(Machine) Dynamic

Uploaded by I-Ahmad Jundi

تلخيص: عيسى الشريف / ديناميكا الآلات

مدرس المساق: د. نضال فرحات

Mechanisms

Rigid Bodies / links interconnected by joint designed for a given job.

Joints: A connection between two or more bodies

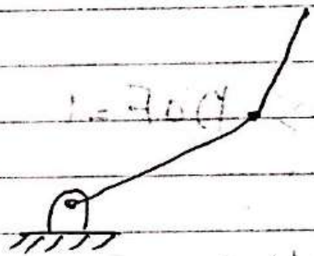
Degrees of Freedom: DOF
Number of Independent Parameters / inputs need to control the motion of the joints

* Two types of spaces:
  - Motion in 2D-plane (x, y, θ) 3 DOF
  - Motion in 3D-space (x, y, z) (α, β, θ) 6 DOF

Types of Joints:

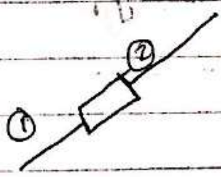
① Revolute Joint:

DOF = 1

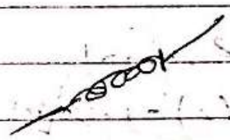


② Prismatic Joint:

DOF = 1



③ Screw Joint:
DOF = 1



④ Cylindrical Joint:
DOF = 2

(5) Spherical Joint: can rotate in 3 angles

DOF = 3

* Mobility: (m)

Number of independent parameters / inputs needed to completely control the motion of mechanism

M = 1 DOF

in 2D: $\boxed{m = 3(n-1) - 2 \times J_1 - J_2}$ Kutzbach

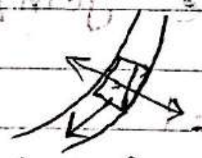
n: number of bodies including the ground only one time

J_1: number of joints that have one DOF.

J_2: " " " " " two DOF

* Contact joint:

(a) Sliding only: => DOF = 1

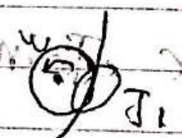


dependent y=f(x) بين x,y يربط في

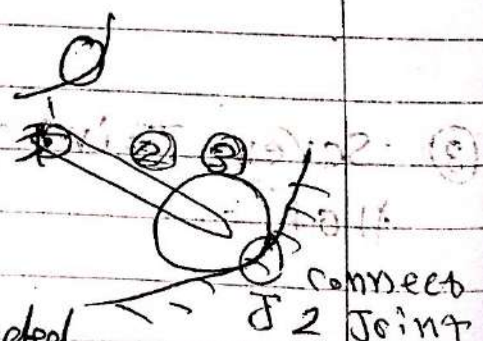
(b) Rolling without sliding:

DOF = 1

No slipping



(c) Rolling with sliding => DOF = 2



Ex $n = 3, J_1 = 2, J_2 = 1$

$m = 3(3-1) - 2(2) - 1 \Rightarrow \boxed{m = 1}$

m > 0 => Independent parameter are needed

m = 0 => Determinate structure (No motion)

m < 0 => Indeterminate " " " => Mechanics

Kutzbach Criteria:

$$\boxed{m = 3(n-1) - 2J_1 - J_2}$$

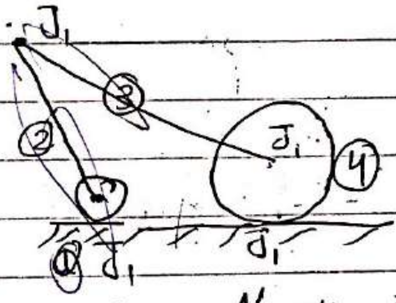
$m = 0$

$m > 0$

$m < 0$

Example:

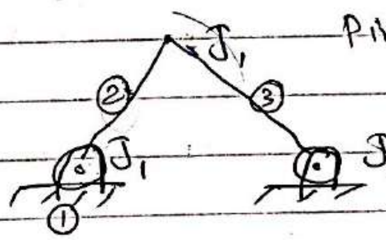
1) $\left.\begin{matrix} n = 4 \\ J_1 = 4 \\ J_2 = 0 \end{matrix}\right\} \Rightarrow m = 1$



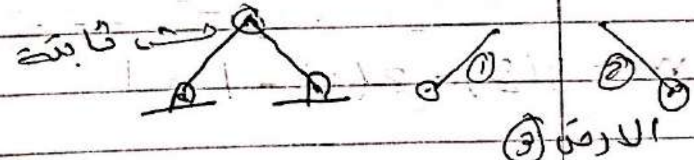
No slipping

2) $\left.\begin{matrix} n = 3 \\ J_1 = 3 \\ J_2 = 0 \end{matrix}\right\} \Rightarrow m = 3(3-1) - 2(3) = 0$ ⇒ Fixed structure

• No motion



Pin - Revolute Joint

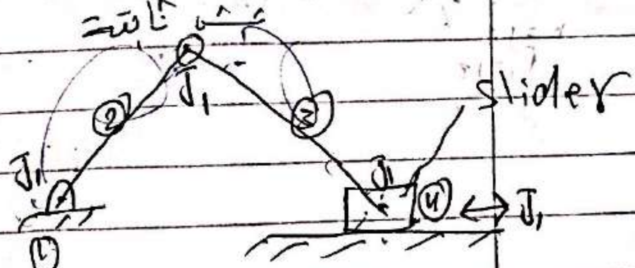


3) $\left.\begin{matrix} n = 4 \\ J_1 = 4 \\ J_2 = 0 \end{matrix}\right\} \Rightarrow m = 1$

لا في حركة

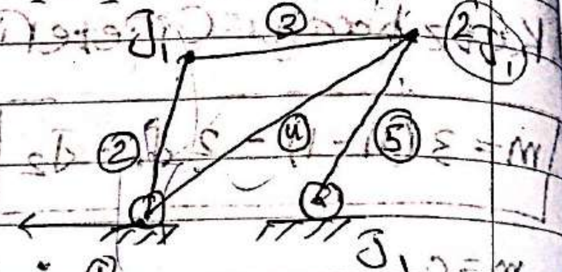
بس أنو اللي بتحكم في الحركة؟

حسب التطبيق



slider crank machine

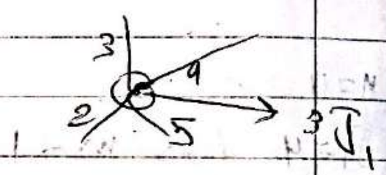
بين 3 و 4
5 و 3 و 4
بثبت واحد وبجي عليه صار تلقائي بين 4 و 5
dependent



$n=5$
$J_1=6$
$J_2=0$
$\Rightarrow m=3(5-1)-2(6)=0$

OR: n = 4 : ground, triangle, A, A
$J_1=4$
$m=0$

بتعامل مع المثلث كأنه جسم واحد
يا ما هيك راح يتغيروا
أي Joint مربوط بأكثر من link
عليه تفصيل



5,2 & 4,2 & 3,2

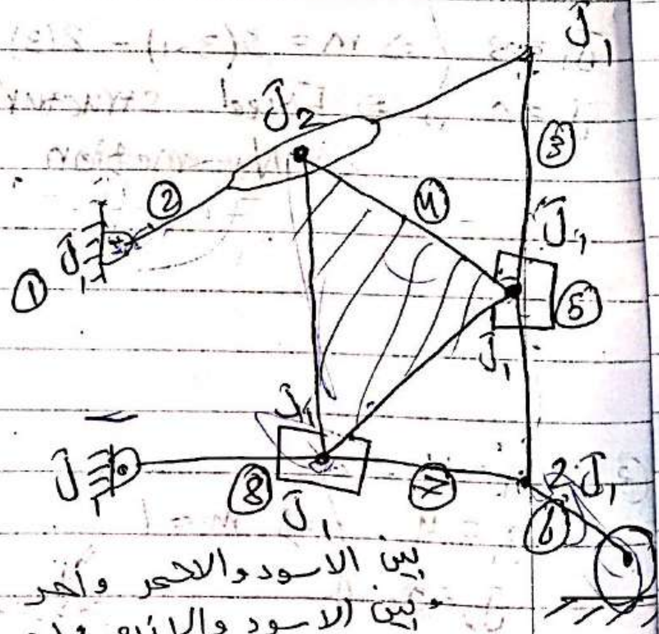
pin داخل slot داخل J_2

4

$n=9$
$J_1=11$
$J_2=1$

$m=3(8)-2(11)-1=1$

ولو كان بدل slot بصير m=1
$n=10$
$J_1=13$
$J_2=0$



بين الاسود والاحمر واحد
وبين الاسود والازرق واحد sliding

Exception to Kutzbach Criteria:

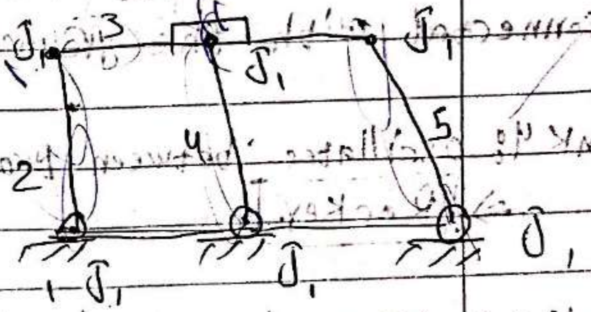
$n = 5$

$J_1 = 6$

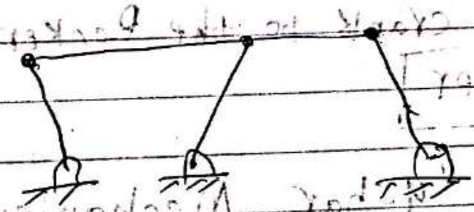
$J_2 = 0$

$m = 3(4) - 2(6) - 0 = 0$

في حركة لانه اطوال متساوية ومتوازية



لو كان هيك ما تتحرك لانه بصير تعارض



Exp:

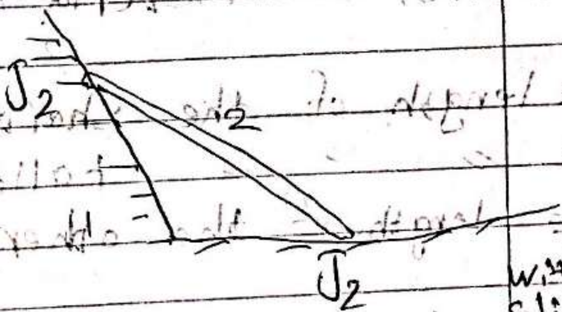
$n = 2$

$J_1 = 0$

$J_2 = 2$

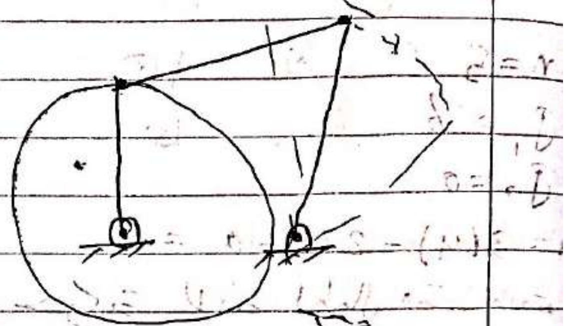
$\Rightarrow m = 3(1) - 2(0) - 2 = 1$

$m = 1$



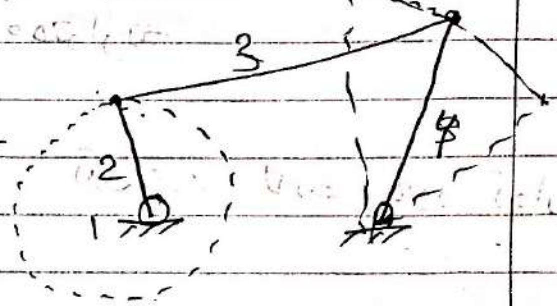
* Four Bar Mechanism:

link 2: makes complete revolution connected with the ground ⇒ $\boxed{\text{crank}}$



link 4: oscillates between two limits
⇒ $\boxed{\text{Rocker}}$

link 3: transmits the motion from the crank to the Rocker
⇒ $\boxed{\text{Coupler}}$



Inversion of 4-bar Mechanism:

Grashof's criteria / mechanism (معايير) — من 4bar

S ≡ length of the shortest link
L ≡ 〃 〃 〃 tallest 〃
p, q ≡ length of the other two links

$$S + L \leq p + q$$

⇒ at least one link can make complete revolution

If shortest link is one of sides ⇒ crank
〃 〃 〃 〃 the ground ⇒ double crank
〃 ⇒ double Rocker No crank
اتصال بالارض

* Types of Four bar Mechanisms:

Grashof's Mechanisms: $S + L \leq P + q$

1) one of the side links is the shortest one. Crank-Rocker

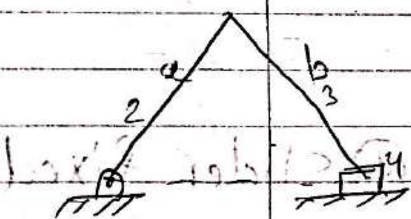
2) S ≡ fixed link
All links make complete revolution
Double Cranck

3) Double Rocker when shortest link ≡ Connecting Rod (Coupler)
مقابل للأرض

4) $S + L = P + q$ Change Point Mechanism
ممكن يعكس الحركة

5) Non Grashof Mechanism Tripple Rocker
$S + L > P + q$ No link Makes Complet Revolution

Slider Crank Mechanisms:

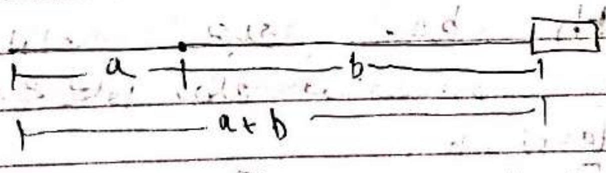


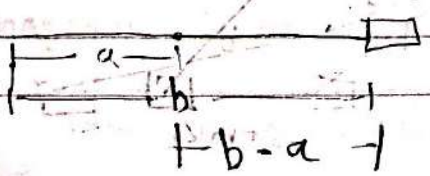
link 2: makes complete revolution ≡ crank

link 4: Slider

link 3: Connecting Rod

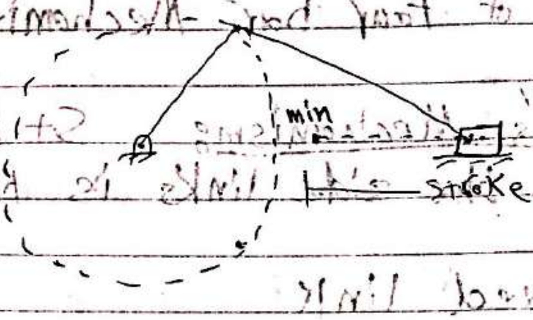
Stroke ≡ the total distance by the slider
distance between the two extreme left & right Positions of the slider





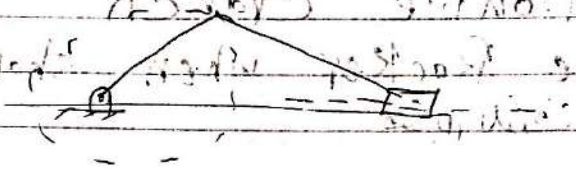
the stroke $= (a+b) - (b-a)$

Stroke $= 2a$

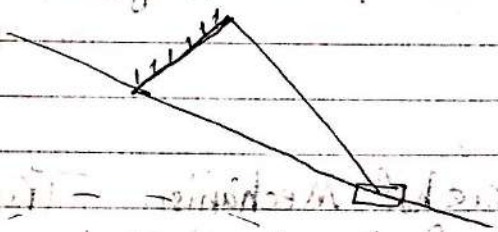


Types of Slider Crank Mechanisms

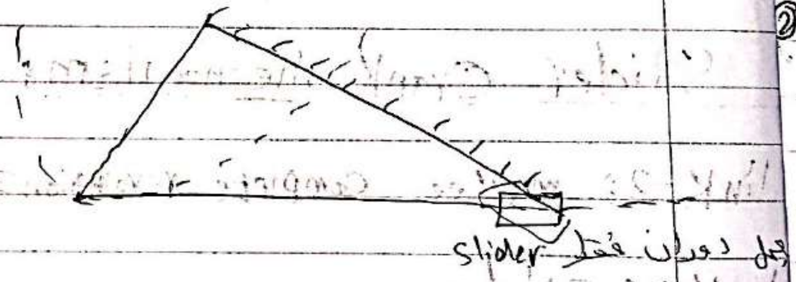
① Slider crank



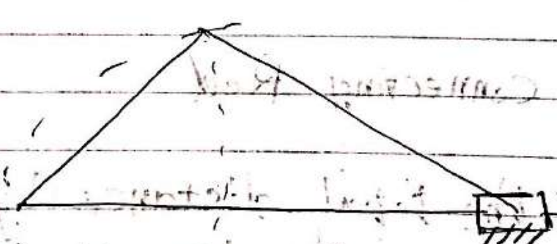
② Crank fixed



③ Connecting Rod Fixed.



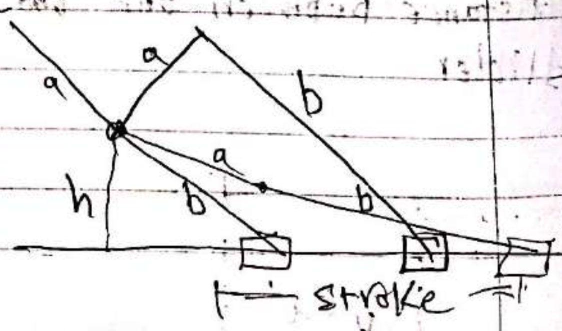
④ Slider fixed



⑤ Offset slider crank Mechanism

$b > a + h$ شرط

اذا مكانش هيك راح يحاول يطلع من مساره



الكبيرة $= \sqrt{(a+b)^2 - h^2}$

الصغيرة $= \sqrt{(b-a)^2 - h^2}$

stroke = الكبيرة ناقص الصغيرة

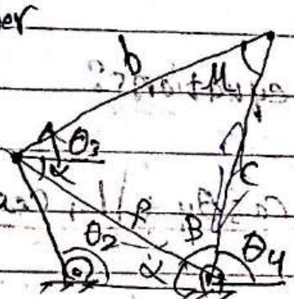
stroke $= \sqrt{(a+b)^2 - h^2} - \sqrt{(b-a)^2 - h^2}$

Position Analysis:

1. Graphical Analysis:
2. Analytical Analysis: using complex Number

Four bar Mechanism:

Graphical Analysis:



Given θ_2 find θ_4

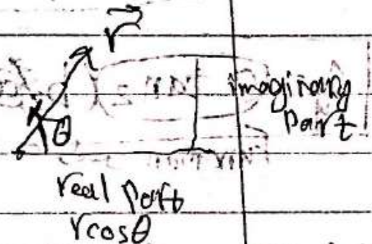
$$f^2 = a^2 + b^2 - 2ab\cos(\theta_2)$$

لأنه θ_2 أكبر من 90 بحط بالقانون (-)

$$\frac{f}{\sin\theta_2} = \frac{a}{\sin\alpha} \Rightarrow \text{I have } \alpha$$

$$\vec{r} = re^{j\theta} = r(\cos\theta + j\sin\theta)$$
$$= r\cos\theta + jr\sin\theta$$
$$= x + jy$$

$$b^2 = f^2 + c^2 - 2fc\cos(B) \Rightarrow \text{I have } B$$



$$\Rightarrow \theta_4 = 180 - (B + \alpha)$$

2. Analytical Method: Position loop equation

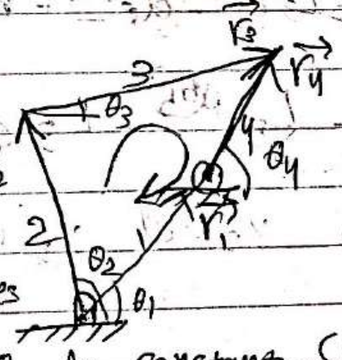
$$\vec{r} = r(\cos\theta + j\sin\theta)$$
$$= re^{j\theta}$$

$$\vec{r_2} + \vec{r_3} - \vec{r_4} - \vec{r_1} = 0$$

$$L_2 e^{j\theta_2} + L_3 e^{j\theta_3} - L_4 e^{j\theta_4} - L_1 e^{j\theta_1} = 0$$

$$L_2(\cos\theta_2 + j\sin\theta_2) + L_3(\cos\theta_3 + j\sin\theta_3)$$
$$- L_4(\cos\theta_4 + j\sin\theta_4) - L_1(\cos\theta_1 + j\sin\theta_1) = 0$$

variables



$\theta_2 \equiv$ input ; & $(\theta_3$ & $\theta_4)$ are outputs , θ_1 is constant (ground)

