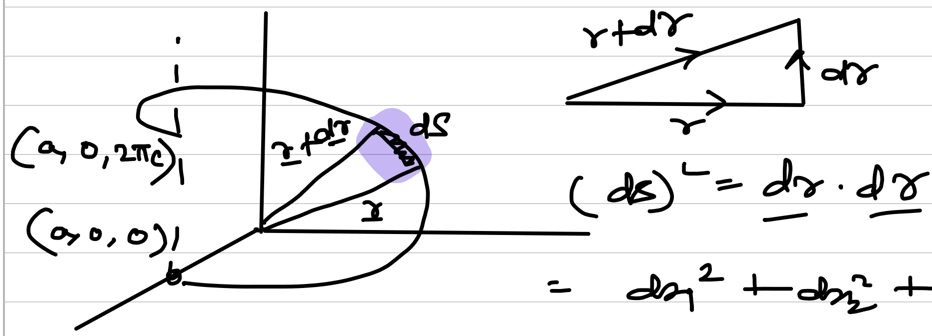
Tangential Normal Force

Position vector expressed in terms of the arc length:

$$r = r(s(t))$$



Example:
Helix



$$(ds)^2 = \underline{dr} \cdot \underline{dr}$$

$$= dx_1^2 + dx_2^2 + dx_3^2$$

$$= (-a\sin(t)\,dt)^2 + (a\cos t\,dt)^2 + (ct)^2$$

$$ds = \sqrt{(a^2+c^2)\,dt^2}$$

$$\int_0^s s = \sqrt{a^2+c^2}\;t$$

$$x_1 = a\cos\left(\frac{s}{\sqrt{a^2+c^2}}\right)$$

$$x_2 = a\sin\left(\frac{s}{\sqrt{a^2+c^2}}\right)$$

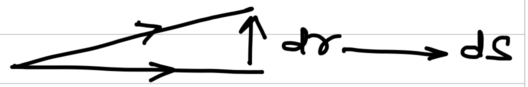
$$x_3 = \frac{c\,s}{\sqrt{a^2+s^2}}$$

why $d\vec{r} \perp \vec{r}$

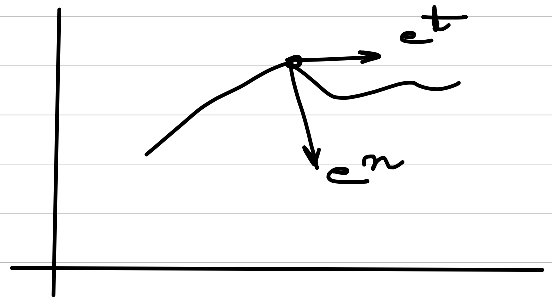
$$\underline{v} = \frac{d\underline{r}}{dt} = \left(\frac{d\underline{r}}{ds}\right) \cdot \underbrace{\left(\frac{ds}{dt}\right)}_{\text{Scalar}}$$

$$\left(\frac{d\underline{r}}{ds}\right) = \lim_{\Delta s \to 0} \frac{|\Delta \underline{r}|}{\Delta s} = 1$$

$\frac{d\underline{r}}{ds} \rightarrow$ unit tangent vector



$$\underset{\sim}{e_t} = \frac{dr}{ds}$$



$e^t \cdot e^t = 1$

$\downarrow$

exists if $r = C^{\infty}$ of S.

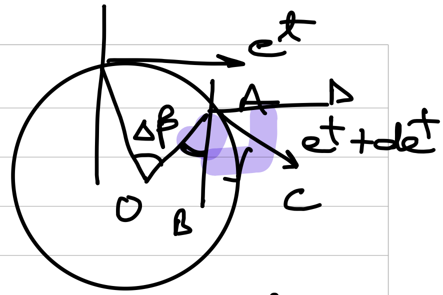
$$\frac{d\underline{e_t}}{ds} \cdot \underline{e_t} + \underline{e_t} \cdot \frac{de_t}{ds} = 0$$

$$e^t \cdot \frac{de^t}{ds} = 0$$

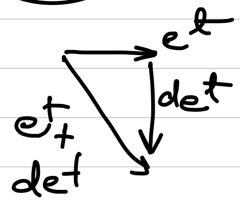
$$\boxed{\frac{d\overline{e^t}}{ds} = \underbrace{K}_{\text{Curvature of curve}} \cdot \bar{n}}$$

given three points, my circle would be unique.

$$\frac{d\underline{e}^t}{ds} = \lim_{\Delta s \to 0} \frac{\underline{\Delta e^t}}{\Delta s}$$



$$\angle OAB + \angle BAC = \pi/2$$



$$\angle BAC + \angle CAD = \pi/2$$

$$|\Delta \bar{e_t}| = |e^t|\,|\tan\beta|$$ small angle

$$|\overline{\Delta e^t}| = |\tan\beta| \simeq \Delta\beta$$

$$|\Delta \bar{e}^t| = \Delta\beta \qquad \frac{\Delta\beta}{\Delta s} = \frac{1}{\rho}$$

$$\frac{de^t}{ds} = K\bar{e}_n$$

$$K = \frac{1}{\rho}$$

$$\bar{r} = \bar{r}(s(t))$$

$$\bar{v} = \frac{dr}{dt} = \frac{d\bar{r}}{ds}\cdot\frac{ds}{dt}$$

$$\bar{v} = \dot{s}\cdot\underline{e^t}$$

$$a = \frac{d\bar{v}}{dt}, \quad a = \frac{d\dot{s}}{dt}\cdot\underline{e^t} + \dot{s}\,\frac{de^t}{dt}$$

$$a = \ddot{s}e^t + \dot{s}\left[\frac{de^t}{ds}\cdot\frac{ds}{dt}\right]$$

$$\bar{a} = \ddot{s}\bar{e}^t + \frac{(\dot{s})^2}{\rho}\bar{e}^n$$

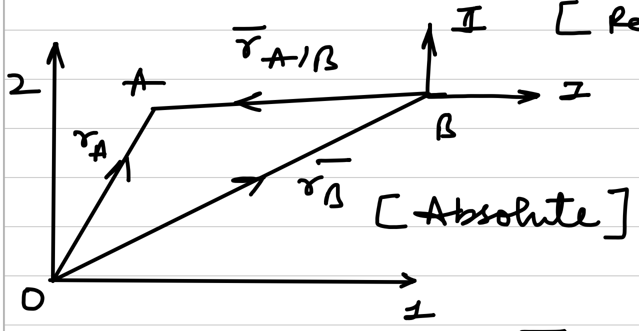
Make a Map.

$e_t - e_n$ is the Serret-Ferret frame

Rigid body.

∞ collection of particles. Distance b/w any 2 is unchanged.

Relative Motion



$$\bar{r}_A = \bar{r}_B + \bar{r}_{B/A}$$

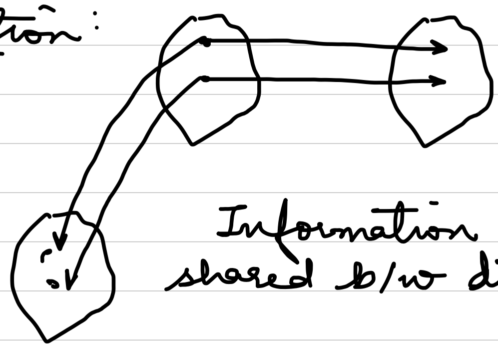
$$\bar{V}_A = \bar{V}_B + \bar{V}_{B/A}$$

$$\bar{a}_A = \bar{a}_B + \bar{a}_{B/A}$$

If B is stationary, or non accelerating then, inertial frame.

Rigid Body Motion:

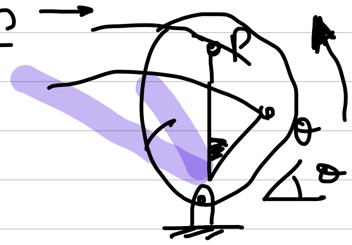
a) Translation:



Information can be shared b/w diff points.

what is the diff. b/w this and Curvilinear motion.

b) Rotation →

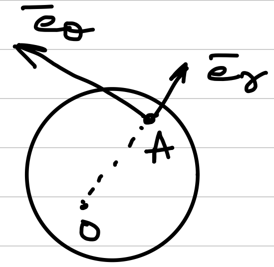


All radial points taking a circular path.

∠ b/w two points always remain the same.

$$\omega = \frac{d\theta}{dt} , \quad \alpha = \frac{d\omega}{dt}$$

$$v_p = r\dot{\theta} e_\theta$$



$$\bar{e}_3 = \bar{e}_1 \times \bar{e}_2$$
$$= \bar{e}_r \times \bar{e}_\theta$$

$$v = r\dot{\theta}\left[\bar{e}_3 \times \bar{e}_r\right]$$
$$= \bar{\omega} \times \bar{r}$$

$\bar{\omega}$ ↓ Angular velocity vector.

e^* is any general rotation axis.

$$\bar{v} = \frac{d\bar{r}}{dt} \Rightarrow \frac{d}{dt}\left(r\,\bar{e}_r\right)$$

$$\bar{v} = r\frac{d\bar{e}_r}{dt}$$
$$= \boxed{\bar{\omega} \times \bar{r}}$$
$$= \bar{\omega} \times r\bar{e}_r$$

$$\frac{d\bar{e}_r}{dt} = \boxed{\bar{\omega} \times \bar{e}_r}$$ → he derived it.

Rate of change of a vector = cross product of its angular velocity vector and the vector itself.

Acceleration: $a = \frac{d\bar{v}}{dt}$

$$= \frac{d}{dt}\left(\bar{\omega} \times \bar{r}\right)$$

$$= \frac{d\bar{\omega}}{dt} \times r + \frac{d\bar{r}}{dt} \times \bar{\omega}$$

$$= \frac{d}{dt}\left(\dot{\theta} \cdot e_3\right) = \frac{d\dot{\theta}}{dt} e_3 = \alpha e_3$$

$$\tilde{a} = \tilde{\alpha} \times \tilde{r} + \bar{\omega} \times \left(\bar{\omega} \times \bar{r}\right)$$

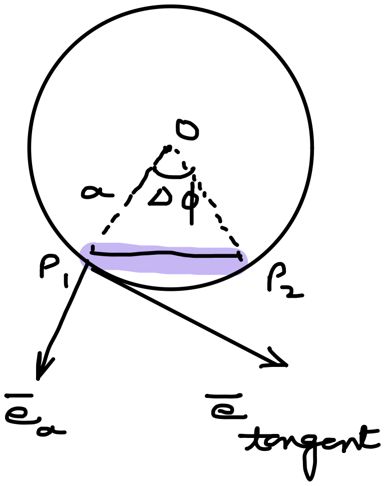
$\bar{r} = r\bar{e}_r \qquad \bar{\omega} = \dot{\theta}\bar{e}_3, \quad \alpha = \alpha\bar{e}_3$

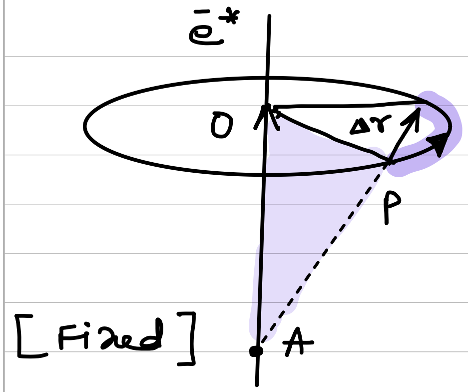
$$a = \alpha r \, \bar{e}_3 \times \bar{e}_r + (\dot{\theta}^2) r \left[\bar{e}_3 \times \bar{e}_3 \times e_\theta\right]$$

$$= \alpha r \tilde{e}_\theta + \dot{\theta}^2 r \left[\bar{r}\right]$$

$$a = \underbrace{r\alpha \tilde{e}_\theta}_{\text{Tangential}} + \underbrace{\dot{\theta}^2 r \tilde{r}}_{\text{Radial}}$$

Rotation about a fixed point





e^* is the axis of rotation

$\angle POP_1 = \Delta\phi$

P_1 is P after Δt

$$V_P = \lim_{\Delta t \to 0} \frac{\Delta r}{\Delta t} =$$

$\Delta r = a\,\Delta\phi$

Tangent to the circle at point P.