Real Part: $L_2\cos\theta_2 + L_3\cos\theta_3 - L_4\cos\theta_4 - L_1\cos\theta_1 = 0$ —— (1)

Imaginary Part: $L_2 \sin\theta_2 + L_3 \sin\theta_3 - L_4 \sin\theta_4 - L_1 \sin\theta_1 = 0$ —— (2)

Position loop equations are nonlinear relative to the variables.

to Solve the equations:

$$L_3 \cos\theta_3 = L_4 \cos\theta_4 + \underbrace{\boxed{L_1 \cos\theta_1 - L_2 \cos\theta_2}}_{A} \quad \text{--- (1)}$$

$$L_3 \sin\theta_3 = L_4 \sin\theta_4 + \underbrace{\boxed{L_1 \sin\theta_1 - L_2 \sin\theta_2}}_{B} \quad \text{--- (2)}$$

$$(1)^2 + (2)^2 = L_3^2 = (L_4 \cos\theta_4 + A)^2 + (L_4 \sin\theta_4 + B)^2$$

$$L_3^2 = L_4^2 \cos^2\theta_4 + A^2 + 2A L_4 \cos\theta_4 + L_4^2 \sin^2\theta_4 + B^2 + 2B L_4 \sin\theta_4$$

$$\underbrace{(L_3^2 - L_4^2 - A^2 - B^2)}_{c} = \underbrace{(2L_4A)}_{a}\cos\theta_4 + \underbrace{(2L_4B)}_{b}\sin\theta_4$$

$$\boxed{\theta_4 = \text{atan}_2(b/a) \pm \text{atan}_2(\sqrt{a^2+b^2-c^2}/c)}$$ 2 sol. for θ_4

Function واحد

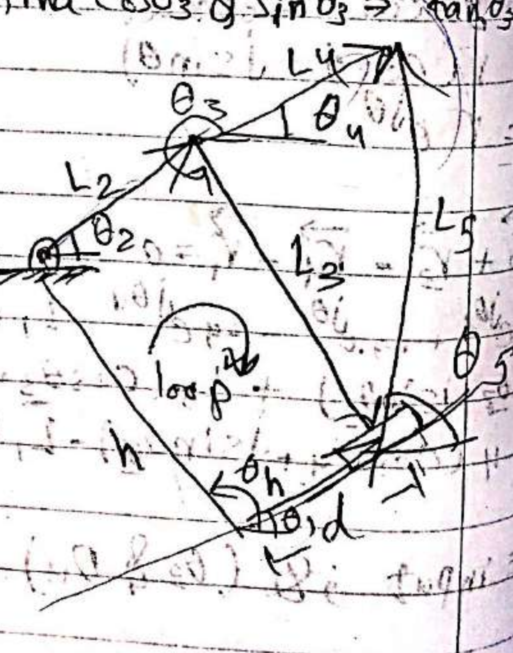
أخذ القيمة الموجبة

Substitute in (1)&(2) then take $\tan\theta_3$ (find $\cos\theta_3$ & $\sin\theta_3$ then $\tan\theta_3$)

$$L_2 e^{j\theta_2} + L_3 e^{j\theta_3} - d e^{j\theta_1} + h e^{j\theta_h} = 0 < \begin{matrix} F(1) \\ F(2) \end{matrix}$$

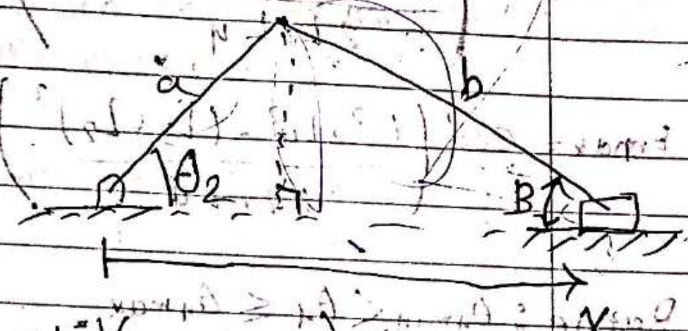
$$L_4 e^{j\theta_4} - L_5 e^{j\theta_5} - L_3 e^{j\theta_3} = 0 < \begin{matrix} F(3) \\ F(4) \end{matrix}$$

$x_1 = \theta_3 \quad x_2 = d \quad x_3 = \theta_4 \quad x_4 = \theta_5$



Slider Crank Mechanism Position Analysis Using Graphical Method:

given θ_2 find X?



$X = a\cos\theta_2 + b\cos B$

$a\sin\theta_2 = b\sin B$

$\sin B = \frac{a\sin\theta_2}{b}$

$(\sin B)^2 = \left(\frac{a\sin\theta_2}{b}\right)^2$ OR $B = \sin^{-1}\left(\frac{a\sin\theta_2}{b}\right)$ لانه $\sin^{-1}$ معرف عالاول والرابع

$1-(\cos B)^2 = \left(\frac{a\sin\theta_2}{b}\right)^2$

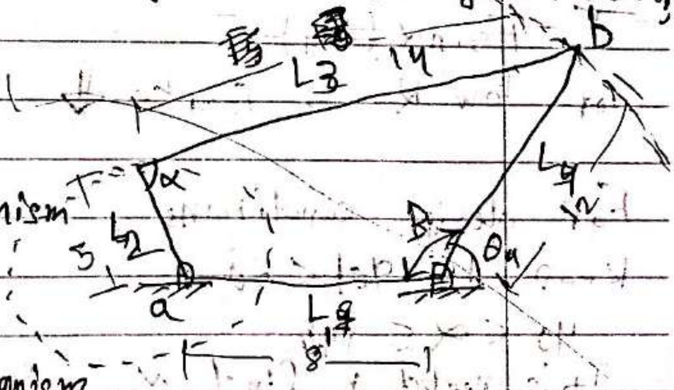
بقدر استخدم قانون الجيب لأنه ما متعلق مع الزاوية المنفرجة

$\cos B = \sqrt{1-\left(\frac{a\sin\theta_2}{b}\right)^2}$

$X = a\cos\theta_2 + b\sqrt{1-\left(\frac{a\sin\theta_2}{b}\right)^2}$

Four Bar Mechanism: Dead Point Configurations (Range of Motion)

given $L_1, L_2, L_3, L_4 \Rightarrow$ find range of motion of Link 4



Sol: Typed of the four bar Mechanism

Does $S+L < p+q$?

$5+14 \overset{?}{<} 8+12$

$19 < 20$ ✓ $\Rightarrow$ Grashof's mechanism

Shortest link is one of the side links $\Rightarrow$ crank Rocker

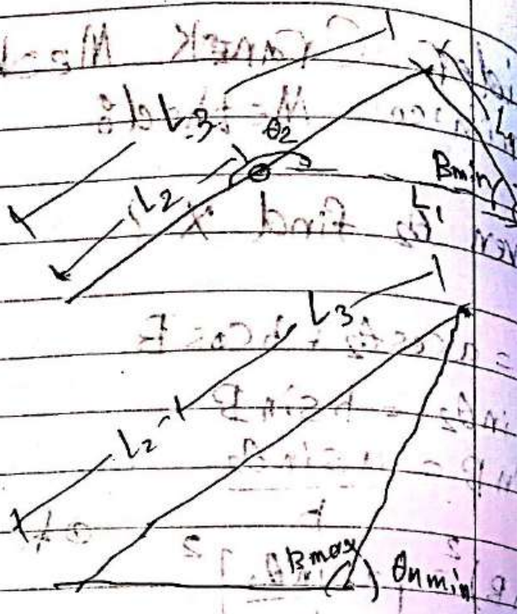
θ_4 is minimum when B is maximum, B is maximum when the distance between a & b is maximum, $\Rightarrow$ when $\alpha = 180°$

the same with (θ_4) ~~minim~~ maximum $\Rightarrow \alpha = 0$

$\theta_{4\,max} = 180 - B_{min}$

$(L_3 - L_2)^2 = L_1^2 + L_4^2 - 2L_1L_4 \cos B_{min}$

$B_{min} = \cos^{-1}\left(\frac{L_1^2 + L_4^2 - (L_3 - L_2)^2}{2L_1L_4}\right)$



$B_{max} = \cos^{-1}\left(\frac{L_1^2 + L_4^2 - (L_3 + L_2)^2}{2L_1L_4}\right)$

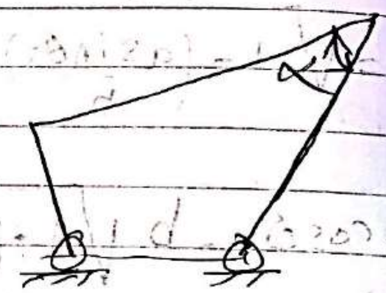
Range: $\theta_{4min} \le \theta_4 \le \theta_{4max}$

by sin law find θ_2

* Transmission Angle:

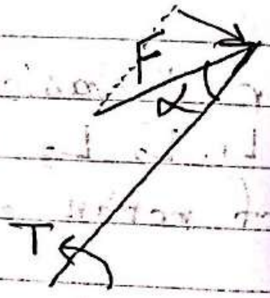
=> Only for crank Rocker

between the Coupler & the Rocker.



Motion is transmitted to link 4 (output) through the coupler. (force)

Coupler -> two force member



$T = F\sin\alpha\,(L_4)$

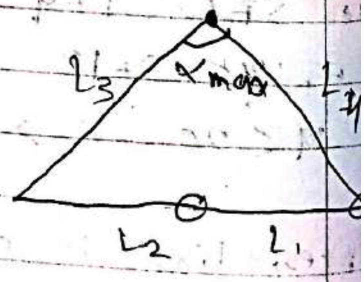
for low α => Tourke ↓

For design conditions

Keep $|\alpha - 90| \le 50°$

$40° \le \alpha \le 140$

=> It is needed to find α_{min} & α_{max}



$\alpha_{max} = \cos^{-1}\left(\frac{L_4^2 + L_3^2 - (L_1 + L_2)^2}{2L_3L_4}\right)$

$\alpha_{min} = \cos^{-1}\left(\frac{L_4^2 + L_3^2 - (L_1 - L_2)^2}{2L_3L_4}\right)$

* Quick Return Mechanism:

Input motor works at a constant angular velocity. ω_2 = Constant
In some applications cutting speed in working stroke is limited, however the speed in the return stroke can be increased using quick return mechanism

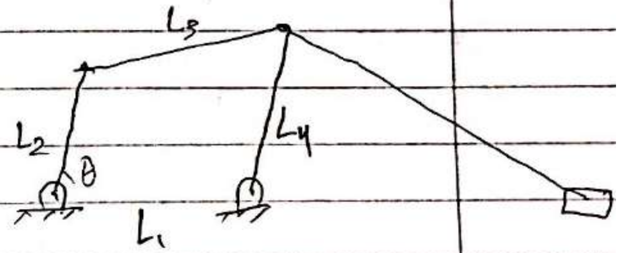
$$\text{Time Ratio } (T.R) = \frac{\text{Time of working stroke}}{\text{Time of Return Stroke}} > 1$$

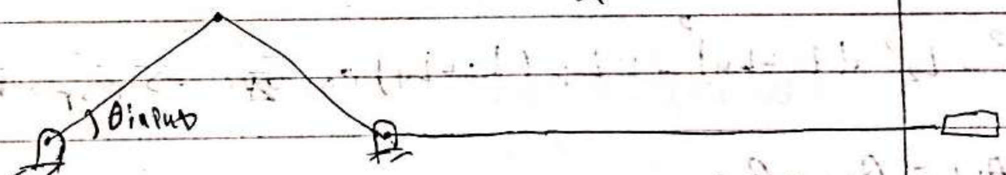
θ_{2L}: angle of input crank when the slider is at extreme left position
θ_{2R}: " " " " " " " " " " Right "

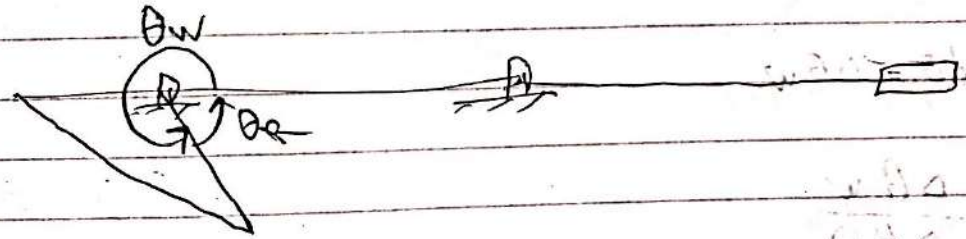
الزمن البطيء هو working عشان بالعكس منكسرش الخشبة مع السرعة

$$\underset{\text{Constant}}{\omega} = \frac{\Delta\theta}{\Delta t} = \frac{\Delta\theta_W}{\Delta t_W} = \frac{\Delta\theta_R}{\Delta t_R}$$

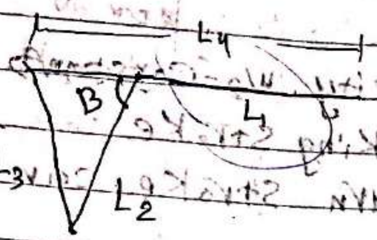
$$T.R = \frac{\Delta t_W}{\Delta t_R} = \frac{\Delta\theta_W/\omega}{\Delta\theta_R/\omega} = \boxed{\frac{\Delta\theta_W}{\Delta\theta_R}}$$

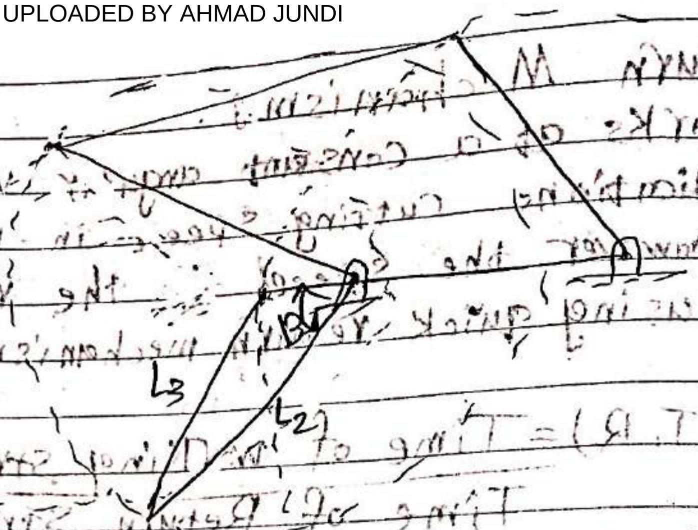






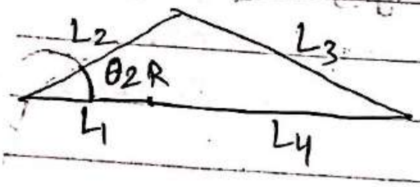
① Drag Link Mechanism.

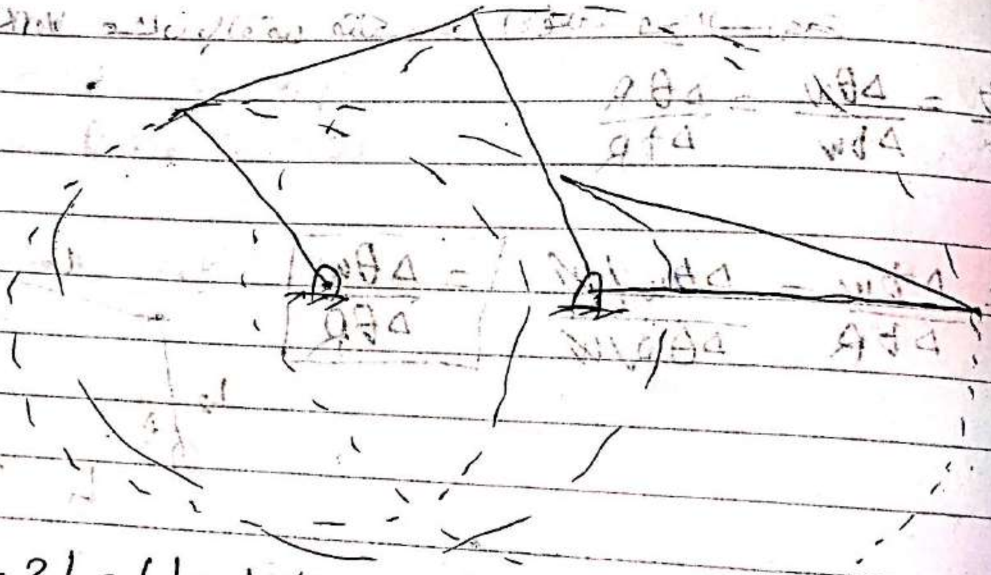




$$L_3^2 = L_1^2 + (L_4 - L_1)^2 - 2L_1(L_4 - L_1)\cos B$$

$$B = \checkmark \Rightarrow \theta_{2L} = 180 + B$$





$$L_3^2 = L_2^2 + (L_1 + L_4)^2 - 2L_2(L_1 + L_4)\cos\theta_{2R} \Rightarrow \theta_{2r} = \checkmark$$

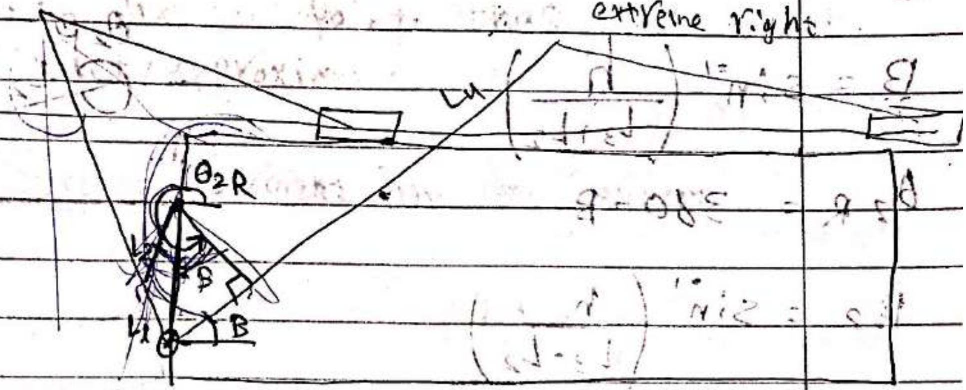
$$\Delta\theta_W = \theta_{2L} - \theta_{2R}$$

$$\Delta\theta_R = 360 - \Delta\theta_W$$

$$T.R = \frac{\Delta\theta_W}{\Delta\theta_R}$$

Stroke $= 2a$

② Crank Shaper Mechanism



$B = \cos^{-1}\left(\frac{L_2}{L_1}\right)$

$\theta_{2R} = 270 + B$

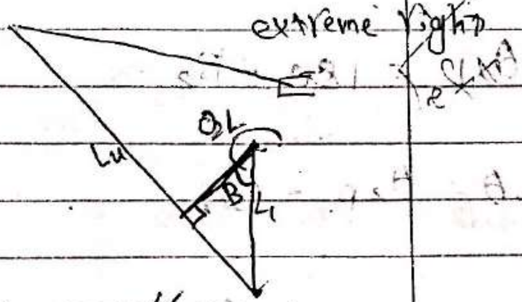
$\theta_{2L} = 270 - B$

$\Delta\theta_R = 2B$

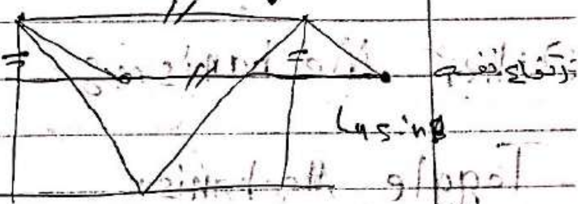
$\Delta\theta_W = 360 - 2B$

$T.R. = \frac{\Delta\theta_W}{\Delta\theta_R}$

Stroke $= 2L_4 \cos B$



متوازي اضلاع

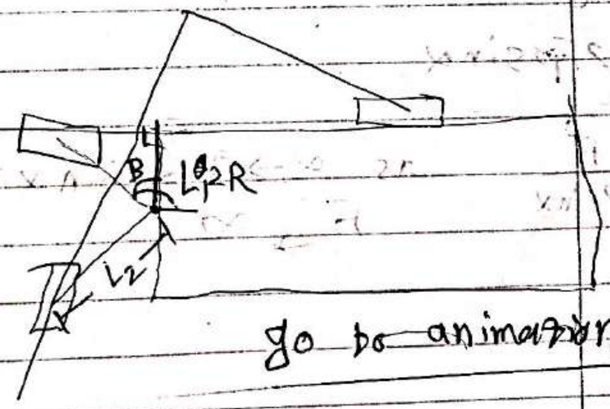


③ whitworth mechanism

$L_2 > L_1$

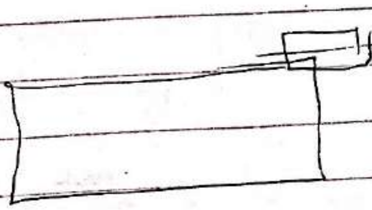
$B = \cos^{-1}\left(\frac{L_1}{L_2}\right)$

$T.R = \frac{360 - 2B}{2B}$



go to animation

Stroke $= 2a$



④ offset silider Mechanism

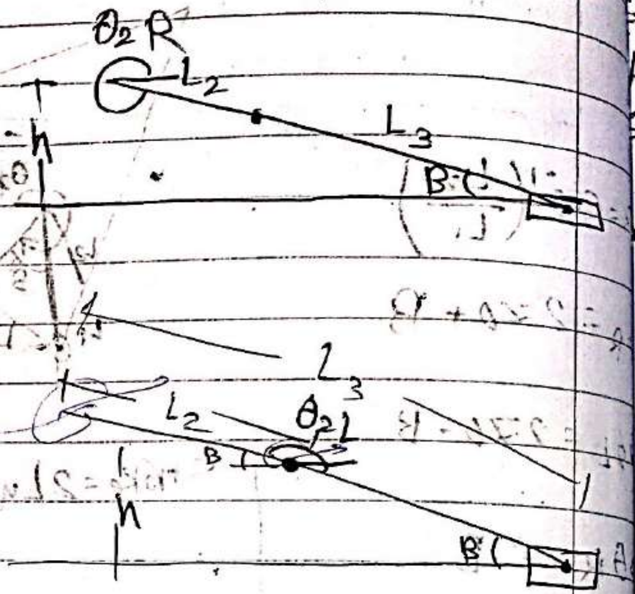
$$B = \sin^{-1}\left(\frac{h}{L_3+L_2}\right)$$

$$\theta_{2R} = 360 - B$$

$$B_2 = \sin^{-1}\left(\frac{h}{L_3-L_2}\right)$$

$$\theta_{2L} = 180 - B_2$$

$$\Delta\theta = \theta_{2R} - \theta_{2L}$$



if $\Delta\theta > 180$ ...

if $\Delta\theta < 180$ ...

Other Mechanism:

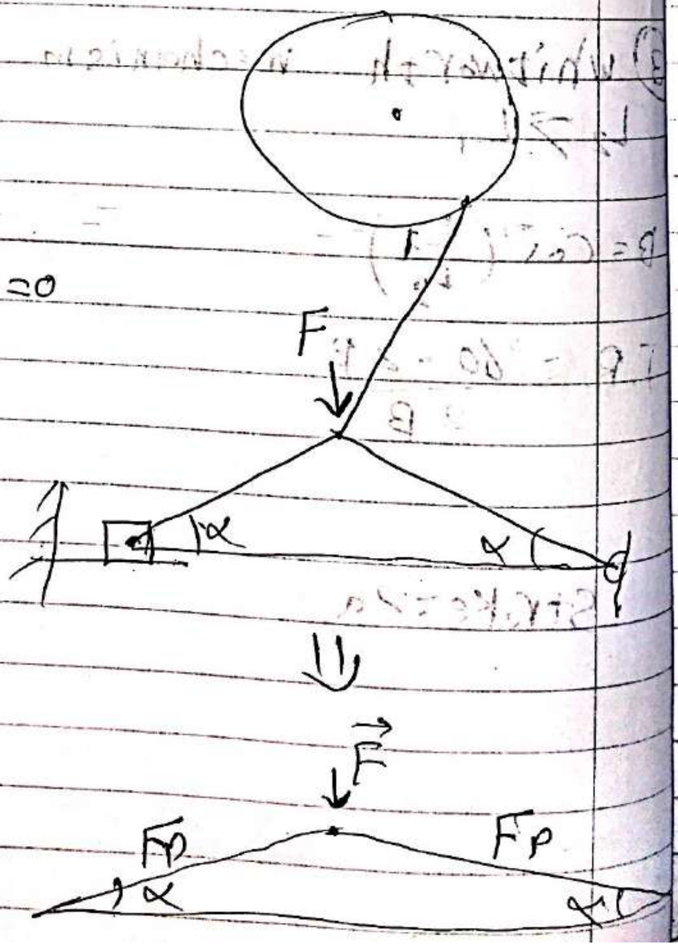
- Toggle Mechanism

$$\Sigma F_y = 0$$

$$F = 2F_p \sin\alpha$$

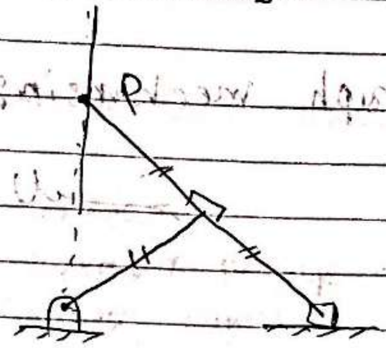
$$F_p = \frac{F}{2\sin\alpha} \quad \text{as } \alpha \to 0 \Rightarrow \sin\alpha = 0$$

$$F \to \infty$$

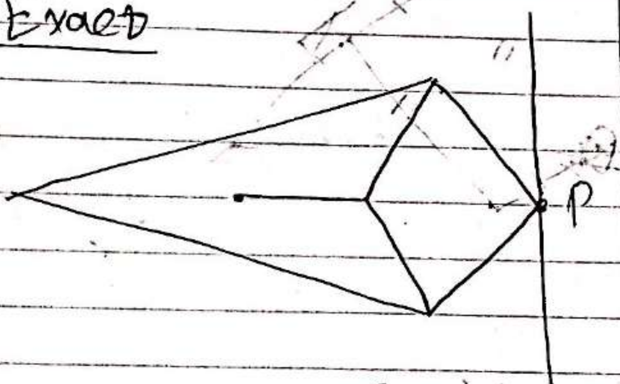


* Straight Line Mechanism:
A a mechanism that has a point that moves in a straight line line (exact/approximate)

* Scott Russol : Exact Straight line mechanism

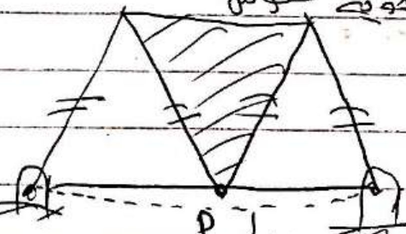


* Peaucellier's Mechanism: Exact



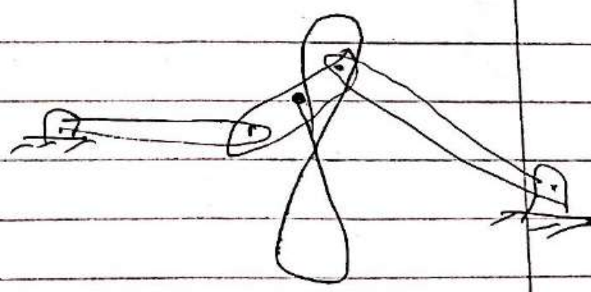
* Robert's mechanism: Approximate

Exact: خط مستقيم تماما
app: فيه تقوس



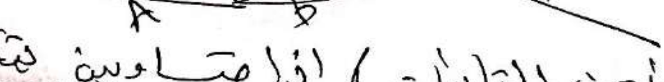
الاطوال متساوية شرط لخط مستقيم

* WATT : Approximate



مش شرط يكونوا متساويات

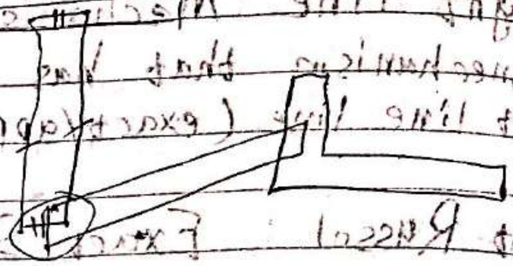
$\frac{A}{B} = \frac{a}{b}$



نسبة النقطة للقطعة = نسبة اطوال الضلعين الثابتات / اذا متساويين يكونوا بالنص
يختلف عليك كمي

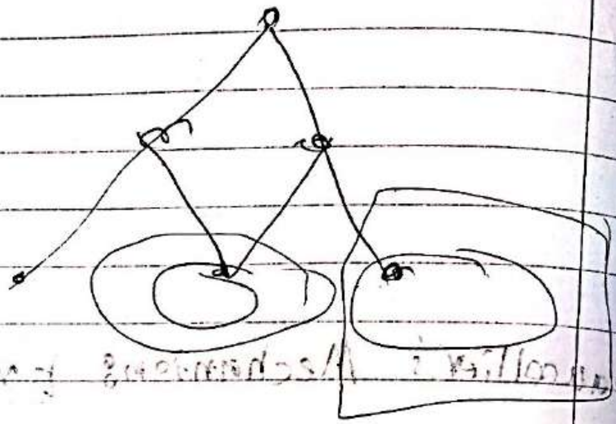
Parallel Mechanism

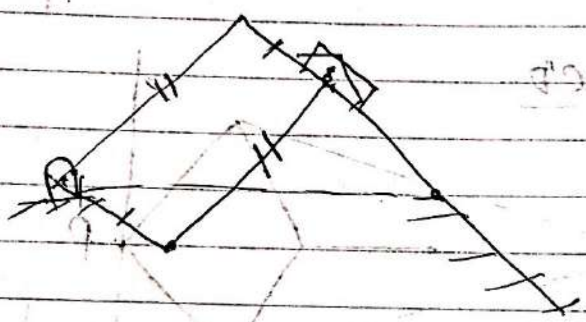
[illegible] orientation [illegible]



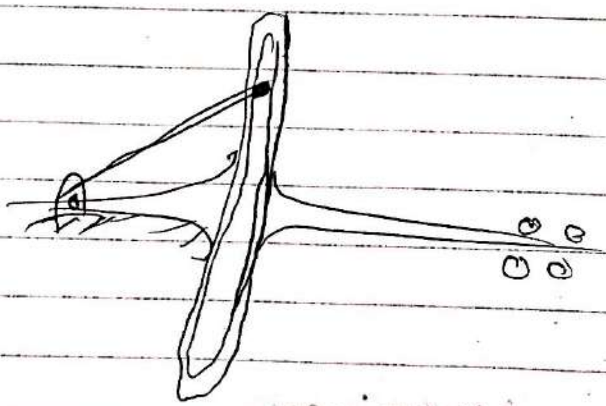
Pantograph mechanism:

النسخ

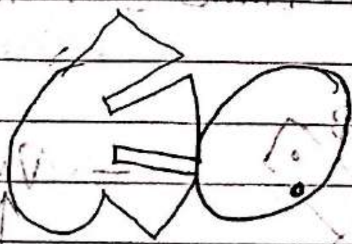




Scott Yoke:



geneba mechanism

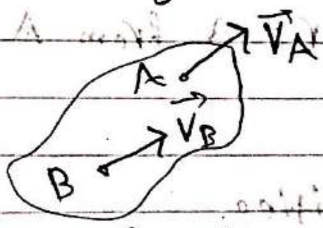


Chapter 2: Velocity and Acceleration Analysis

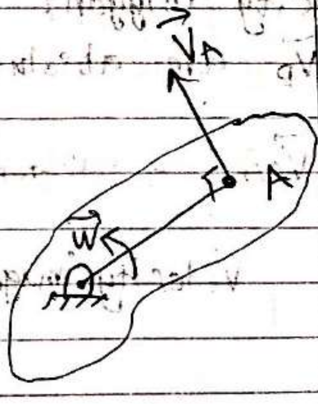
* Velocity Analysis:
① Velocity polygons → Acceleration ① acceleration polygons
② Instant centers ② complex number
③ Complex numbers

① Velocity Polygons:
* Types of motion of Rigid body in plane:
① Translation

$\vec{V}_B = \vec{V}_A$
$\vec{w} = 0$



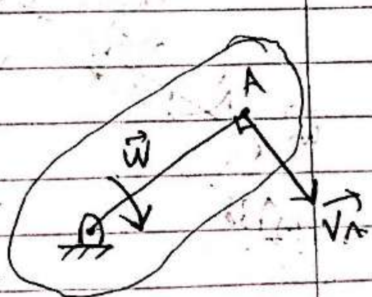
② Rotation about a fixed axis:



$\vec{V}_A = \vec{w} \times \vec{r}_{A/O}$

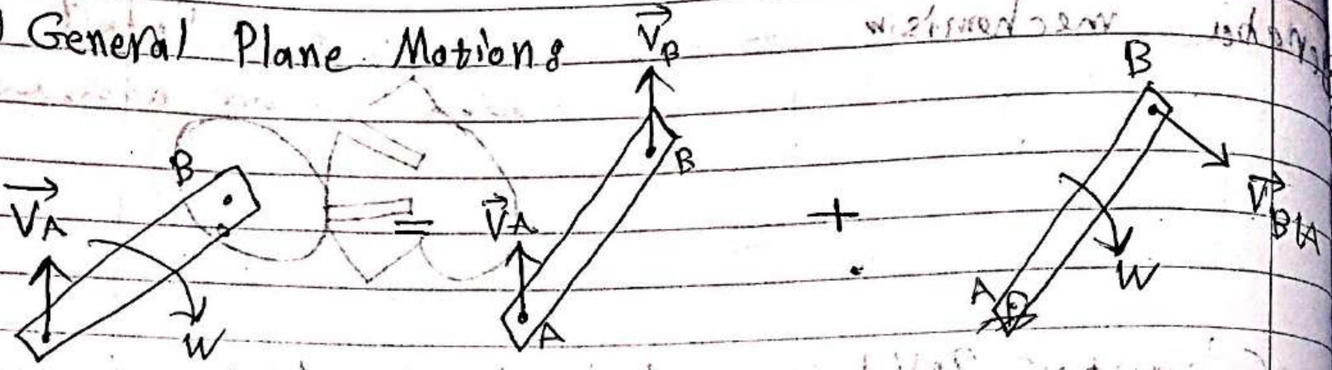
$\vec{r}_{A/B}$ = Position vector of point A relation to O "from O to A"

$\vec{V}_A \perp \vec{w}$
$\vec{V}_A \perp \vec{r}_{A/O}$
$\vec{V}_A$ "in the direction of $\vec{w}$ (rotation)"



$V_A = w\, r_{A/O}$ magnitude

③ General Plane Motions



General plane motion translation as "A" Rotation about A (Relative

$\vec{V}_{B/A} = \vec{V}_B - \vec{V}_A$

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

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

$\vec{V}_{B/A} \perp \vec{r}_{B/A}$ & $\vec{W}$.

$\vec{V}_{B/A}$ "in the direction of $\vec{W}$" rotation sense

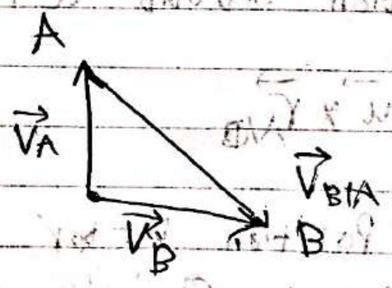
$\vec{r}_{B/A} \equiv$ Position vector of B w.r.t A from A to B

* Velocity polygons:

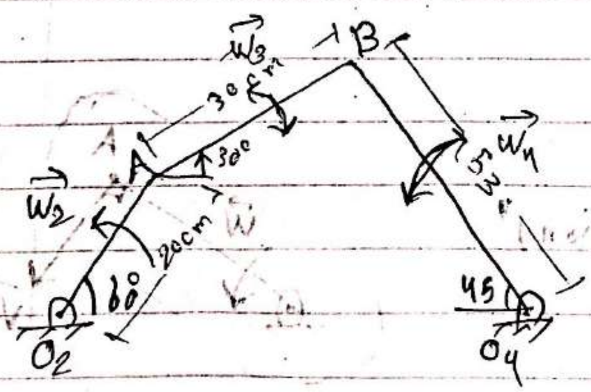
$\vec{V}_A$ & $\vec{V}_B$ are absolute velocities.

$\vec{V}_A = \vec{V}_{A/O}$ ⇒ Vector from 'O' to 'A'

Velocity image of link AB



Ex:

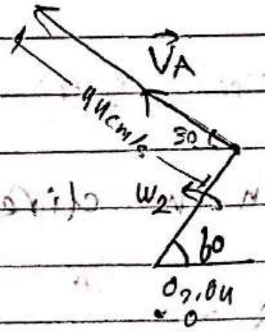


given $W_2 = 2$ rad/s in the direction shown ~~fixed~~ find: $\vec{W}_4$ & $\vec{W}_3$

Start with Known link:

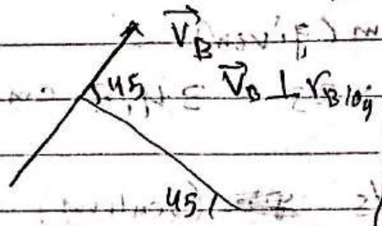
$\vec{V}_A = \vec{w}_c \times \vec{r}_{A/O_2} + \vec{V}_{O_2}$ } link 2

$V_A = (2)(22) = 44\ cm/s$



$\vec{V}_B = \vec{w}_4 \times \vec{r}_{B/O}$ } link 4

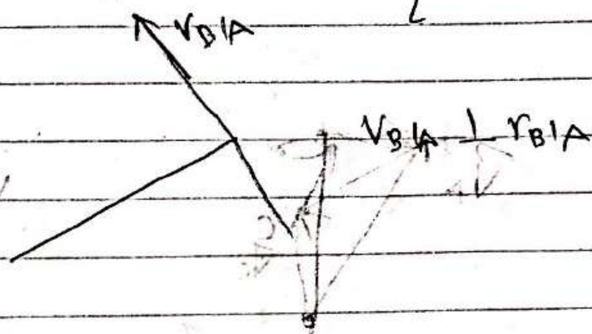
$\vec{V}_B \perp \vec{r}_{B/O_4}$



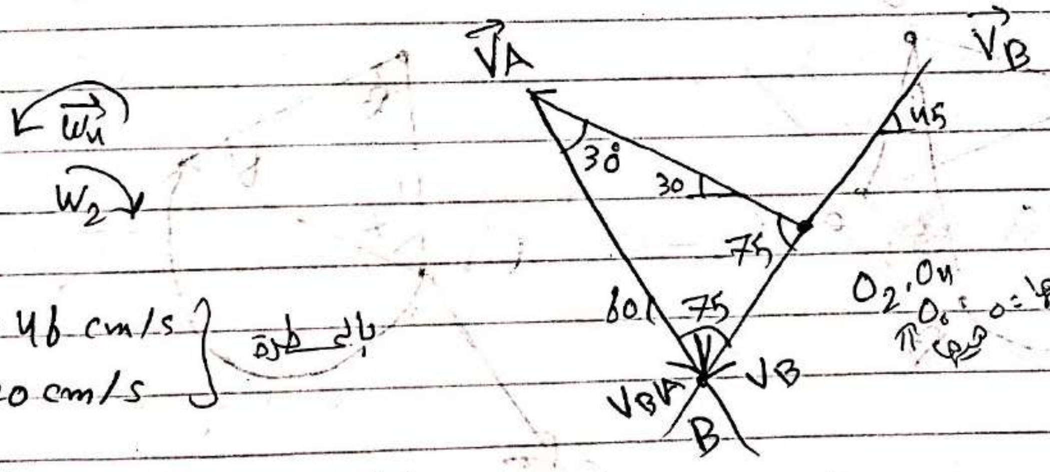
$\vec{V}_B \perp r_{B/O_4}$ } to satisfy $\vec{V}_{B/A} = \vec{w}_3 \times \vec{r}_{B/A}$ B & A must be on the same link

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

$\vec{V}_{B/A} = \vec{w}_3 \times \vec{r}_{B/A}$



Velocity image:



كل نقطة V الها = 0 فرضها

$\vec{V}_{B/A} = 46\ cm/s$ } بالمسطرة

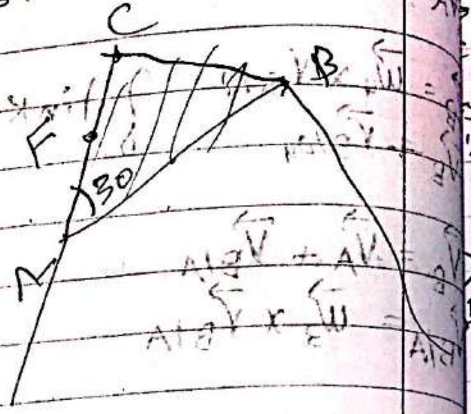
$V_B = 20\ cm/s$

$w_4 = \dfrac{V_B}{r_{B/O_4}} = \dfrac{20}{53}$ rad/s counter clock wise

$w_3 = \dfrac{V_{B/A}}{r_{B/A}} = \dfrac{46}{30}$ rad/s clock wise

$\vec{V_C} = \vec{V_A} + \vec{V_{C/A}}$

$\vec{V_{C/A}} \perp \vec{r_{C/A}}$ in the direction of $\vec{\omega_3}$

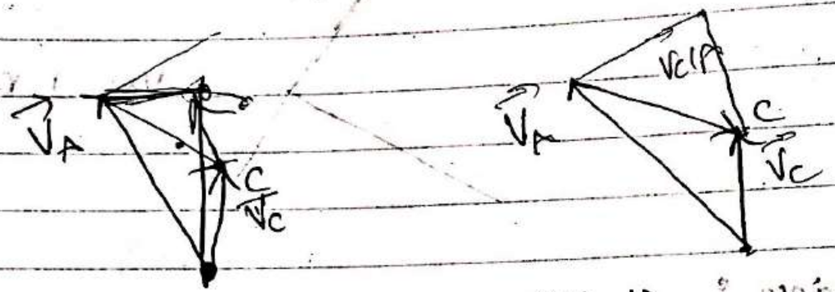


$\vec{V_{C/A}} = \omega_3 \ \vec{r_{C/A}}$

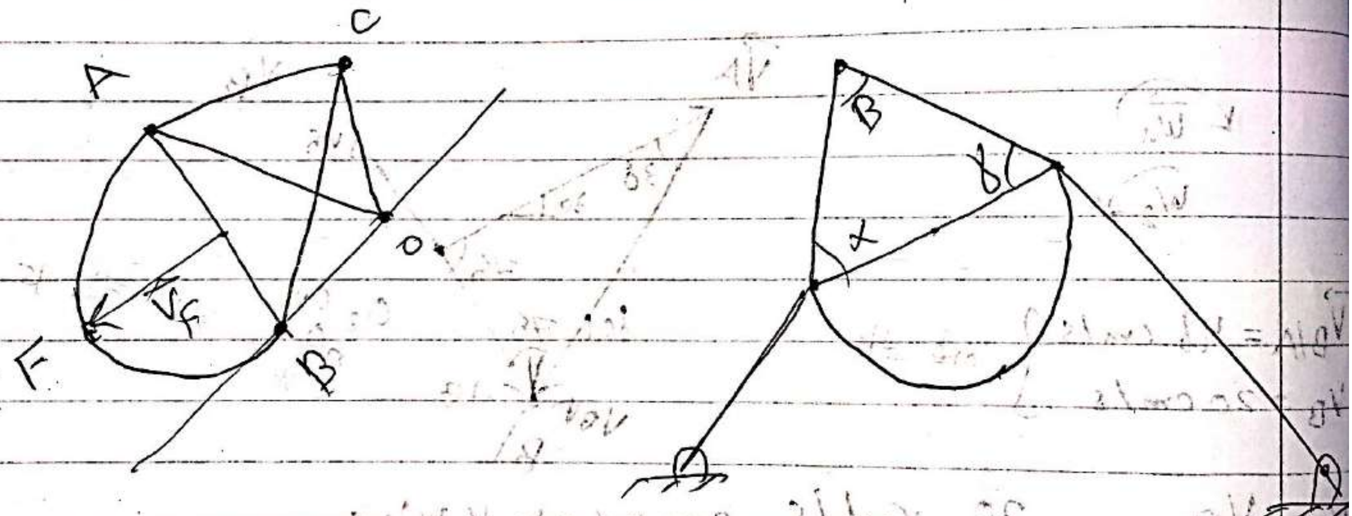
$r_{C/A} = 23 \text{ cm (given)}$

$V_{C/A} = 1.5 \times 23 = 34.5 \text{ cm/s}$

$V_C = 15 \text{ cm/s}$ (scaling)



بالاعتماد على أن قيم رسم المثلث

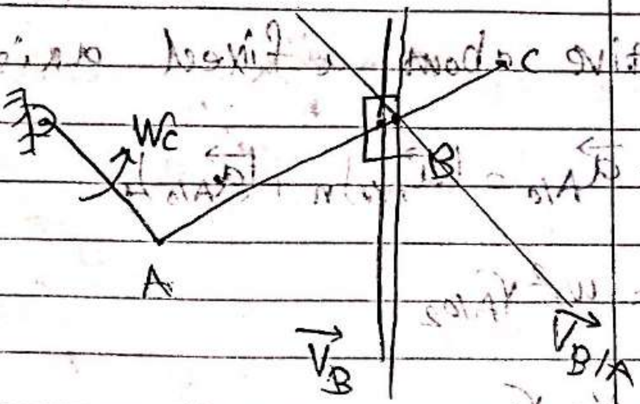


~~Relative Motion on the same link:~~

$\vec{V}_C = \vec{V}_A + \vec{V}_{C/A}$

مجهول قيمة واتجاه V_C مجهول قيمة $V_{C/A}$

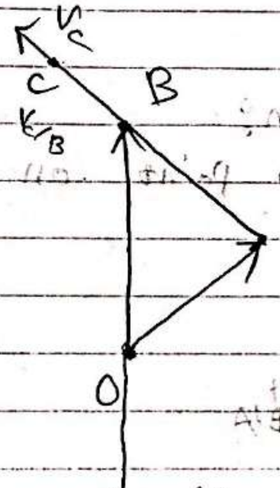
ومعلوم بتقدر تحل



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

مجهول فقط قيمة V_B , $V_{B/A}$ بتقدر تطلع

$$\frac{V_{C/B}}{V_{C/A}} = \frac{r_{C/B}}{r_{C/A}}$$ نسبة وتناسب

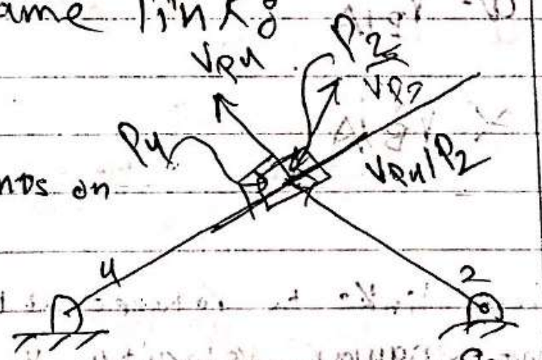


$$\frac{V_{C/B}}{V_{A/B}} = \frac{r_{C/B}}{r_{A/B}}, \quad \frac{V_{C/B}}{r_{C/B}} = \frac{V_{A/B}}{r_{A/B}} = \omega_3$$

Relative Motion on the same link:

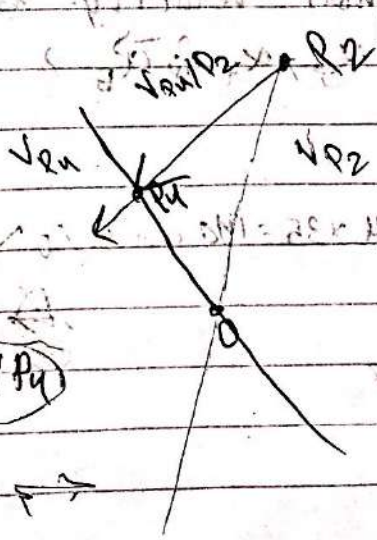
$\vec{V}_{P_2/P_4} = \vec{V}_{P_2} - \vec{V}_{P_4}$

$\vec{V}_{P_4/P_2} = \vec{V}_{P_4} - \vec{V}_{P_2} = -V_{P_2/P_4}$ } assume two coincident points on both links



$\vec{V}_{P_4} = \vec{V}_{P_2} + \vec{V}_{P_4/P_2}$

$V_{P_2} = \omega_2 \times r_{P_2/O_2} = 1 \times 50 = 50 \text{ mm/s}$



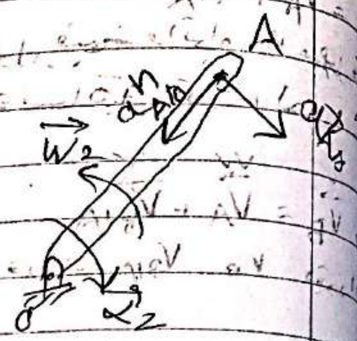
حركة P_2 بالنسبة الى نقطة على الـ link 4 straight line

$$\vec{a}_{P_2} = \vec{a}_{P_4} + (\vec{a}_{P_2/P_4})_{rel} + 2\vec{\omega}_4 \times V_{P_2/P_4}$$

جسم بتحرك بالنسبة لجسم بدور

Relative Motion: Analysis Acceleration using Polygon

Relative about a fixed axis:

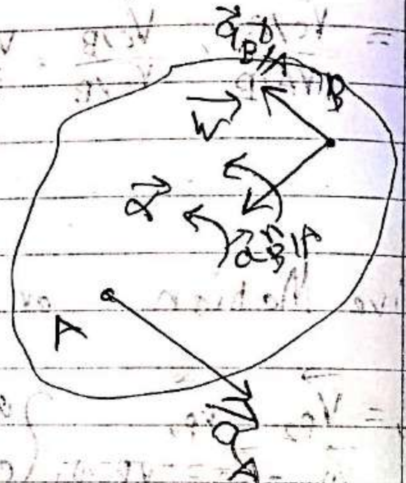


$\vec{a}_A = \vec{a}_{A/o} = (\vec{a}_{A/o})_n + (\vec{a}_{A/o})_t$

$a^n_{A/o} = w_2^2 r_{A/o_2}$

$a^t_{A/o} = \alpha_2 r_{A/o_2}$

General Motion:
A & B are two points on the same rigid link



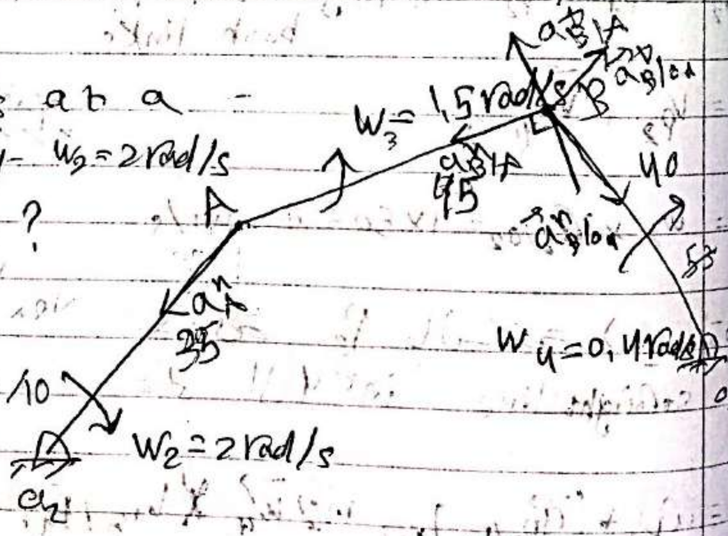
$\vec{a}_B = \vec{a}_A + \vec{a}_{B/A}$

$\vec{a}_{B/A} = \vec{a}^n_{B/A} + \vec{a}^t_{B/A}$

$a^n_{B/A} = w^2 r_{B/A}$

$a^t_{B/A} = \alpha r_{B/A}$

Ex: given links to rotates at a constant angular velocity $w_2 = 2$ rad/s shown, determine α_3, α_4 & $\vec{a}_B$?



$\alpha_2 = 0$

$\vec{a}_A = \vec{a}^n_A + \vec{a}^t_A$

$a^n_A = w_2^2 r_{A/o_2} = 4 \times 35 = 140$ cm²/s /10

$a^t_A = 0 = \alpha_2 r_{A/o_2}$

لما يكون عندي جسم يدور وفي جسم ثاني يتحرك بكون في عندي Coraleos acc.
لما ادور واحد شوف جسم يتحرك لا

$\vec{a}_B = \vec{a}_A + \vec{a}^n_{B/A} + \vec{a}^t_{B/A}$ $\vec{a}_{B/A}$

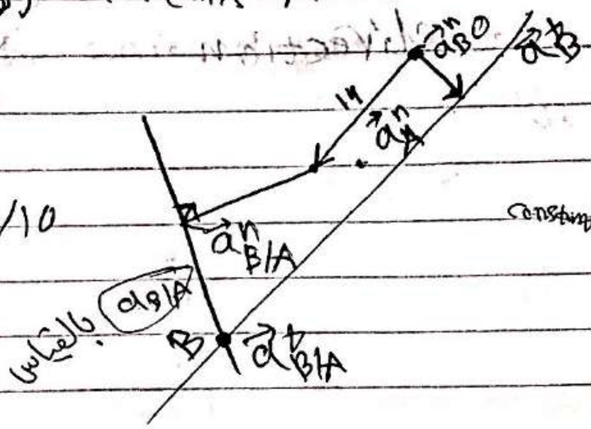
$a^n_{B/A} = w_3^2 \, r_{B/A} = (1.5)^2 (4.5) = 10.1 \, cm/s^2 / 10$

$\vec{a}_B = \vec{a}^n_B + \vec{a}^t_B$

$\vec{a}^n_B = w_4^2 \, r_{B/O_4}$

$= (0.4)^2 \times 40 = 6.4 / 10$

$\alpha_3 = \dfrac{a_{B/A}}{r_{B/A}}$



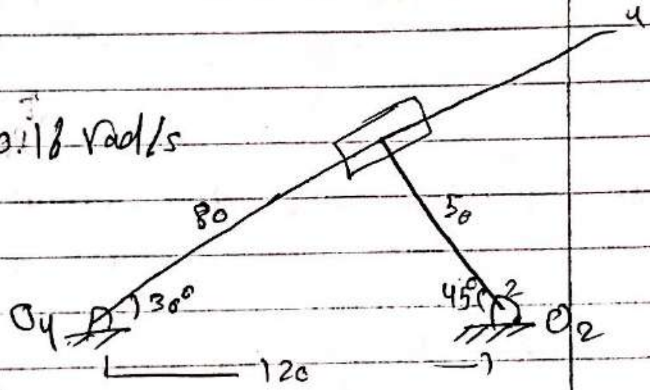
constant نحن طول الضلع ثابت يعطيني

Ex:

$w_4 = V_{P_4} / r_{P_4/O_4} = \dfrac{13}{80} = 0.18 \, rad/s$

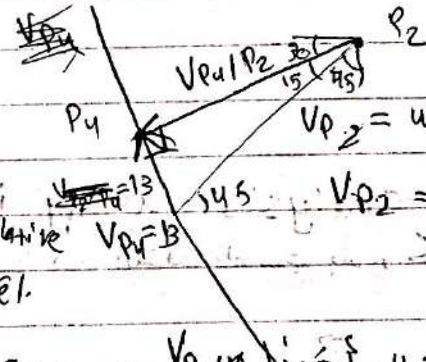
$a^n_{P_4} = w_4^2 \, r_{P_4/O_4}$

$a^n_{P_4} = 2.1 \, mm/s^2$



$a^n_{P_2} = w_2^2 \, r_{P_2/O_2} = 1^2 \times 50 = 50 \, mm/s^2$

$a^t_{P_2} = \alpha_t \cdot r_{P_2/O_2} = \underset{given}{0} \quad V_{P_2/O_2} = 0$



$a^n_{P_2} + a^t_{P_2} - 2 w_4 \times V_{P_2/P_4} = a^n_{P_4} + a^t_{P_4} + (a_{P_2/P_4})_{relative}$

$a^n_{P_2} + a^t_{P_2} + 2 w_4 \times V_{P_4/P_2} = a^n_{P_4} + a^t_{P_4} + (a_{P_2/P_4})_{rel}$

في هذا السؤال أخذنا V_{P_2/P_4} و a_{P_2/P_4} لأنه P_2 يتحرك بخط مستقيم بالنسبة لـ P_4 أما P_4 يتحرك بمنحنى بالنسبة لـ P_2 الأسهل ، $(a_{P_2/P_4})_{rel}$ باتجاه الخط
أما لو كان عندي بالمعادلة a_{P_2/P_4} بيصير منحنى و بقسمها لمركبتين
$a^n_{P_2/P_4} = \dfrac{(V^2_{P_2/P_4})_{rel}}{\rho}$ هيها معلومة ، وبضل عندي $a^t_{P_2/P_4}$ مجهول ،

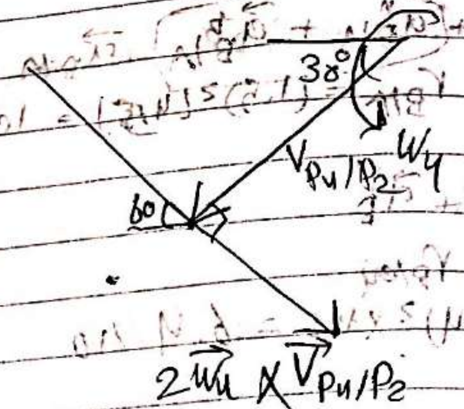
$|2 w_4 \times V_{P_4/P_2}| = 2 \times 0.18 \times 48.3 = 15.5$ magnitude

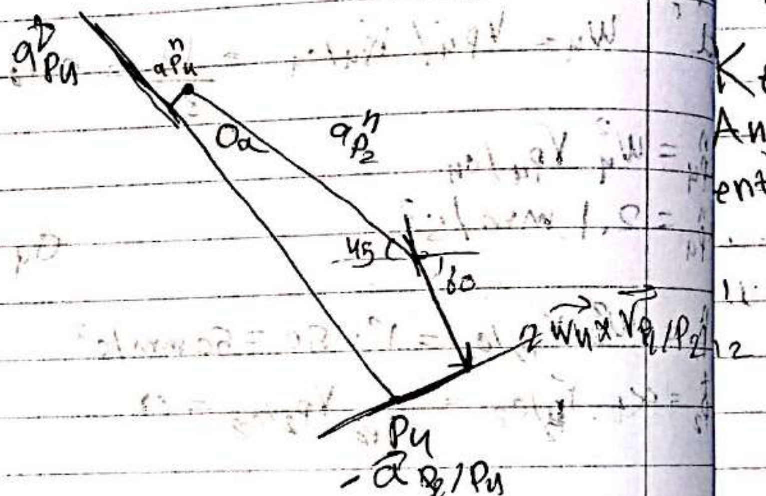
$V = W \times r$ perpendicular to r with direction to W Example

$2W \times V_{relative}$: direction $\perp$ to the track.

$a_{relative}$: = with = =

direction





Velocity analysis using instantaneous Center:

النقطة سرعتها صفر عند هديك اللحظة بحيث انه النقطة التانية بتدور حولها.