$$\tilde{\Delta r} = a\,\Delta\phi\,(\tilde{e}^* \times \tilde{e}_a)$$

Direction $e_{\Delta r}$

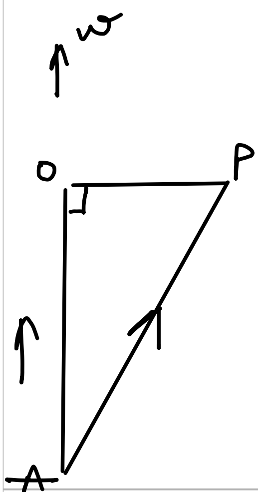
$$= e_r^* \times e_a$$

$$V_P = \lim_{\Delta t \to 0} \frac{a\,\Delta\phi\,(e^* \times \bar{e}^a)}{\Delta t}$$

$$= \lim_{\Delta t \to 0} \frac{\Delta\phi}{\Delta t}\left[r_{P/O}\right]$$

$$= \omega\,\bar{e}^* \times \bar{r}_{P/O}$$

$$= \bar{\omega} \times \bar{r}_{P/O}$$



In ΔAOP,

$$r_{P/A} = r_{O/A} + r_{P/O}$$

$$\bar{v}_P = \bar{\omega} \times \left[\bar{r}_{P/A} - \bar{r}_{O/A} \right]$$

$$\bar{v}_P = \bar{\omega} \times \bar{r}_{P/A} - \cancelto{0}{\bar{\omega} \times \bar{r}_{O/A}}$$

$$\bar{V}_P = \bar{\omega} \times \bar{r}_{P/A}$$

$$\frac{d}{dt}\left(\bar{r}_{P/A}\right) = \bar{\omega} \times \bar{r}_{P/A}$$

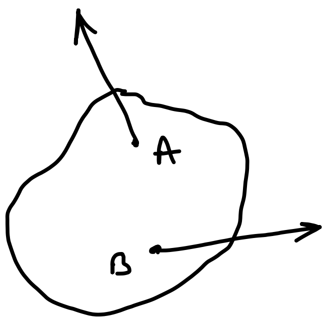
Acceleration:

$$\bar{a} = \frac{d\bar{v}}{dt}, \quad \bar{a} = \frac{d}{dt}\left(\bar{\omega} \times \bar{r}_{P/A}\right)$$

$$= \frac{d\bar{\omega}}{dt} \times \bar{r}_{PA} + \bar{\omega} \times \frac{d\bar{r}_{PA}}{dt}$$

$$\Rightarrow \bar{\alpha} \times \bar{r}_{P/A} + \bar{\omega} \times \bar{v}$$

$$\boxed{\bar{a} = \bar{\alpha} \times \bar{r}_{P/A} + \bar{\omega} \times \bar{v}}$$



For a plane case, $\omega = \omega \bar{e}_3$

w.r.t point B, since distance between points A and B does not change, the rel. motion A/B is rotational.

$$V_{A/B} = \bar{\omega} \times \bar{r}_{A/B}$$

$$\bar{V}_A = \bar{V}_B + \bar{\omega} \times \bar{r}_{A/B}$$

$\bar{\omega}$ is Independent of frame?

$\vec{V}_{A/B} = \vec{\omega} \times \vec{r}_{A/B}$

Planar case $\longrightarrow$ 2 components and thus 2 equations

diff. w.r.t time,

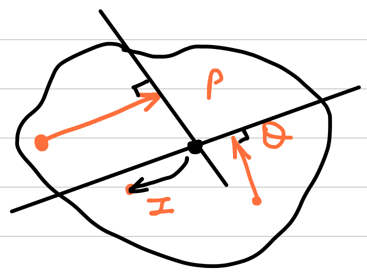
$$\bar{a}_A = \bar{a}_B + \frac{d}{dt}\left(\vec{\omega} \times \vec{r}_{A/B}\right)$$

$$\vec{a}_A = \vec{a}_B + \alpha \times \vec{r}_{A/B} + \vec{\omega} \times \vec{v}_{A/B}$$

$$\bar{V}_A = \bar{V}_B + \bar{\omega} \times \bar{r}_{A/B}$$

If at a given instance, $\bar{V}_B = 0$, then it becomes the int. point of rotation
$\downarrow$
Centre.

Axis is called inst. axis of rotation.



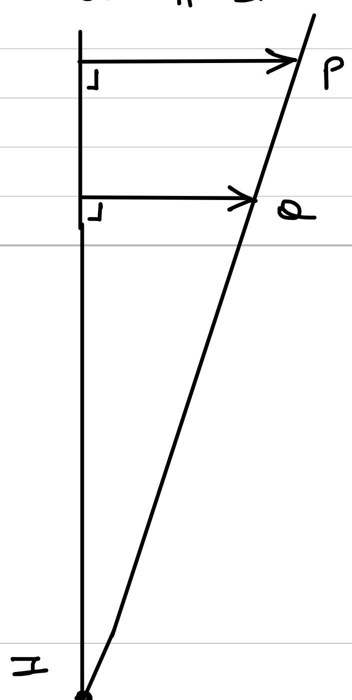
$I \longrightarrow$ Inst. Center

$$\bar{V}_P = \cancel{\bar{V}_I}^{\,0} + \underline{\omega} \times \underline{r}_{P/I}$$

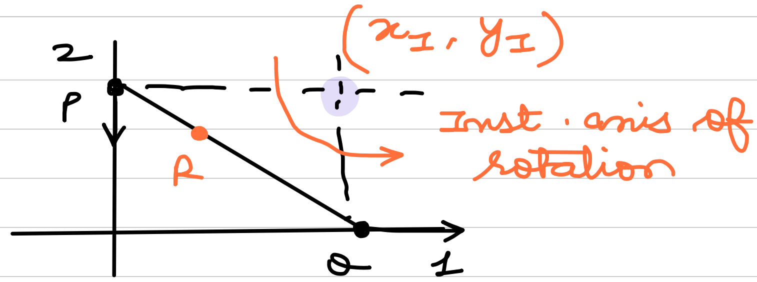
$$\bar{V}_Q = \cancel{\bar{V}_I}^{\,0} + \bar{\omega} \times \bar{r}_{Q/I}$$

Int. of lines $\perp r$ to radii.

Special case: If the velocity vectors are $\parallel$ to each other.