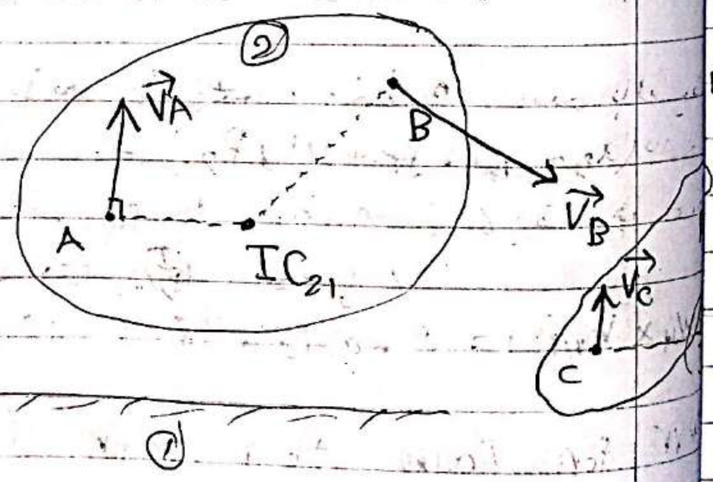
$\vec{V}_{IC_{12}} = 0$

$\vec{V}_B = \vec{V}_{IC_{12}} + \vec{V}_{B/IC_{12}}$

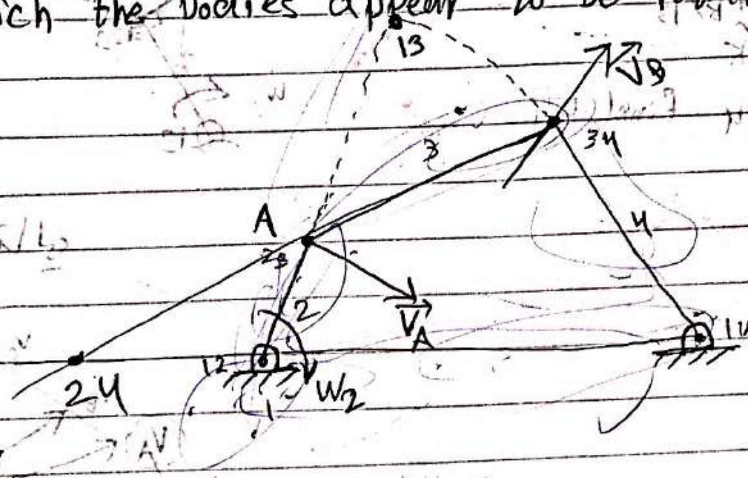
$\vec{V}_B = 0 + \vec{V}_{B/IC_{12}}$

$\vec{V}_{B/IC_{12}} = \vec{W}_2 \times \vec{r}_{B/IC_{12}}$

$V_{B/IC_{12}} = W_2 \, r_{B/IC_{12}}$



IC ≡ ① A point in the plane at which the velocity is equal on both bodies.
② A point about which the bodies appear to be rotating relative to each other.



\# of $IC_s = \frac{n(n-1)}{2}$

\# $IC_s = \frac{4 \times 3}{2} = 6$

12 13 14
23 24 → how?
34

Kennedy's Theorem:
Any three bodies moving in plane have three relative instantaneous centers that lie on a straight line.

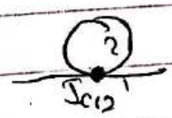
1 2 3
12 13 23 → on the straight line

1 3 4	2 3 4	1 2 4
13 14 34	23 34 24	12 24 14

$V_{24} = rw$ Known — Rotation about fixed axis ⇐ link 2 على 24 نقطة

24 — — link 4 ⇐ بدور حول 14

Primary IC:
① At pins
② At contact points, without slipping



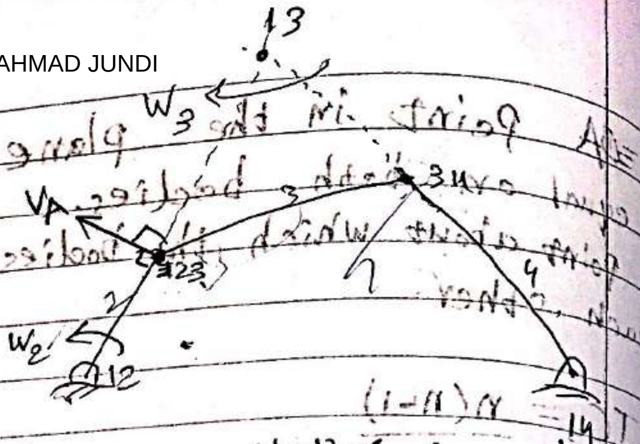
$\vec{V_A} = w_2 \, r_{A/12}$

$\vec{V_A} = w_3 \, r_{A/13}$ find w_3

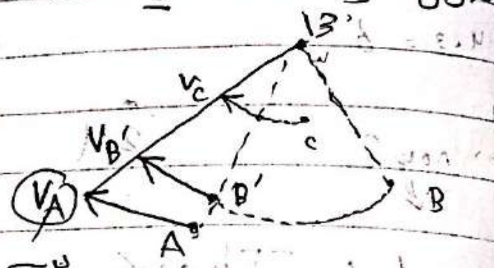
$\vec{V_B} = w_3 \, r_{B/13}$

$\vec{w_3} = -w_3 \hat{k}$

$V_B = w_4 \, r_{B/14}$ find w_4



نحل w_3 كالتالي

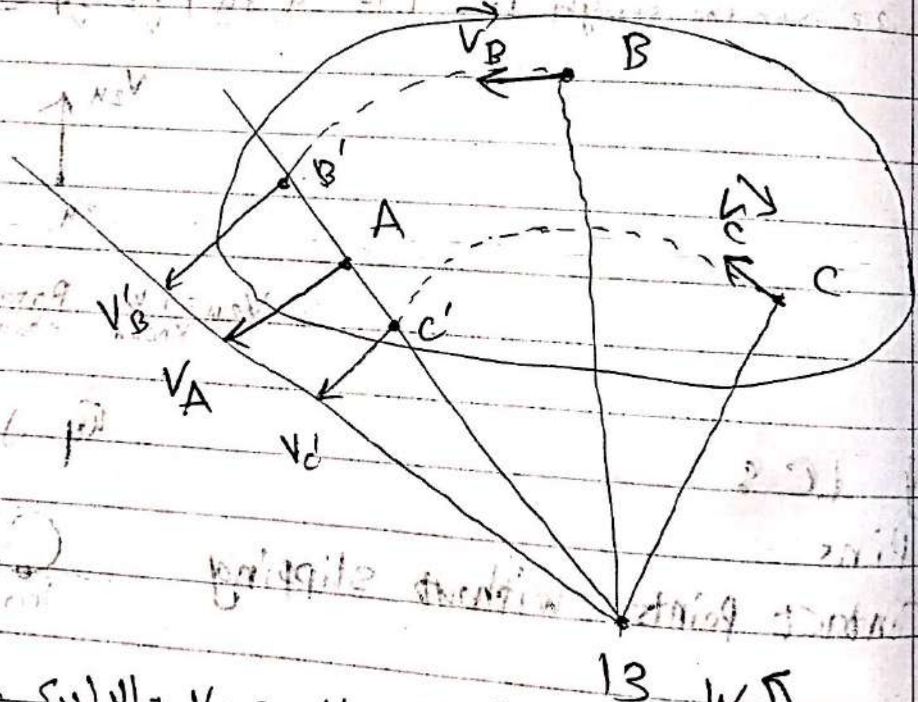


$V_A = w_2 r_{A/12}$ نرسم طولها حسب

تشابه المثلثات: $\frac{V_B'}{r_{B'/13}} = \frac{V_A}{r_{A/13}}$

ستخرجش الآلة الحاسبة

الأمر لإيجاد السرعة اي نقطة على الجسم 3.



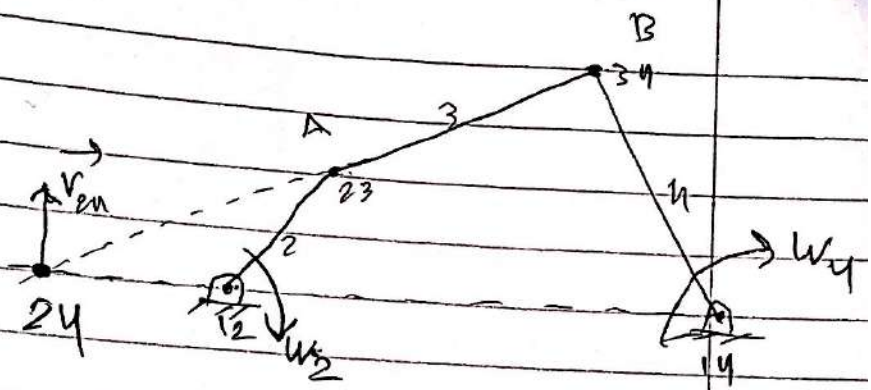
تشابه مثلثات بطول قيمة V_C و V_B والدايركشن بعرفه

$w_2 = 2 \text{ rad/s}$

بالقلم

$V_{24} = w_2 \, r_{24/12}$

$V_{24} = 2 \times 18 = 32 \text{ cm/s}$



$V_{24} = w_4 \, r_{24/14}$

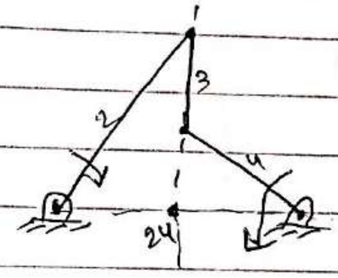
$w_4 = \frac{V_{24}}{r_{24/14}} = \frac{32}{80} = 0.375$

بالقلم

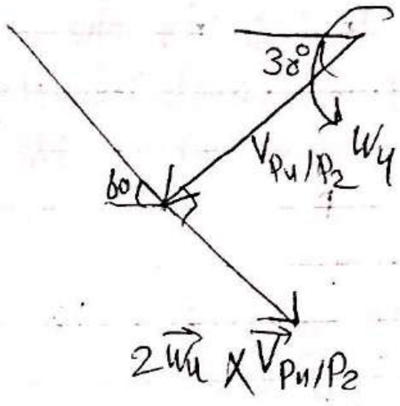
$V_{14/42} = (w_4 - w_2) \, V_{14/24}$

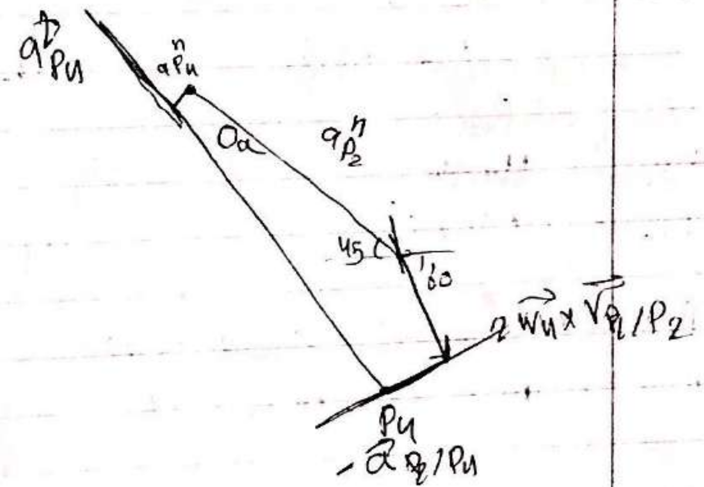
$V_{24/1\text{ink}4} = 0$

cr link 2



direction





Velocity analysis using Instantaneous Center :

IC: نقطة سرعتها صفر. عند هيكل اللحظة بحسب انه النقطة الثابتة بتدور حولها.

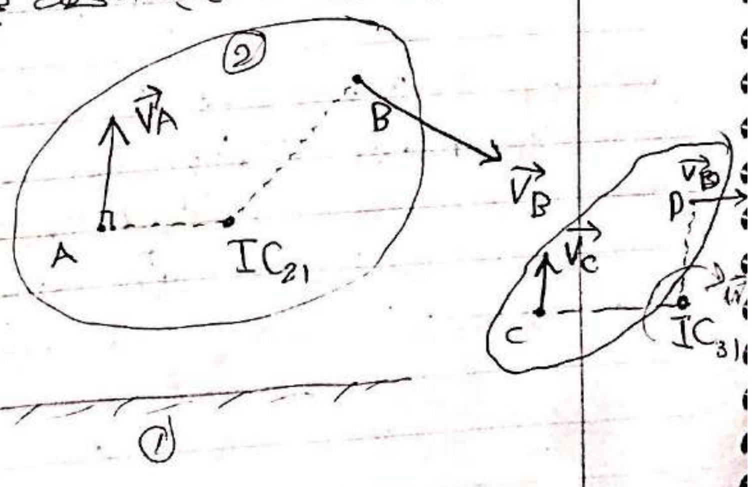
$\vec{V}_{IC_{12}} = 0$

$\vec{V}_B = \vec{V}_{IC_{12}} + \vec{V}_{B/IC_{12}}$

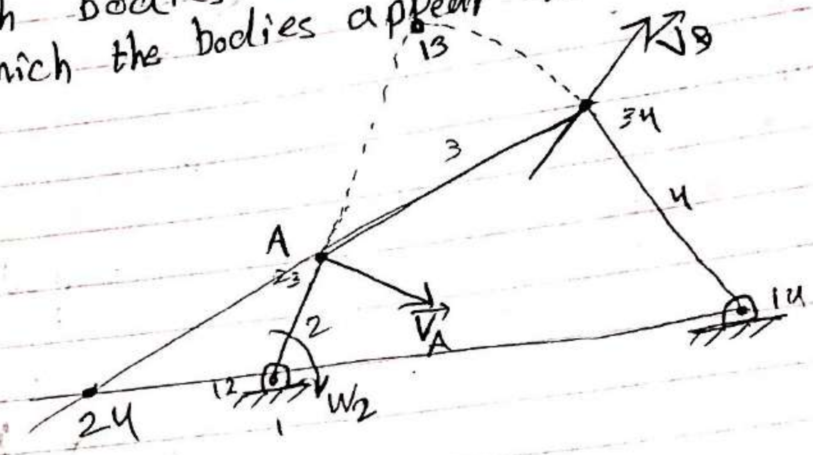
$\vec{V}_B = 0 + \vec{V}_{B/IC_{12}}$

$\vec{V}_{B/IC_{12}} = \vec{\omega}_2 \times \vec{r}_{B/IC_{12}}$

$V_{B/IC_{12}} = \omega_2 r_{B/IC_{12}}$



IC ≡ ① A point in the plane at which the velocity is equal on both bodies.
② A point about which the bodies appear to be rotating relative to each other.



$\# \text{ of } IC_s = \frac{n(n-1)}{2}$

$\# IC_s = \frac{4\times3}{2} = 6$

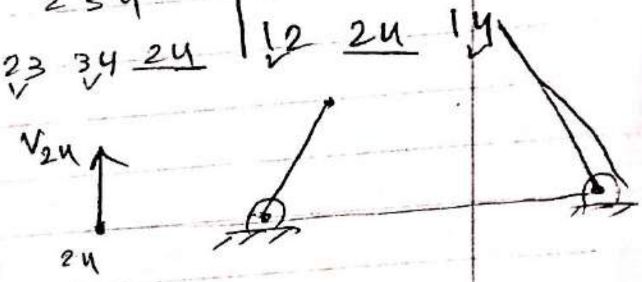
12 13 14
23 (24) → how?
34

Kennedy's Theorem:

Any three bodies moving in plane have three relative instantaneous centers that lie on a straight line.

1, 2, 3
12 13 23 → on the straight line

134	234	124
13 14 34	23 34 $\underline{24}$	12 $\underline{24}$ 14



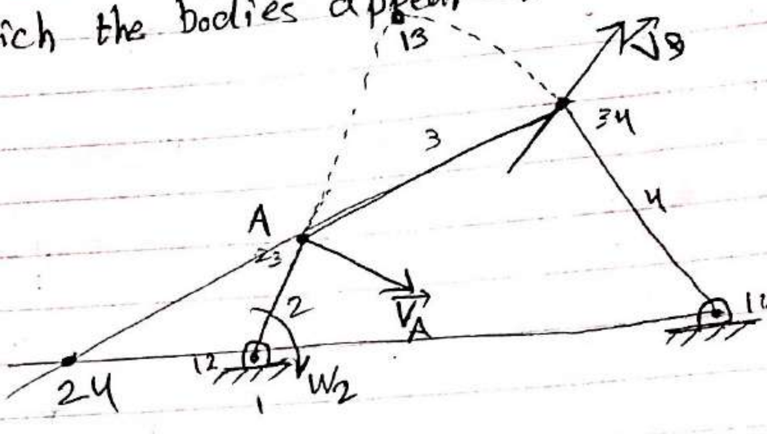
$V_{24} = r\omega$ Known   Rotation about fixed axis ⇐ link2 على نقطة 24

tiy بقول ⇐ link4 -- -- 24

Primary IC:

① At pins
② At contact points, without slipping

IC ≡ ① A point in the plane at which the velocity is equal on both bodies.
② A point about which the bodies appear to be rotating relative to each other.



$$\# \text{ of } IC_s = \frac{n(n-1)}{2}$$

$$\# IC_s = \frac{4 \times 3}{2} = 6$$

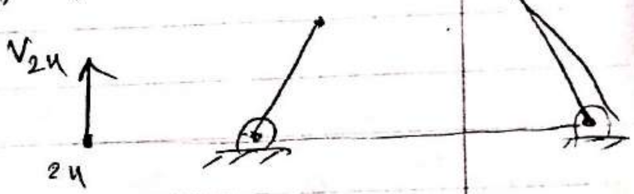
12 13 14
23 24 → how?
34

Kennedy's Theorem:

Any three bodies moving in plane have three relative instantaneous centers that lie on a straight line.

1, 2, 3
12 13 23 → on the straight line

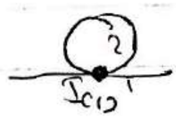
1 3 4	2 3 4	1 2 4
13 14 34	23 34 24	12 24 14



$V_{24} = r w$ Rotation about fixed axis ⇐ link2 لما تبع 24
known

Trig بحول ⇐ link4 = = 24

Primary IC:
① At pins
② At contact points, without slipping



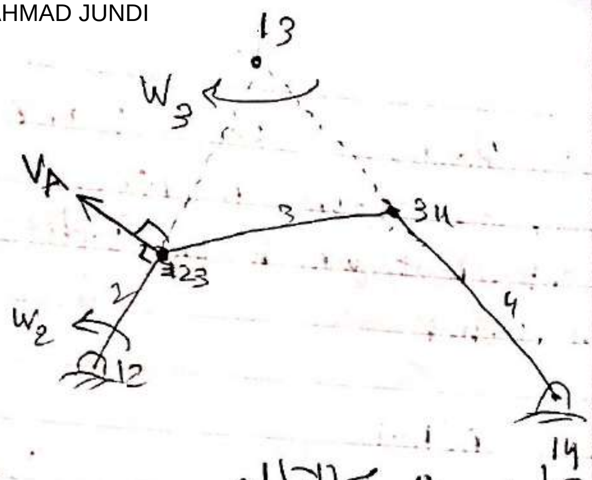
$\vec{V}_A = w_2 \, r_{A/12}$

$\vec{V}_A = w_3 \, r_{A/13}$ find w_3

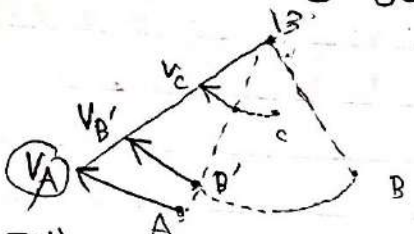
$\vec{V}_B = w_3 \, r_{B/13}$

$\vec{w}_3 = -w_3 \hat{k}$

$\vec{V}_B = w_4 \, r_{B/14}$ find w_4



ممكن أحول w_3 كالتالي

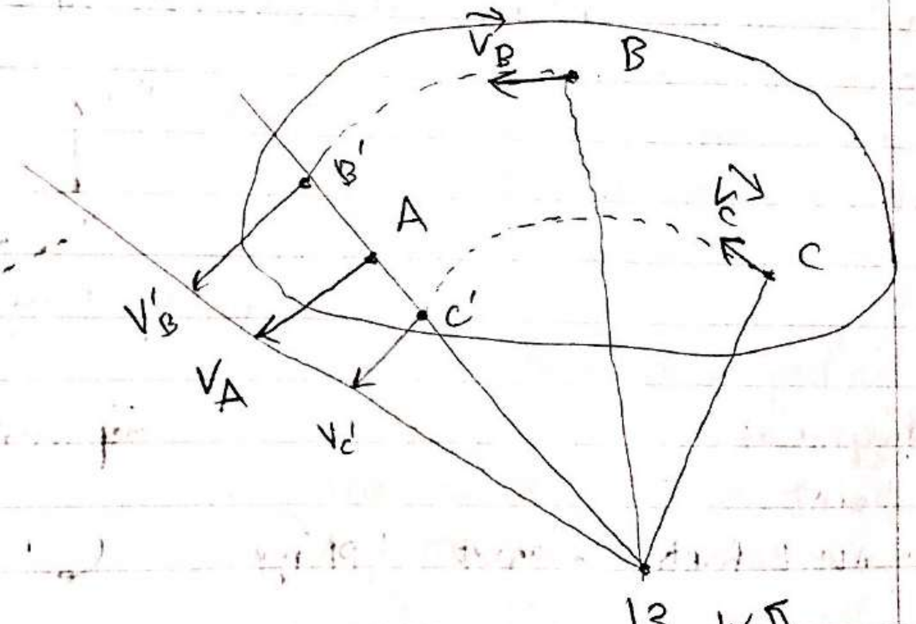


برسم طولها حسب $V_A = w_2 r_{A/12}$

تشابه مثلثات: $\dfrac{V_{B'}}{r_{B'/13}} = \dfrac{V_A}{r_{A/13}}$

هيك بستخدمش الآلة الحاسبة

كذلك الأمر لإيجاد السرعة اي نقطة على الجسم 3.



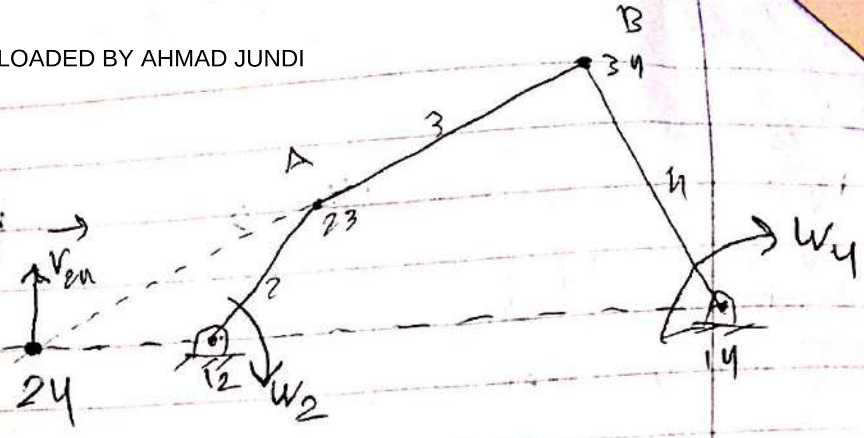
تشابه مثلثات بطول قيمة V_c و V_B والدائرة حتى يعرف

$\omega_2 = 2$ rad/s

بالقياس

$V_{24} = \omega_2 \, r_{24/12}$

$V_{24} = 2 \times (16) = 32$ cm/s



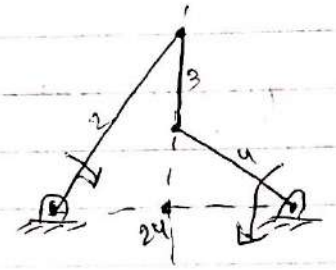
$V_{24} = \omega_4 \, r_{24/14}$

$\omega_4 = \frac{V_{24}}{r_{24/14}} = \frac{32}{80} = 0.375$

بالقياس

$V_{14/24} = (\omega_4 - \omega_2) \, r_{14/24}$

$V_{24/\text{link } 4} = 0$ or link 2

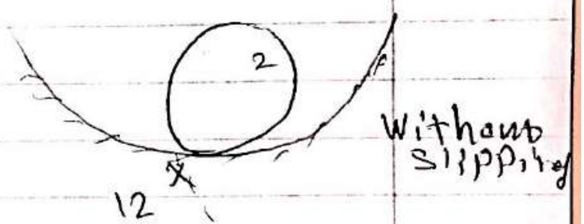


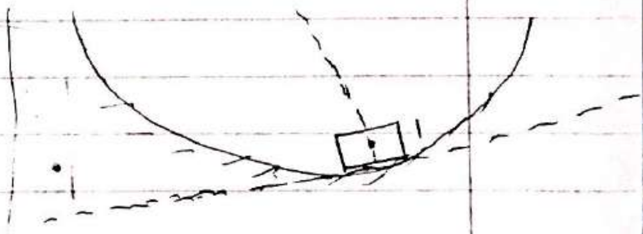
③ Contacts:

ⓐ without slipping (Rolling)

ⓑ Sliding without Rolling

at the center of curvature of the relative path between the two bodies

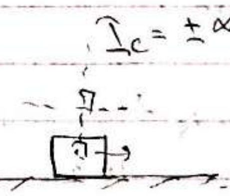


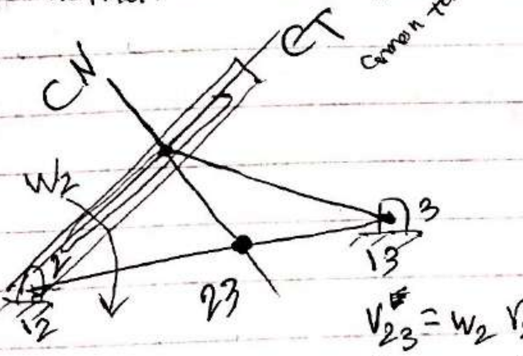


ⓒ Rolling with Sliding

(Pin inside a slot)

a point some where on the common normal direction.





12 23 13

$V_{23} = \omega_2 \, r_{23/12}$

$V_{23} = \omega_3 \, r_{23/13}$

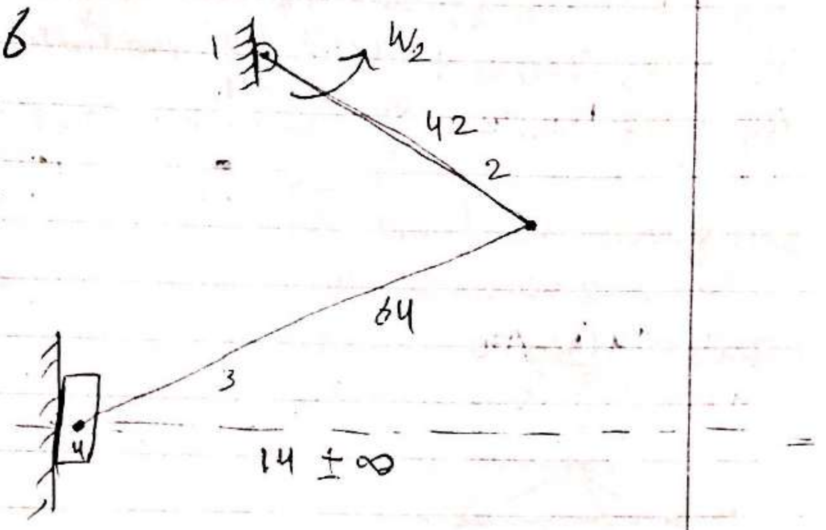
$\frac{\omega_3}{\omega_2} = \frac{r_{23/12}}{[illegible]}$

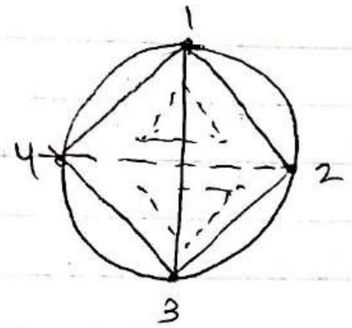
-X:

of $I_c = \frac{n(n-1)}{2} = \frac{4(3)}{2} = 6$

given $\omega_2 = 2$ rad/s

find $\vec{V}_{slider}$



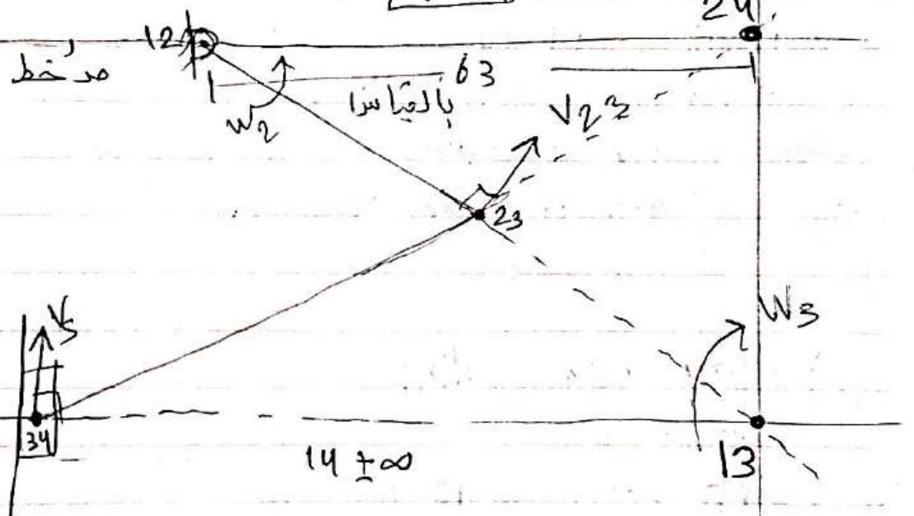


عشان اوجد 24 ، هادا الضلع مشترك مع مثلثين : 412 , 432

$\Leftarrow$ 24 $\boxed{12 \quad 14}$; 24 $\boxed{23 \quad 34}$ $\Rightarrow$ تقاطع امتدادهم بيعطيني 24

13 $\Leftarrow$ 13 $\boxed{12 \quad 23}$; 13 $\boxed{14 \quad 34}$

مد خط من 12 ل 14 و 14 $\infty \Leftarrow \theta = 0$ زاوية للخط



اتجاه V_{23} مرهون بـ W_2 ، W_3 مرهون بـ V_{23}

V_3 مرهون بـ W_3

$V_{24} = W_2 \times r_{24/12}$

$= 2 \times 63 = 126$ cm/s

$V_s = 126$ cm/s ↑

$\omega_4 = \frac{V_{24}}{r_{24/14}} = \frac{126}{\infty} = 0$

$\vec{V}_{34} = \vec{V}_{24} + \cancel{\omega_4} \times \vec{r}_{34/24}$

$\boxed{\vec{V}_{34} = \vec{V}_{24}}$

$V_{23} = W_2 \, r_{23/12} = 2 \times 42 = 84 \text{ cm/s}$

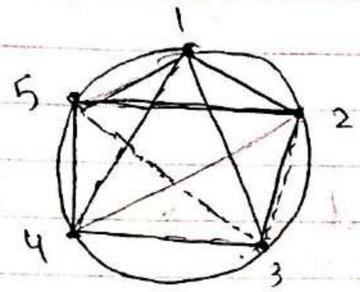
$V_{23} = W_3 \, r_{23/13} \Rightarrow W_3 = \frac{84}{74} \; \cancel{\text{rad}} \text{ rad/s}$

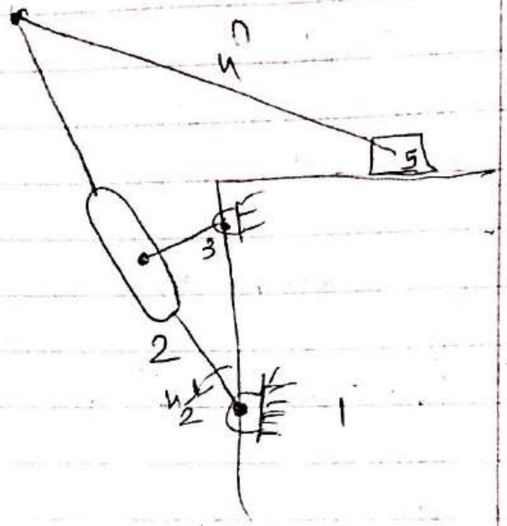
$V_{34} = W_3 \, r_{34/13} = \frac{84}{74} \times 112 = 127 \text{ cm/s}$

Ex: given w_2 find $\vec{V_5}$

$w_2 = 2 \text{ rad/s CCW}$

$\# I_c = \frac{5(4)}{2} = 10$





$\boxed{12 \quad 13}$ 23 with CN pin slot

$\boxed{12 \quad 15}$ 25 ⇒ 25 ✓

$\boxed{24 \quad 45}$ 25

$\boxed{15 \quad 13}$ 35 كله بطلع $\pm\infty$

$\boxed{25 \quad 23}$ 35 ⇒ بستفيدش ⇐ طريقة تانية

$\boxed{15 \quad 45}$ 14

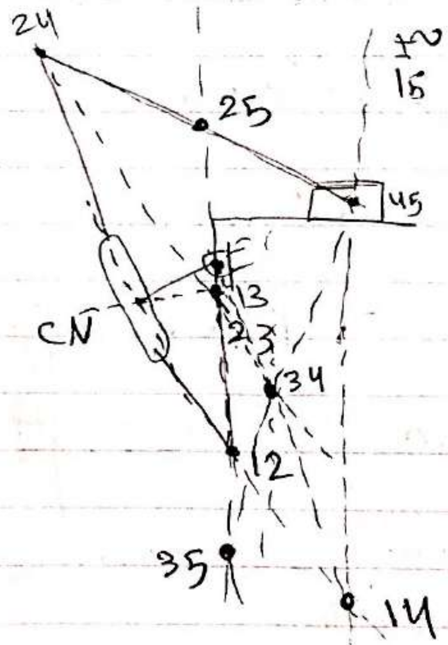
$\boxed{12 \quad 24}$ 14 ✓

$\boxed{31 \quad 14}$ 34 وقف !

$\boxed{32 \quad 24}$ 34 . بتطلع ⇐ كافي Vslider

$\boxed{32 \quad 25}$ 35

$\boxed{34 \quad 45}$ 35



from w_2 find V_{23} then W_3 then V_4 then W_4 then V_{45}

$V_{23} = W_2 \, r_{23/13}$

$w_2 = \frac{V_{23}}{r_{23/13}}$, $V_{24} = W_2 \, r_{24/12}$, $W_4 = \frac{V_{24}}{r_{24/14}}$, $V_{45} = W_4 \, r_{45/15}$ ✓ #

OR: $-V_{35} = W_3 \, r_{35/13}$, $V_{slider} = V_{35}$

Velocity and acceleration analysis using complex numbers:

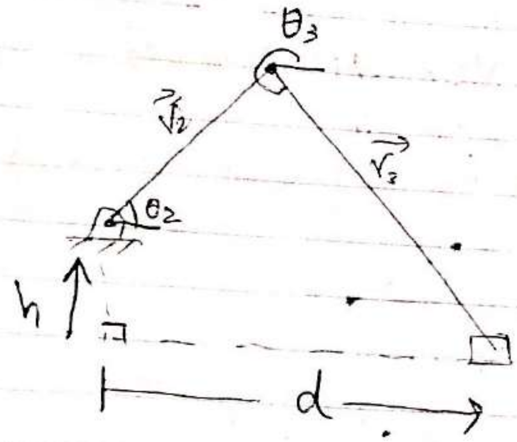
Position loop:

equation:

$\vec{r_2} + \vec{r_3} - \vec{d} + \vec{h} = 0$

$2e^{j\theta_2} + L_3 e^{j\theta_3} - d e^{j0} + h e^{j90} = 0$

$2e^{j\theta_2} + L_3 e^{j\theta_3} - d + jh = 0$



Velocity equation: $\vec{V} = \frac{d\vec{r}}{dt}$

$L_2 j e^{j\theta_2} \dot{\theta}_2 + L_3 j e^{j\theta_3} \dot{\theta}_3 - \dot{d} + 0 = 0$

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

$2j\left(je^{j\theta_2}\dot{\theta}_2^2 + e^{j\theta_2}\ddot{\theta}_2\right) + L_3 j\left(je^{j\theta_3}\dot{\theta}_3^2 + e^{j\theta_3}\ddot{\theta}_3\right) - \ddot{d} = 0$

$\frac{de^{jx}}{dt} = \frac{de^{jx}}{dx} \cdot \frac{dx}{dt} = je^{jx} \frac{dx}{dt}$

velocity: $L_2 j e^{j\theta_2} \dot{\theta}_2 + L_3 j e^{j\theta_3} \dot{\theta}_3 - \dot{d} = 0$

$\Rightarrow L_2 j \dot{\theta}_2 (\cos\theta_2 + j\sin\theta_2) + L_3 j \dot{\theta}_3 (\cos\theta_3 + j\sin\theta_3) - \dot{d} = 0$

Real Part: $-L_2 \boxed{\dot{\theta}_2} \sin\theta_2 - L_3 \boxed{\dot{\theta}_3} \sin\theta_3 - \boxed{\dot{d}} = 0$

maginary Part: $L_2 \boxed{\dot{\theta}_2} \cos\theta_2 + L_3 \boxed{\dot{\theta}_3} \cos\theta_3 = 0$

given input $\dot{\theta}_2 \equiv$ known

Unknown: $\dot{\theta}_3, \dot{d}$

$$\begin{bmatrix} L_3\sin\theta_3 & 1 \\ L_3\cos\theta_3 & 0 \end{bmatrix} \begin{bmatrix} \dot{\theta}_3 \\ \dot{d} \end{bmatrix} = \begin{bmatrix} -L_2\sin\theta_2 \\ -L_2\cos\theta_2 \end{bmatrix} \dot{\theta}_2$$

$A\vec{x} = \vec{b}$

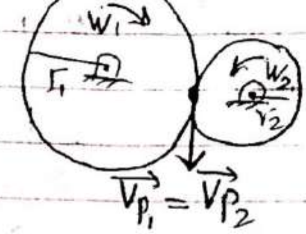
$\dot{x} = A^{-1}\vec{b}$

Gear Trains:

Types of gear trains:

① Simple gear train

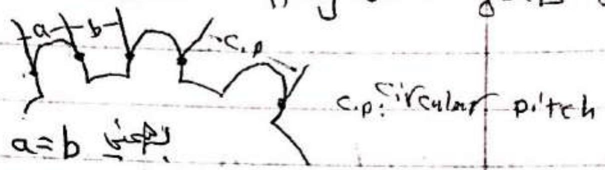
one gear on each shaft



$$\vec{V}_{P_1} = \vec{V}_{P_2} = w_1 r_1 = w_2 r_2$$

$$V_R = \frac{w_1}{w_2} = \frac{-r_2}{r_1} \equiv \text{Velocity ratio}$$

slipping فش gears بال



a = b بالضبط

$$\frac{w_1}{w_2} = \frac{-r_2}{r_1}$$

$$\frac{w_2}{w_3} = \frac{-r_3}{r_2} \; ; \quad \frac{w_3}{w_4} = \frac{-r_4}{r_3}$$

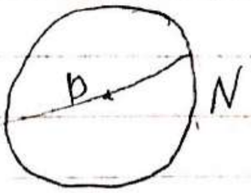
$$V_R = \frac{w_{in}}{w_{out}} = \frac{w_1}{w_4} = \frac{w_1}{w_2} \frac{w_2}{w_3} \frac{w_3}{w_4} = \frac{-r_4}{r_1}$$ Gears 2&3 are idle gears

$$\frac{w_1}{w_4} = \frac{w_1}{w_2} \frac{w_2}{w_3} \frac{w_3}{w_4} = \left(\frac{-r_2}{r_1}\right)\left(\frac{-r_3}{r_2}\right)\left(\frac{-r_4}{r_3}\right)$$ => to increase the distance between the input & output gears.