EXAMPLE :



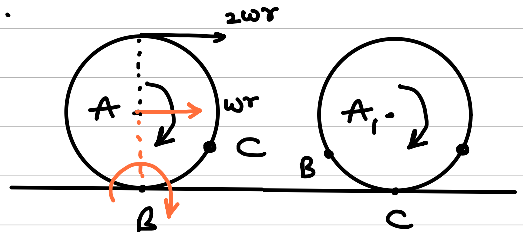
$$\left(\frac{x_I}{L}\right)^2 + \left(\frac{y_I}{L}\right)^2 = 1$$

$$\vec{V}_R = \cancel{\vec{V}_I}^{\,0} + \vec{\omega} \times \vec{r}_{R/I}$$

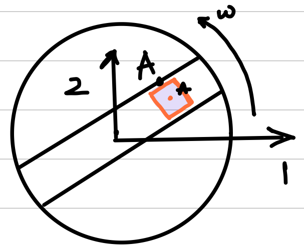
$$\vec{V}_R = \vec{\omega} \times \vec{r}_{R/I}$$

$$|V_R| = \omega \, |r_{R/I}|$$

Disk :

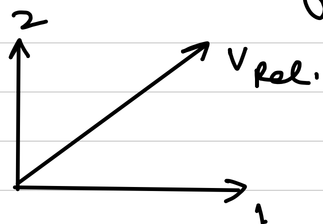


Turn table with slot .



$$\bar{V}_P = \bar{V}_0 + \bar{\omega} \times \bar{r}_{P/0}$$

we will have rel. motion of A and B.

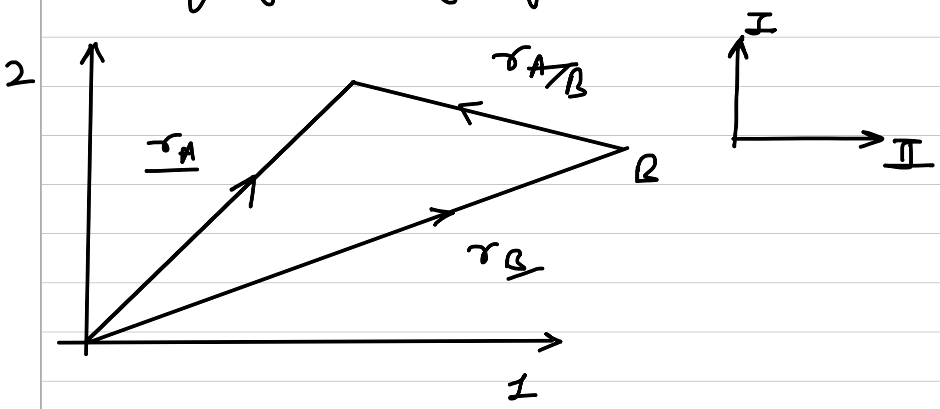


$V_A = V_P + V_{Rel}$

$$\vec{V}_A = \vec{V}_0 + \vec{\omega} \times \vec{r}_{P/0} + \vec{V}_{rel}$$

WEEK 3

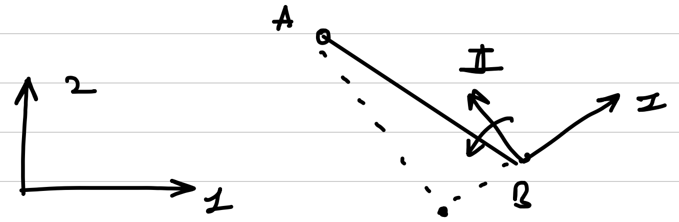
Rotating frame of refr.



$$\overline{r_A} = \overline{r_B} + \overline{r_{A/B}}$$

$$\overline{V_A} = \overline{V_B} + \overline{V_{A/B}}$$

$$\overline{a_a} = \overline{a_B} + \overline{a_{A/B}}$$



Inertial frame Rotating frame

$$\underset{= II}{\overrightarrow{AB}} : x_I \overline{e_I} + x_{II} e_{II}$$

$$\overline{r_A} = \overline{r_B} + x_I \overline{e_I} + x_{II} \overline{e_{II}}$$

$$\overline{V_A} = \overline{V_B} + \dot{x}_I \overline{e_I} + x_I \dot{\overline{e}}_I + \dot{x}_{II} \overline{e_{II}}$$
$$+ x_{II} \dot{\overline{e}}_{II}$$

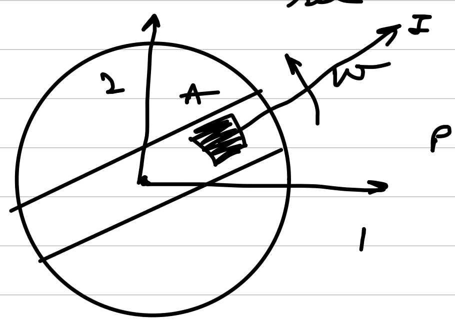
$$\dot{\overline{e}}_I = \omega \times e_I$$

$$\dot{\overline{e}}_{II} = \omega \times e_{II}$$

$$= \bar{v}_B + \dot{x}_I \bar{e}_I + x_I \bar{\omega} \times \bar{e}_I + \dot{x}_{II} \bar{e}_{II} + x_{II} \bar{\omega} \times \bar{e}_{II}$$

$$= \bar{V}_B + \underbrace{(\dot{x}_I e_I + \dot{x}_{II} e_{II})}_{V_{rel}} + \bar{\omega} \times \bar{r}_{A/B}$$