(−) to invert velocity direction

* To enable to mesh two gears, both must have the same circular pitch

Circular pitch $= \frac{\pi D}{N}$ for pitch circle



~~$M = \frac{\pi D}{N}$~~

~~Modul = m = π~~

$$\frac{\pi D_1}{N_1} = \frac{\pi D_2}{N_2} = m_1 = m_2$$

all calculation (velocity ratio) are made basing on the pitch circle

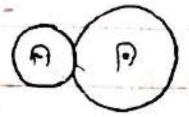
Module $= m = \frac{D}{N}$ SI metric

Diametral pitch $P = \frac{N}{D}$ English units

$$\frac{w_1}{w_2} = \frac{-r_2}{r_1} = -\frac{D_2}{D_1} = \frac{-m_2 N_2}{m_1 N_1} = \frac{-N_2}{N_1}$$

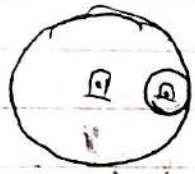
* Connection between gears:

① External:



$$\frac{w_1}{w_2} = \frac{-N_2}{N_1}$$

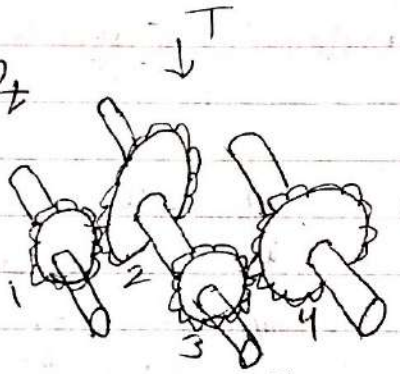
② Internal



$$V_R = \frac{N_2}{N_1} = \frac{w_1}{w_2}$$ فشل ـــ سالب ، اتجاه الدوران نفسه

② Compound Gear Train:

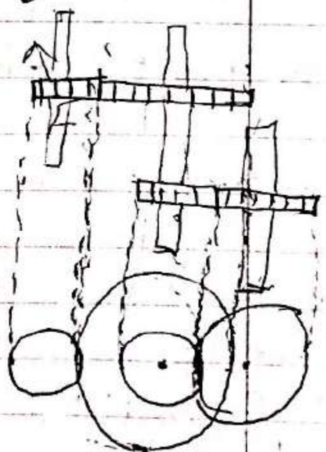
More than one gear on one shaft



$$\frac{w_1}{w_2} = \frac{-N_2}{N_1}$$

$$w_3 = w_2$$

$$\frac{w_3}{w_4} = \frac{-N_4}{N_3}$$



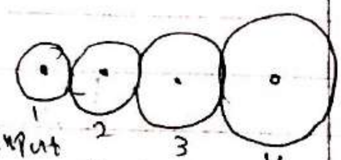
$$V_R = \frac{w_{in}}{w_{out}} = \frac{w_1}{w_4} = \frac{w_1}{w_2}\,\frac{w_2}{w_3}\,\frac{w_3}{w_4}$$

$$V_R = \frac{-N_2}{N_1}(1)\left(\frac{-N_4}{N_3}\right) = \frac{N_2 N_4}{N_1 N_3} = \frac{w_1}{w_4}$$

$$= \frac{w_1}{w_4}$$

$$V_R = \frac{w_{in}}{w_{out}} = \frac{\text{Product of Driven teeth}}{\text{Product of Driver teeth}} = \frac{-N_2}{N_1}\,\frac{-N_4}{N_2}$$

$$V_R = \frac{W_{in}}{W_{out}} = \frac{\text{Driven}}{\text{Driver}} = \frac{-N_2}{N_1}\,\frac{-N_3}{N_2}\,\frac{-N_4}{N_3} = \frac{-N_4}{N_1}$$



for simple gears

$Y = \frac{W_{in}}{W_{out}}$ ⇐ input بلف بسرعة Y أضعاف الـoutput.
⇐ T_{output} أكبر من T_{input} بـ Y أضعاف
أعلى Torque ← قوة أعلى

Power:

$T_{in} W_{in} = T_{out} W_{out}$

$$\frac{W_{in}}{W_{out}} = \frac{T_{out}}{T_{in}}$$

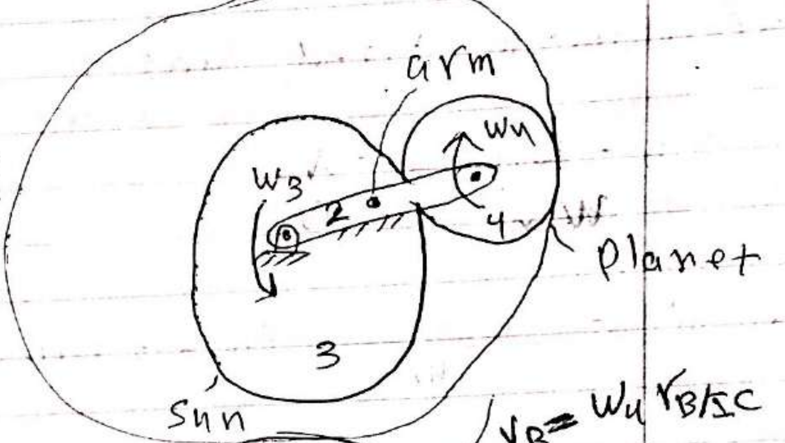
$$V_R = \frac{W_{in}}{W_{out}} = \frac{\Pi \text{ Driven}}{\Pi \text{ Driver}}$$

Velocity Ratio

$\prod_{i=1}^{n} i = 1 \times 2 \times 3$

$$\text{Train Value } (e) = \frac{W_{out}}{W_{in}} = \frac{\Pi \text{ Driver}}{\Pi \text{ Driven}}$$

③ Planetor Gears:

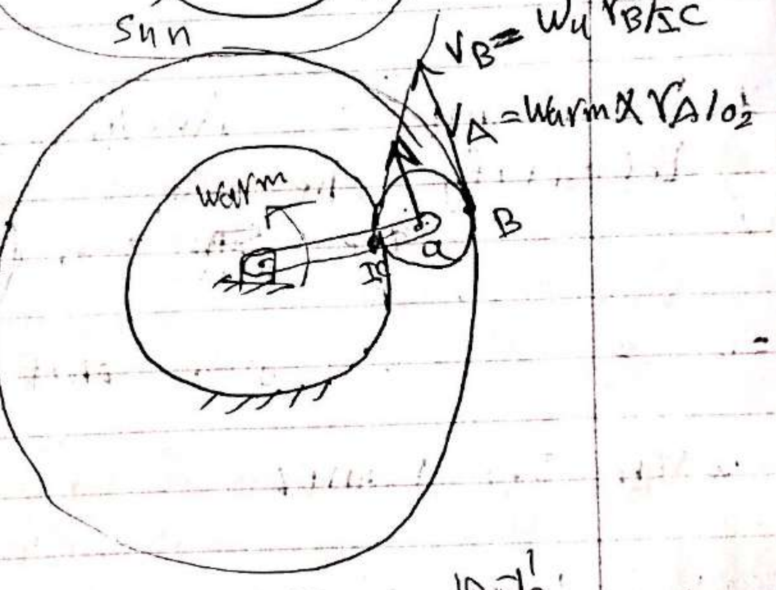


a. Arm is the fixed ground

$$\frac{W_3}{W_4} = \frac{-N_4}{N_3}, \quad \frac{W_3}{W_5} = \frac{-N_4}{N_3} \cdot \frac{N_5}{N_4}$$

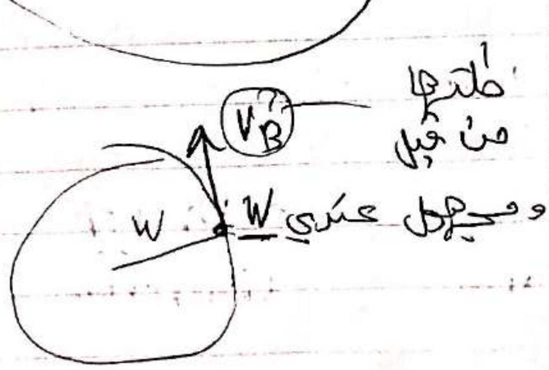
$$\frac{W_3}{W_5} = \frac{-N_5}{N_3}$$

b. Sun is fixed:



W_3

* نقطة التقاء الـtwo gears سرعتها 0
لأنه الـW للـsun = 0
← النقطة الموجودة على الـarm
الها V مش صفر لأنه في W_{arm}.



Relations Relative to the arm:

$$\frac{W_{out}/arm}{W_{in}/arm} = \frac{\prod Driver}{\prod Driven}$$

دائما واقفه على arm وبوقف

ال gears تبعته اما انا fixed

$$\Rightarrow \frac{W_{out} - W_{arm}}{W_{in} - W_{arm}} = \frac{-N_3 \times N_4}{N_4 \times N_5}$$

$$\boxed{\frac{W_5 - W_{arm}}{W_3 - W_{arm}} = \frac{-N_3}{N_5}}$$

According to fixed suns:

$$\frac{W_5 - W_{arm}}{0 - W_{arm}} = \frac{-N_3}{N_5}$$

$$Ex: \frac{W_5 - 2}{-2} = \frac{-20}{40} \Rightarrow W_5 = 3 \text{ rad/s (ccw)}$$

* Procedure of Analysis:

① Identify the arm.

② = the Planet gear (its axis rotating and is supported by the arm)

③ = = gears that are (directly connected in mesh) with the Planet

ال gears اللي بتركبوا بيعض

Call then the input & output

$$\frac{W_{out}/arm}{W_{in}/arm} = \frac{\prod Driver}{\prod Driven}$$

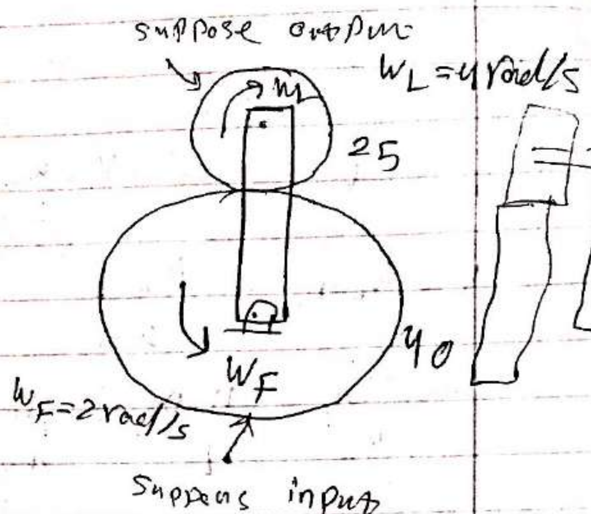
Ex: Find Warm?

Planet = Gear (L)

$$\frac{W_{out}/W_{arm}}{W_{in}/W_{arm}} = \frac{\pi\ Driver}{\pi\ Driven} = \frac{-N_F}{N_L}$$

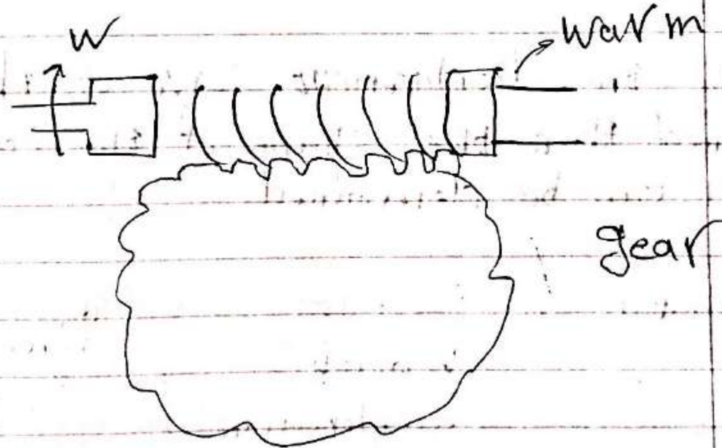
$$\frac{W_L - W_{arm}}{W_F - W_{arm}} = \frac{-48}{25}$$

$$\frac{-4 - W_{arm}}{2 - W_{arm}} = \frac{-40}{25} \Rightarrow W_{arm} =$$



Problem 7.32

Power Gear:



Lead: the distance that the warm gear advances when it rotates one complete revolution.

$L = N_W \times P$

$V = W_G r_G$

$\frac{2\pi}{s} \Rightarrow \frac{L}{s}$ كل لفة كاملة بتعطيني مسافة L للنقطة بتحركها $\frac{rev}{s} \Rightarrow \frac{L}{s}$

عشان نصيرها بـ $W_{rad/s} \Rightarrow V \quad \Rightarrow \quad V = \frac{W_w L}{2\pi}$

$$\Rightarrow V = w_G r_G = \frac{W_w L}{2\pi}$$

$$\Rightarrow \boxed{\frac{W_w}{W_G} = \frac{\pi D_o}{L} = \frac{N_G P}{N_w P} = \frac{N_G}{N_w}}$$

but $P = \frac{\pi D_o}{N_G}$

معلى معطيات السؤال تكون N_G ، N_w أو D_o ، N_w ، P بدي اعرف اتعامل معهم

Cam & Follower:

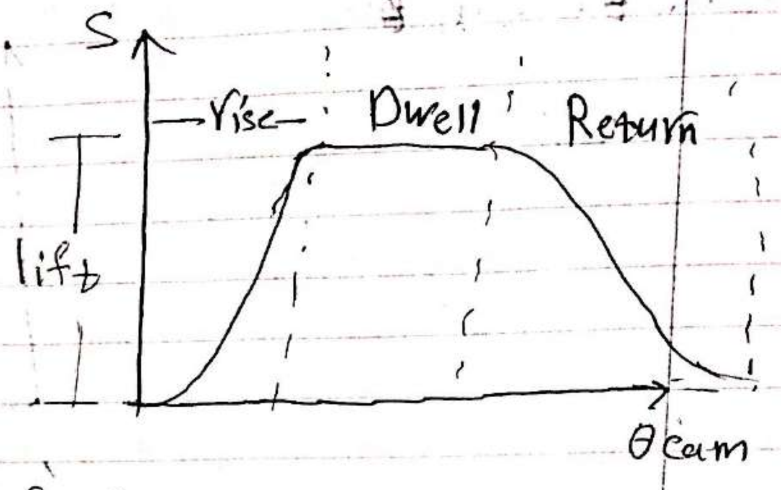
Disk Cam with → flat face follower / → Radial Roller follower

Firstly the displacement curve of the follower must be designed than the shape of the cam that produces this motion can be determined

Continuous in Position, Velocity, acceleration → finite Jake

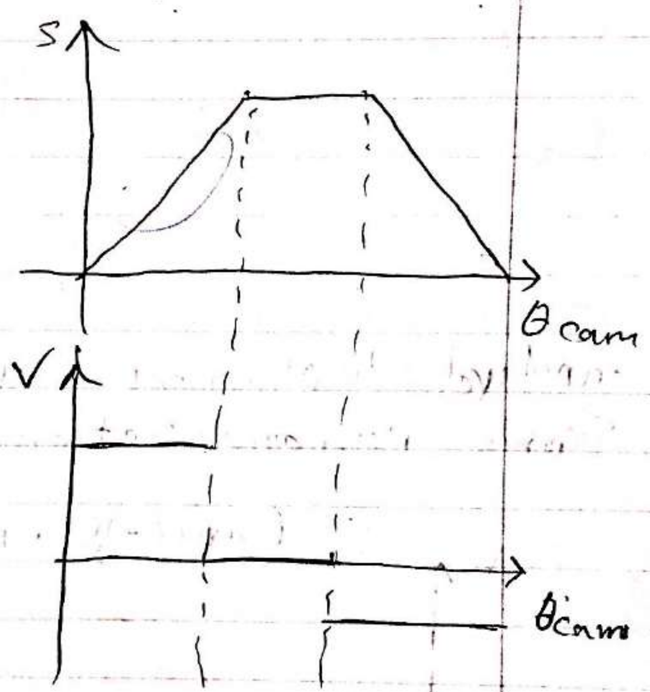
$$J = \frac{da}{dt}$$

Follower Displacement Curve:



Types of displacement curves:

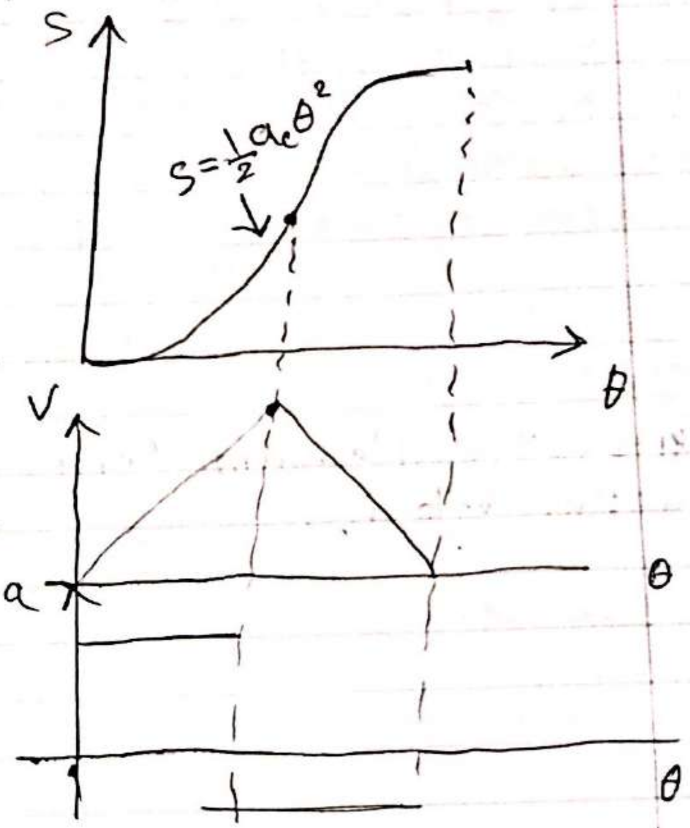
① Constant Velocity:



2) Constant acceleration deceleration:

$$S = S_0 + V_0\,\theta + \frac{1}{2}\,a_c\,\theta^2$$

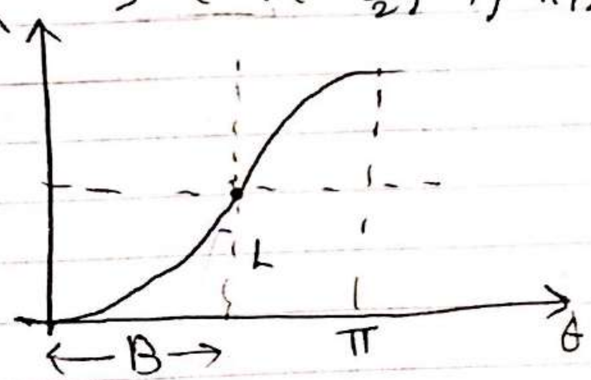
$$S = \frac{1}{2}\,a_c\,\theta^2$$

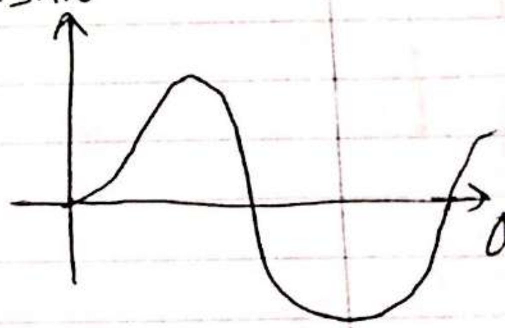


Standard displacement Curves:

1) Simple harmonic motion curve:

$$S = \left(\sin\left(\theta - \frac{\pi}{2}\right) + 1\right) h/2$$





a: by concave (up or Down)

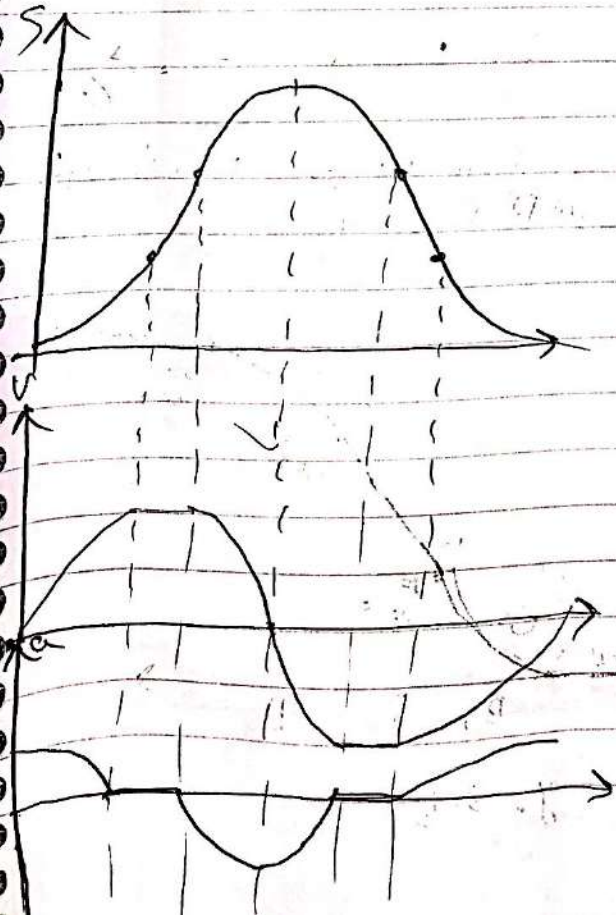
* Characteristics of Harmonic motions:
  - lowest peak acceleration
  - lowest pressure angle
  - Can't be matched with dwell → V=0, a=0 مابصير نقطة إلها v=a=0
  - Can't be used in high Velocity application

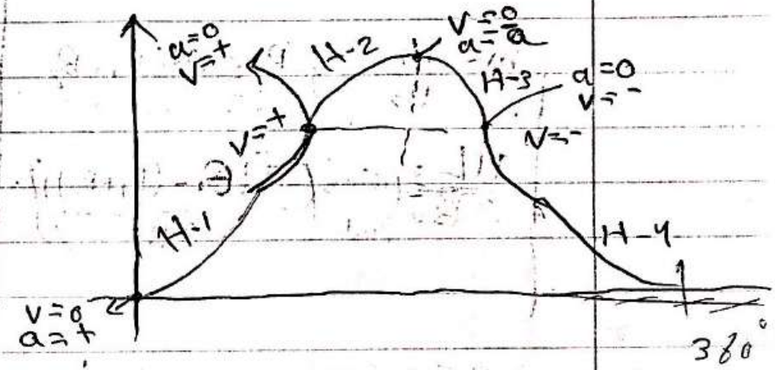
* Cycloidal Motion:
  - Highest acceleration
  - = pressure angle
  - Can be matched with dwell
  - low velocity app