=



Diff. the velocity

$$\bar{a}_A = \bar{a}_B + \dot{\omega} \times r_{A/B} + \omega \times \frac{d}{dt}(\bar{r}_{A/B}) + \frac{d}{dt}(V_{rel})$$

$$r_{A/B} = x_I e_I + x_{II} e_{II}$$

$$\frac{d}{dt}(\bar{V}_{rel}) = \frac{d}{dt}\left(\dot{x}_I e_I + \dot{x}_{II} e_{II}\right)$$

$$= \ddot{x}_I e_I + e_{II} \ddot{x}_{II}$$

$$\dot{x}_I \dot{e}_I + \dot{x}_{II} \dot{e}_{II}$$

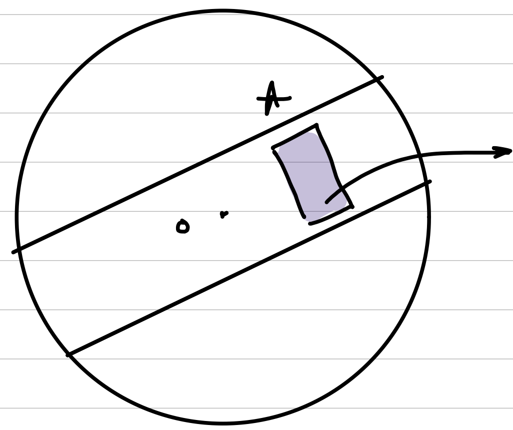
=

$$\bar{a}_A = \bar{a}_B + \bar{\alpha} \times \bar{r}_{A/B} + \bar{\omega} \times (\bar{\omega} \times \bar{r}_{A/B} + \bar{V}_{rel})$$

$$+ \ddot{x}_I \bar{e}_I + \ddot{x}_{II} \bar{e}_{II} + \bar{\omega} \times \bar{V}_{rel}$$

$$= \bar{a}_B + \bar{\alpha} \times \bar{r}_{A/B} + \bar{\omega} \times (\bar{\omega} \times r_{A/B})$$

$$+ 2\bar{\omega} \times \bar{V}_{rel} + \bar{a}_{rel}$$



A coincides with point P at the given instant ~~of time~~.

$$\bar{a}_p = \bar{a}_o + \bar{\omega} \times (\bar{\omega} \times \bar{r}_{p/o}) + \bar{\alpha} \times \bar{r}_{p/o}$$

$$\vec{a}_{A/p} = \underbrace{2\,\bar{\omega} \times \bar{V}_{rel}}_{\text{Coriolis}} + \bar{a}_{rel}$$

diff of global rel. acc - relative accn in Rot. frame.

$$a_A = a_B + a_{A/B}$$

$$\downarrow$$

$$\omega \times (\omega \times r_{A/B}) + \bar{\alpha} \times \bar{r}_{A/B} + a_{rel}$$

$$+ 2(\omega \times V_{rel})$$

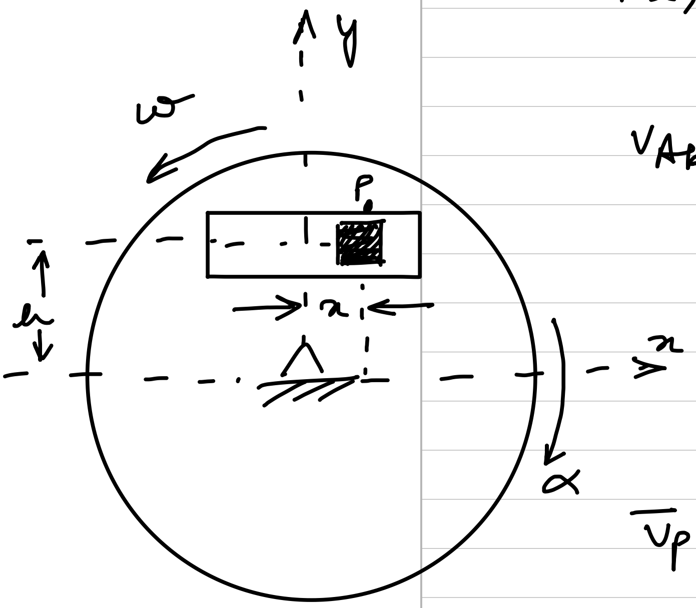
-6400

$$a_A = a_B + \frac{16}{3} \times \left(\frac{16}{3} \times 500\right) + \alpha \times 500 + 0$$

$$a_B = 6.4(-\hat{i})$$

Example:

$h, x, \omega, \alpha, \frac{dx}{dt}, \frac{d^2x}{dt^2}$



$V_{Absolute}$ and a_{abs}

at $t_1 \rightarrow$ coincides with P.
[assumption]

$$\bar{r}_{AO} = \bar{r}_A = \bar{r}_P \quad (x\bar{e}_1 + h\bar{e}_2)$$

$$\bar{v}_P = \bar{v}_O + \bar{\omega} \times \bar{r}_{P/O}$$

$$= \omega\bar{e}_3 \times [x\bar{e}_1 + h\bar{e}_2]$$

$$= \omega x\bar{e}_2 - \omega h\bar{e}_1$$

$$\bar{V}_A = \bar{V}_P + \bar{V}_{A/P}$$

$$\bar{V}_{abs} = \omega x\bar{e}_2 - \omega h\bar{e}_1 + \underbrace{\frac{dx}{dt}\bar{e}_1}_{V_{rel}}$$

$$\bar{a}_P \Rightarrow \vec{a}_O + \vec{a}_{P/O}$$

$$\Rightarrow \bar{a}_{P/O} = \bar{\omega} \times (\bar{\omega} \times \bar{r}_{P/O}) + \alpha \times \bar{r}_{P/O}$$

$$\bar{a}_P = \alpha[-xe_2 + he_1] - \omega^2[xe_1 + he_2]$$

$$a_A = a_P + a_{P/A}$$

$$a_{A/P} = a_{rel} + 2\bar{\omega}\times\underbrace{\bar{V}_{rel}}_{\text{Not the absolute } V}$$

$$a_{rel} = \left(\frac{d^2x}{dt^2}\right)\bar{e}_1$$

$$\text{Coriolis} = 2\bar{\omega}\times\bar{V}_{rel} = 2\omega\frac{dx}{dt}\bar{e}_2$$

$$a_A = \alpha\left[-xe_2 + he_1\right] - \omega^2\left[xe_1 + he_2\right] + \frac{d^2x}{dt^2}\bar{e}_1$$

INTRO TO MECHANICS

Higher pair → Point contacts

Lower pair → Surface contacts.

Robotics → open chain.

Mechanism : links joined by joints or kinematic pairs.

Joint → Lower
→ higher [point / line]

Machine → Combination of mechanisms to provide power from source to load.

Linkage mechanism :

DOF → Min. no. of inputs to completely specify location of all links.

Revolute → 1 DOF

Prismatic → 1 DoF
Trans

θ → kuch nahi hai?

Kutzbach / Grubber Criteria :

Planar Case :

3 DOF
↓
Every link

n links

Each link → 3 DoF

3N

total → 3n DoF

LINKS
↑

1 link is grounded, DoF : $F = 3(n-1)$

Fixed link.

If all remaining links are isolated.

High → Point Contact

Points

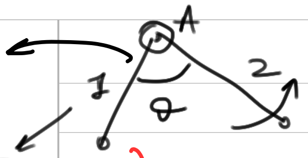
Lower → Surface Contact.

hi

Mech → Translating Motion | Mach → Transmitting power.

grounded Link

3DoF



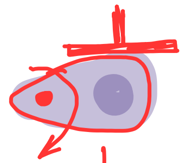
1

2

$3[2-1] - 2\cdot 1 - 0$

DoF → 1

Due to the joint, we require only θ to be known



quick rises and falls as well

Each turning pair reduces the DoF by

$[3-1] = 2$

If j are turning joints →

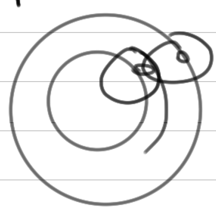
$$\text{DoF} = 3[n-1] - 2j$$

If we have "h" higher pair

Reduction

$h[3-2]$

$-2J$. $\qquad -1$



DoF, modified :

$$\boxed{F = 3[n-1] - 2j - h}$$

Kutzbach.

If $F = 1$, Constraind Mechanism

$$\boxed{1 = 3[n-1] - 2j - h}$$

Grubbler Criteria.

with one grounded Link.

All these of 2D Closed loops.

Definitions : Link : Body common to 2 or more joints.

Kutzback → derive the DoF of a kinematic chain.

$$\text{DOF} = 3[L-1] - 2J - H$$

[Planar Mech.

No. of links, Joints, higher pairs

CLOSED LOOP → $6(n-1) - (6-1)j_1$
$(6-2)j_2$
$(6-3)j_3$
$(6-4)j_4$
$(6-5)j_5$

Link → 3 DOF
↓
1 Redundant
↓
2 Eff.

→ Lower pair
↓
Removes 1 DOF.

→ higher pair
↓
−2 DOF

$$F = 6[n-1] - 5j_1 - 4j_2 - 3j_3 - 2j_4 - j_5$$

where j_K denotes, joint with K DOFs

Planar Linkage, with lower pair
↓
Number synthesis.

Can't have arbitrary no. of joints.

$$F = 3[n-1] - 2j$$

$$J = \frac{\{3(n-1) - F\}}{2}$$ → Restricted

n = ! F
↓

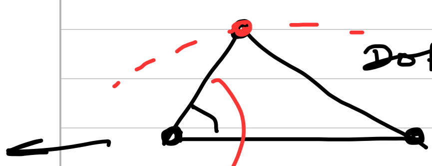
odd	even
even	odd

$$F \Rightarrow [I - 3(n-1)] \% 2 = 0$$

odd − odd ⟶ n ⟶ Even.
Even − Even ⟶ n ⟶ odd

$3[2]\cdot 2[3] - h$
0

For a closed loop ⟶ Mi. no. of links $= 3$.



Length can't change!

DOF → 0 → Can't move at all.
$n = 3$
$j = 3$

$$F = 3(3-1) - 2\times 3$$

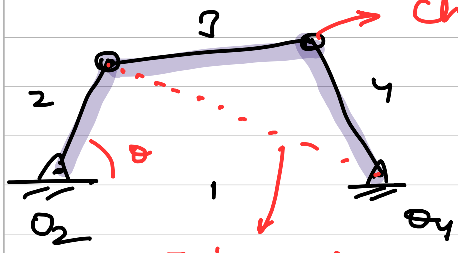
Structure ↙ $F = 0$

all trusses are triangular.

Triangular mechanisms cannot move, length of sides can't change for mechanism, no. of links should be 4.

Min.

Diagonals length can change



Changes on its own

This can change

$n = 4; \; j = 4$

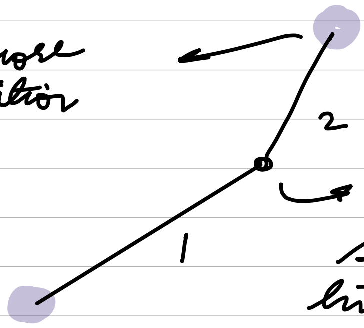
$F = 3[4-1] - 2 \times 4$

$= 9 - 8$

$= 1$

$3[3] - 2[4] \Rightarrow 1$

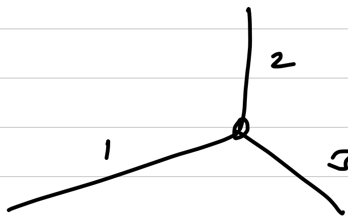
More addition



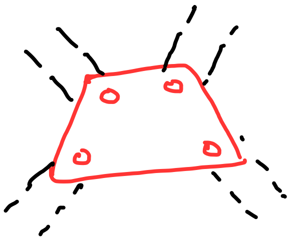
Binary link

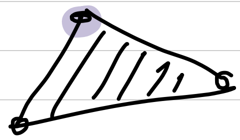
Joint simple hinge.

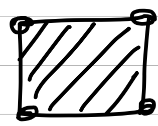
All joints are simple.



Not a simple joint







Links

Ternary

Quarternary

$n_k \rightarrow$ how many more

$n_2 \rightarrow$ binary, $n_3 \rightarrow$ ternary

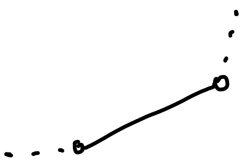
Links

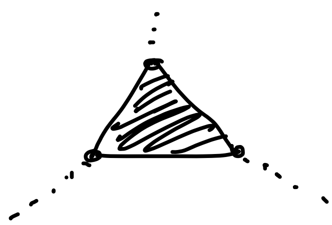
$n = 0 + n_2 \ldots n_k$

joints $\rightarrow j$, Each is a simple hinge.

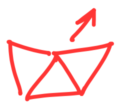
No. of elements $\rightarrow 2j$

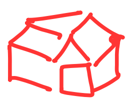
$2n_2$





Fixed





$n = n_2 + n_3 \; . \; - - - \; n_k \longrightarrow$ No. of links

k - joints can be made

$\boxed{2J} = 2n_2 + 3n_3$

Total no. of elements.

$2j = 2n_2 + 3n_3 \dots kn_k$

Kutzbach criteria.

$F = 3[n_2 + n_3 \dots\dots$

Joint → 2 links would have been these

Kutzbach criterion

If $F = 1$ [Constrained mechanism]

$3n - 2j - h = 4$

Kutzbach → DOF

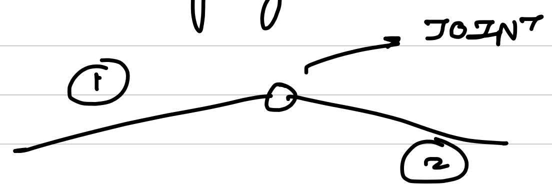
Grubbler crit.

grubbler → Contrained designs

$n_1, n_3 \dots n_k$ be binary, tertiary, ... links.

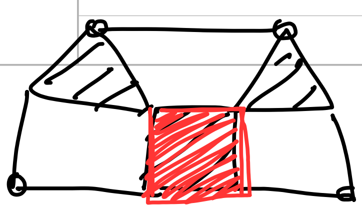
$n = n_2 + n_3 \dots n_k$.

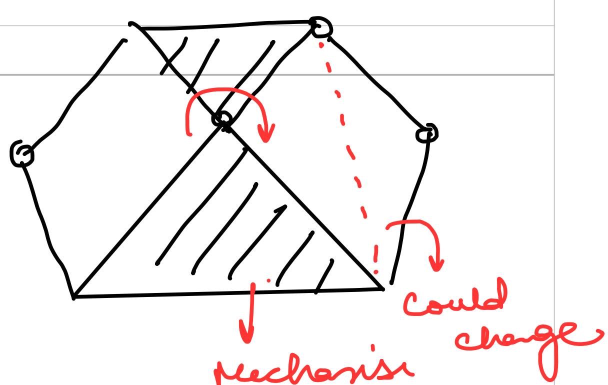
j → no. of joints



Total no. of elements.

given n no. of links, we want to find the min. no. of hinges, link.





N → no. of links → Min hinges, link

n → even

$n = 8$, $DOF = 1$, $j = 10$

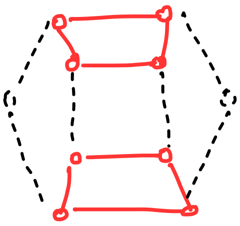
$1 = 3[n-1] - 2j$

$\boxed{3n - 2j = 4}$

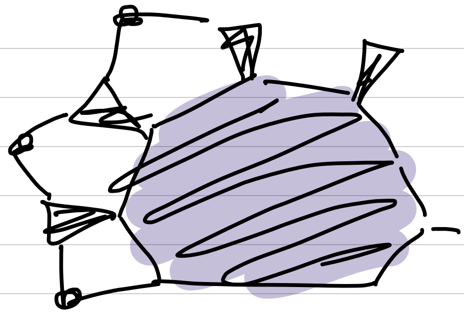
$\boxed{n = n_2 + n_3 \cdots n_4}$

$2j = 2n_2 + 3n_3 \cdots n\, n_n$

$\boxed{j = 10,\ n = 8}$ → Konse.



→ Maxi link capacity.



No. of links

$= k + [k - 1 + 1]$

$= 2k$ hinge

$n =$ even

Mi. of elements → n $\left[\frac{n}{2}, \frac{n+1}{2}\right]$

given "n" links, we can have a link with max. $\frac{n}{2}$ [n = even]

$\left[\frac{n+1}{2}\right]$ n = odd

hinges.

$F = 1$; $n = 6$

$1 = 3[n-1] - 2j$

$j = 7$

$\frac{n}{2} \longrightarrow \frac{6}{2} \to 3;$

$j = 7$,

hinges → 3. what's the use

joints

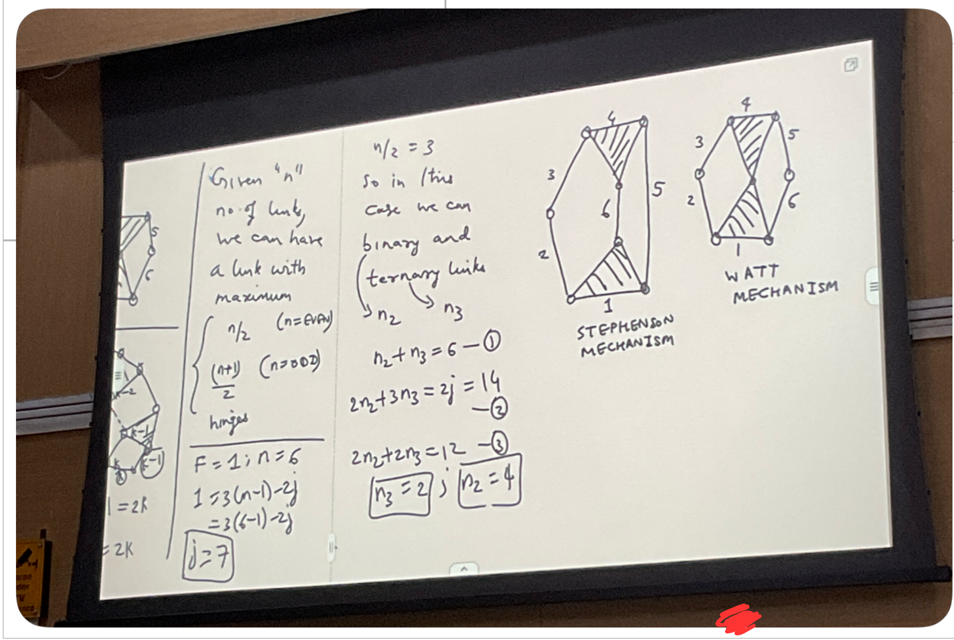
$n = 6$

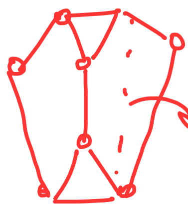
2 → link 1, 3
1 → 2, 6, 5
4 → 3, 6, 5
3 → 4, 2
6 → 1, 4
5 → 4, 1

$n_2 + n_3 = 6$

$2n_2 + 3n_3 = 14$

$n_2 = 4$; $n_3 = 2$





Can be Changed.

$\frac{n}{8} \rightarrow n_4$

$16 = 2n_2 + 3n_3 + 4n_4$

$n_2 + n_3 + n_4 = 7$

↓

Family of solutions'

$\cancel{x} = 3[6] - 2j$

$j = 8$

$n = 7$; $F = 2$

$F = 3(n-1) - 2j$

$j = 8$

Links with max no. of hinges

$\Rightarrow \frac{7+1}{2} = 4 \rightarrow$ Bin Quart Tern.

$n_2 + n_3 + n_4 = 7$

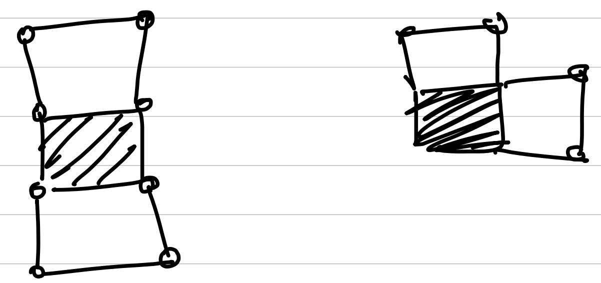
$2n_2 + 3n_3 + 4n_4 = 16$

get a family of solution

$$\boxed{n_3 + 2n_4 = 2}$$

$$\boxed{\begin{array}{l} n_3 = 2, \ n_4 = 0 \\ n_3 = 0, \ n_4 = 1 \end{array}}$$

$n_2 = 6$

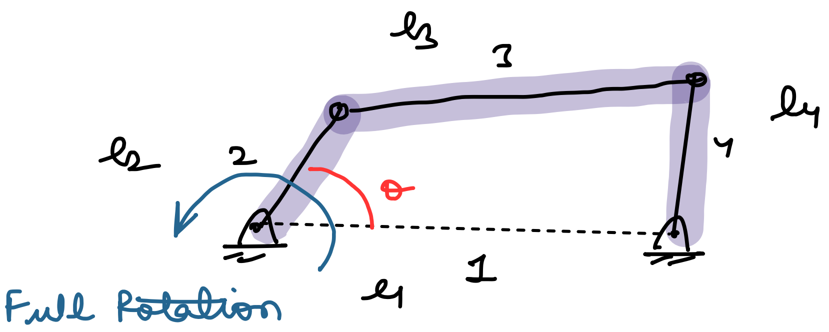


✓✓

understood.

4-BAR MECHANICS

MAINS!



GRASHOFF.

$\theta \rightarrow$ defines the whole state.

$\boxed{s+l <}$

s → Rigid banata hai.

CRANK ↓ the one that rotates fully.

s, p, q, l

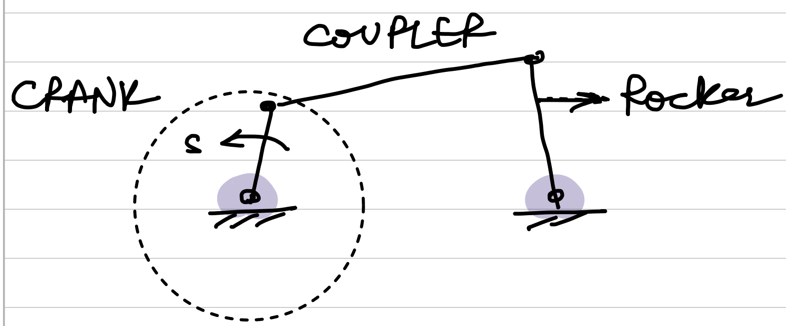
If $s+l < p+q$

then one of the links will undergo full rotation.

If $l+s > p+q$ → triple rocker mechanism.

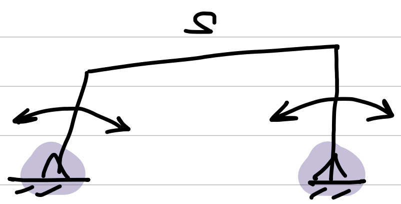
Link adjacent to s is fixed, shortest will complete one rotation and will have a crank rocker mechanism.

SIDE LINK MECHANISM:



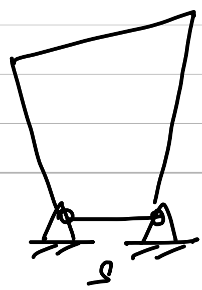
Double Rocker

b) If link opposite to "s" is fixed we have double rocker mech.



Double CRANK

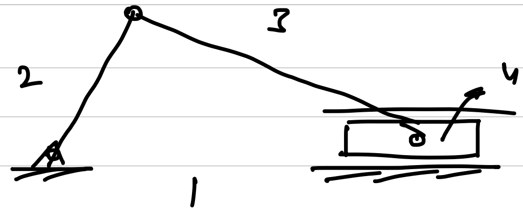
c) If s is fixed, we will have a double crank mechanism.



Rag link

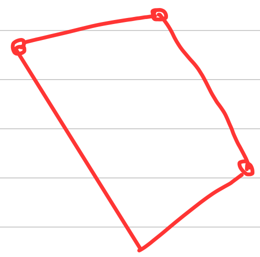
Inversion of mechanisms are obtained by Changing fixed length

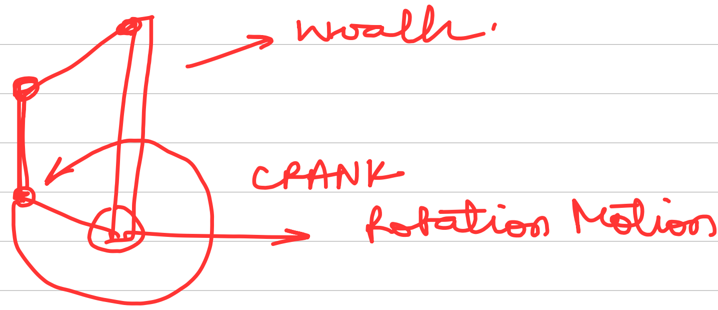
GRASOFF → satisfy hona chahiye.



$$F = 3[4-1] - 2\times4 = 1$$

Pump Jack :





First bicycle → germany.

Karl Drais.

Watt's linkage → suspension.

↓

James Watt, engine wala.

Mechanism → Inversions.