* Eigth Power polynomial:
  In termediate

Problem 330

Conditions نفحص ال





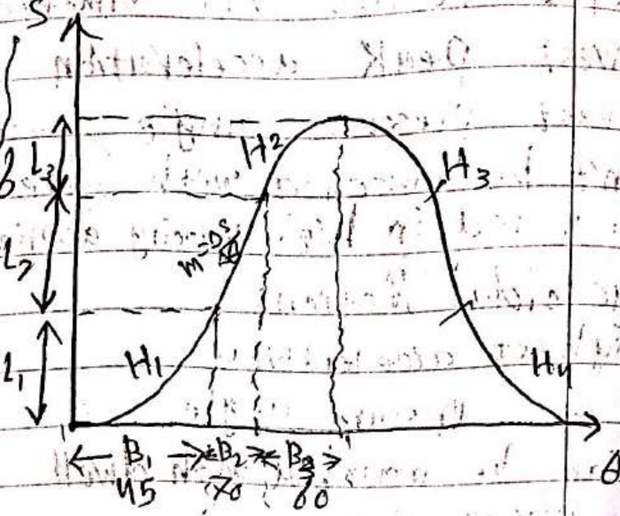
بشوف بداية H-2 هل v=+ ؟ a=0 ؟ نعم ✓

3. [17, 22, 36, 38, 40, 43, 44

عشان أوجد S لنقطة ما، عندي طريقتين إما بعوضها في Global أو في local
بس بشروط إنه يوجد θ اللي بدي أعوضها مثلا θ=130 Global = 130 − 115 في local
for (H_2)
ويوجد S بعدها بأخذ بعين الاعتبار الـshift يعني $S_{المطلوبة} = L_s + L_1 + S$
لما أعوض بحول لدرجات $90 = \frac{\pi}{2}$

$$S = f(\theta) = \begin{cases} L_1\left(1-\cos\frac{\pi\theta}{2B_1}\right), & 0 \le \theta \le B_1 \\ \frac{L_2}{B_2}(\theta - B_1) + L_1, & B_1 \le \theta \le B_1 + B_2 \\ L_3\left(\sin\pi\frac{(\theta-(B_1+B_2))}{2B_3}\right) + L_1 + L_2, & B_1 + B_2 \le \theta \le B_1 + B_2 + B_3 \end{cases}$$

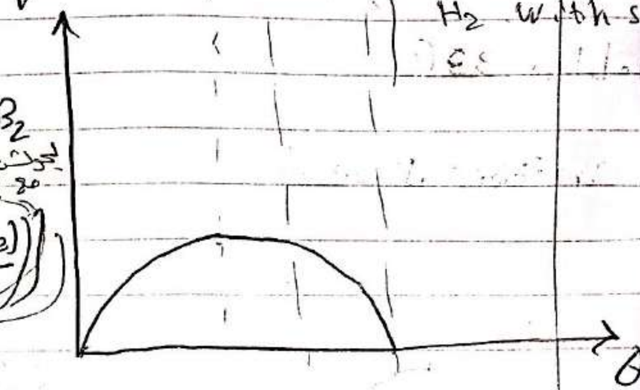
45, 115, 125



$s = f(\theta) = $ { H_1
الحل straight line eq. with shift
H_2 with shift

$$V = V(\theta) = \begin{cases} \frac{\pi L_1}{2B_1}\sin\left(\frac{\pi\theta}{2B_1}\right), & 0 \le \theta \le B_1 \\ m = \frac{L_2}{B_2}, & B_1 \le \theta \le B_1 + B_2 \\ \frac{\pi L_3}{2B_3}\left(\cos\left(\frac{\pi(\theta-(B_1+B_2))}{2B_3}\right)\right), & \end{cases}$$

3.14/2 rad ← بحول ، deg ← 180 بحول لأنه بتصير مع بعض



هاي V مش حقيقية ، ناقصة $\dot{\theta}$ لأنه

$$v = \frac{ds}{dt} = \frac{ds}{d\theta}\frac{d\theta}{dt} = V(\theta)\,\dot{\theta}$$

إذا جبي إياها لتطبيق معين بضربها في $\dot{\theta}$ أو W

لما تظهر π 3.14 لحالها بدنا sin أو cos
يعني استعمل radius خاصة لـ β اللي عندها

Prob. 3.23

Harmonic Motion with Dwell? No
إذا بربط H أو C بختار H.

بفحص بداية ونهاية كل C_1, C_2
وبشوفه هل تطابقه

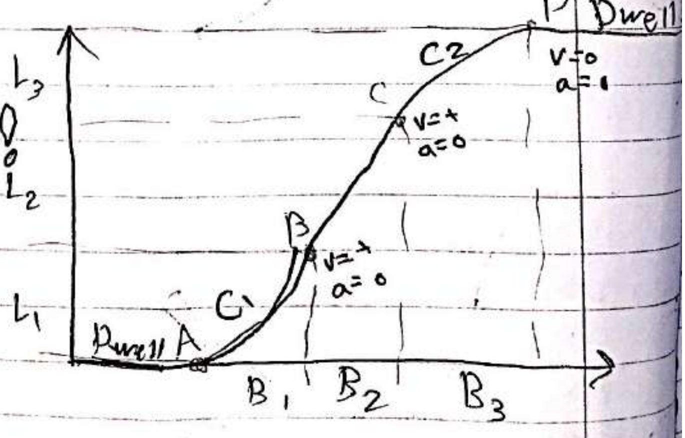
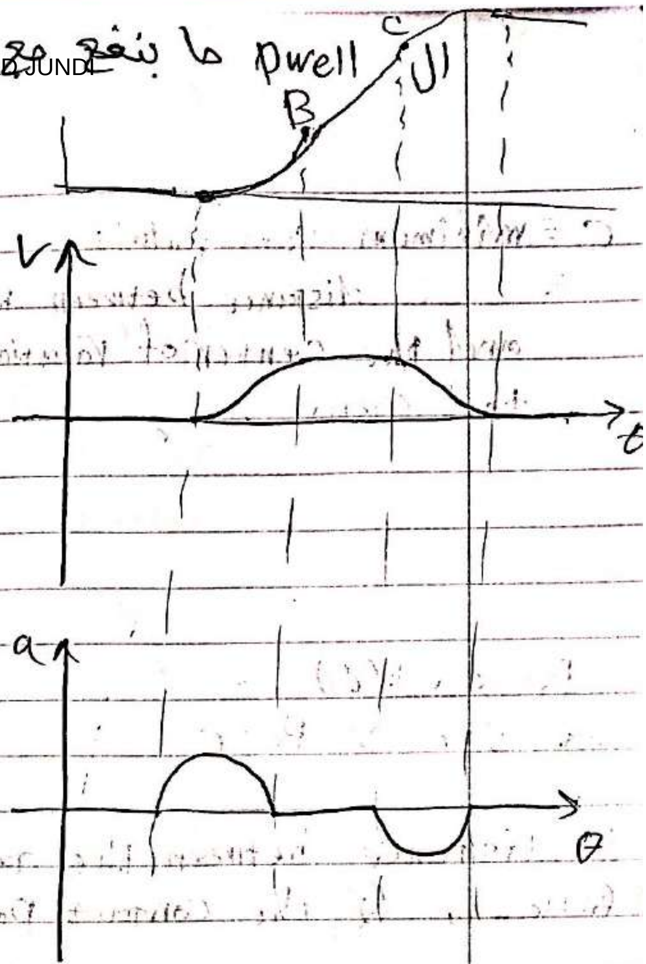


Fig. 3.48

$$a = \frac{d^2 s(\theta)}{dt^2} = \frac{d^2 f(\theta)}{d\theta^2}\cdot\frac{d\theta^2}{dt}$$

$o = u = V = s$ لأنه ما في ما بنفع مع Harmonic dwell



at B:

from left $a_B^- = a_B^+$ from right) acc.

acc. useless since $[=0]$

vel.: from left $V_B^- = V_B^+$ from right

$$V_B^- = V = \frac{L_1}{B_1}\left(1 - \cos\left(\pi\left(\frac{B_1}{B_1}\right)\right)\right)$$

$$= \frac{2L_1}{B_1}$$

$V_B^+ =$ the slope $= \frac{L_2}{B_2}$, $V_B^- = V_B^+$

$$\Rightarrow \frac{2L_1}{B_1} = \frac{L_2}{B_2} \Rightarrow \boxed{B_1 = \frac{2L_1}{L_2} B_2}$$

at C: acc. useless $(a_c^+ = a_c^- = 0)$

from left: $V_c = \frac{L_2}{B_2}$

local $0 = \theta$; C_2 عند بداية

global $B_1 + B_2 = \theta$

from Right:

$$V_c = \frac{2L_3}{B_3}$$

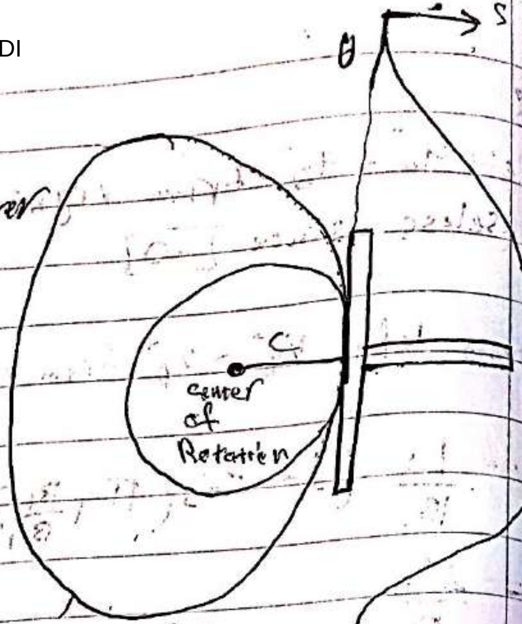
$$\Rightarrow \frac{L_2}{B_2} = \frac{2L_3}{B_3}$$

$$\Rightarrow B_3 = \frac{2B_2L_3}{L_2}$$

$$V = \frac{L_3}{B_3}\left(1 + \cos\pi\frac{(\theta - (B_1 + B_2))}{B_3}\right)$$

C ≡ minimum cam radius

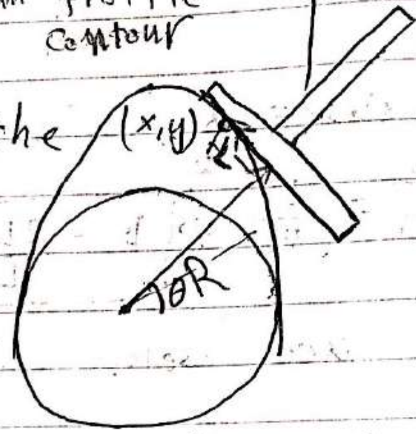
≡ distance between the follower and the center of rotation of the cam.



$R = C + f(\theta)$

at $\theta = 0 \Rightarrow R = C$

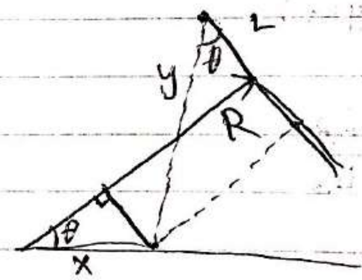
L ≡ distance between the axis of the follower & the contact point



(x,y) يمثل شكل ال cam

$$\begin{cases} R = x\cos\theta + y\sin\theta \\ L = y\cos\theta - x\sin\theta \\ L = \dfrac{dR}{d\theta} = \dfrac{df(\theta)}{d\theta} = V \end{cases}$$

من المعادلات



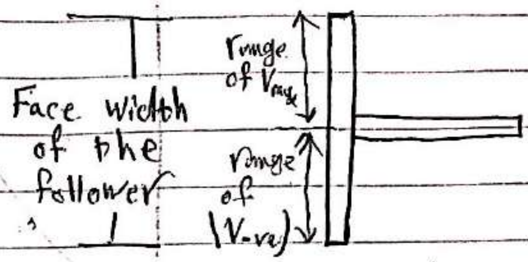
$\Rightarrow \boxed{L = V}$

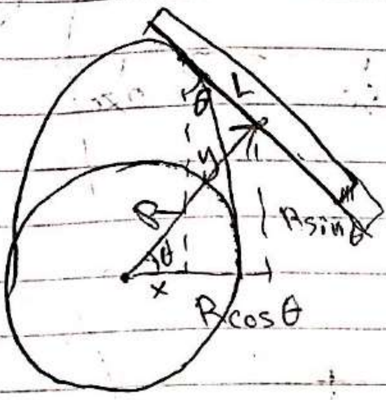
if V = Positive ⇒ Contact Point is ~~located~~ on the upper part the axis of the follower.

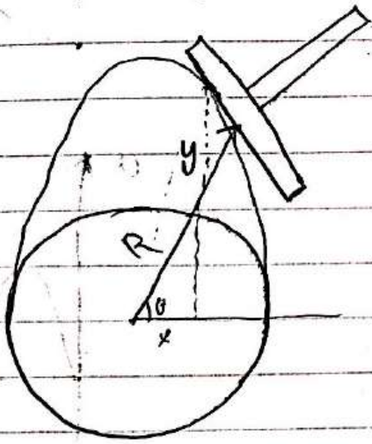
V = negative ⇒ Contact point is on the lower part the follower axis.

Symmetry for Local !

Theoritical face width of the follower $= V_{max} + |V_{negative}|$







$x = R\cos\theta - L\sin\theta$
$y = R\sin\theta + L\cos\theta$

cust: θ   اذا كانت ال circle صغيرة ⇐

$$\boxed{\frac{dx}{d\theta} = 0 \quad \frac{dy}{d\theta} = 0}$$

Cust / Cam pointing

أقل C بتعطيني تدبب بال cam بالتالي Contact Point بتتغير تقريباً

$x = (c + f(\theta))\cos\theta - f'(\theta)\sin\theta$

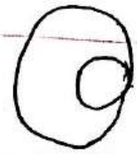
$\frac{dx}{d\theta} = f'(\theta)\cos\theta - (c + f(\theta))\sin\theta - (f''(\theta)\sin\theta + f'(\theta)\cos\theta)$

$\frac{dx}{d\theta} = -(c + f(\theta) + f''(\theta))\sin\theta = 0$ مستحيل $0 = \cos\theta = \sin\theta$ ⇐ التيرم الثاني هو الي حطناه بصفر

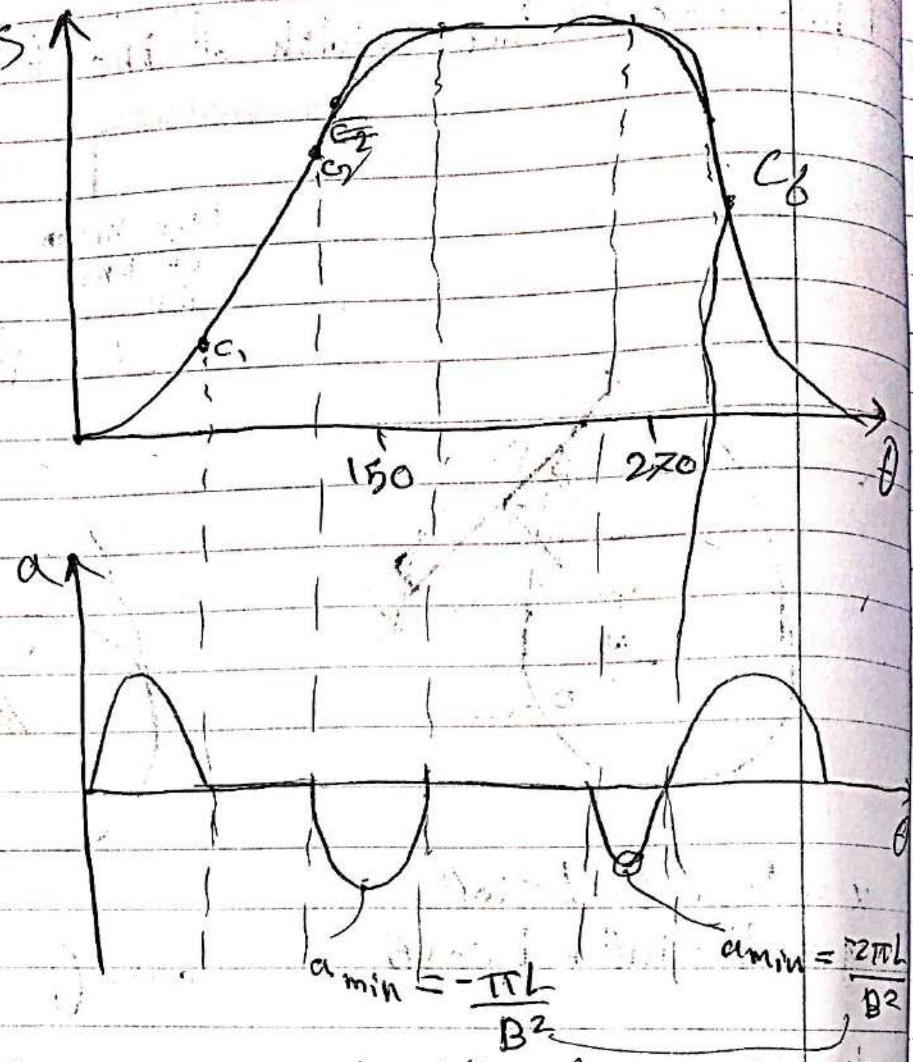
$\frac{dy}{dx} = +(c + f(\theta) + f''(\theta))\cos\theta = 0$

$\Rightarrow [c + f(\theta) + f''(\theta)] = 0 \Rightarrow$ Cust occurs

find minimum negative value then chose $c > |\ \ |$ to avoid cust



ممكن نلاقي بعض انواع ميكانيزم ال cam بال circle زي هيك



local

$f(150) = \frac{\pi L}{B^2}$ 1st min

shift الـ 80

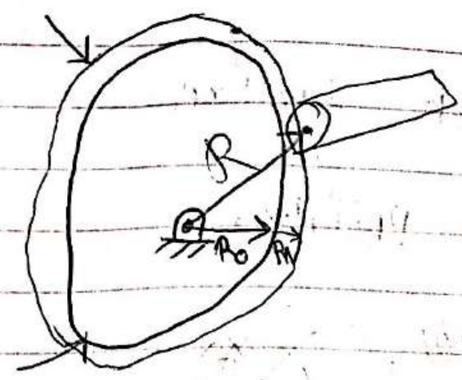
مع المعادلات و الـ sinosoidal amplitude
لما تكون sin = 1

$f(270) = \frac{2\pi L}{B^2}$ 2^{nd} min

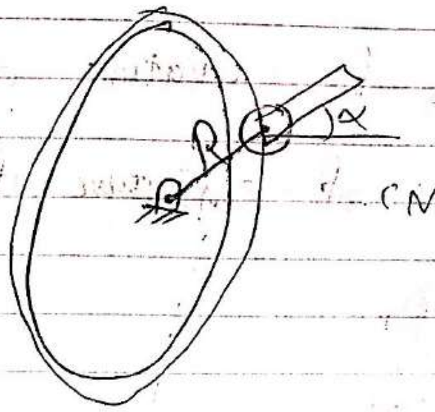
if ~~c > |1st|~~ $c > |f(\theta) + f''(\theta)|_{min\,1\&2} \Rightarrow$ No Cust

Disk cam with radial roller follower :

Pitch surface



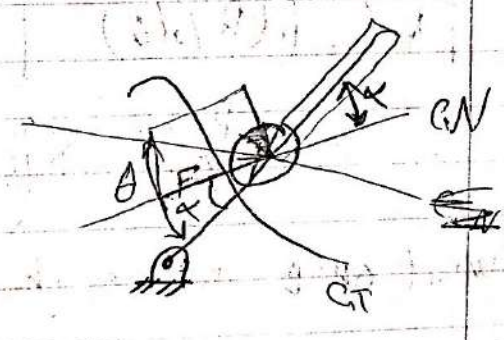
Cam
Profile



$R_o \equiv$ minimum distance between roller center & center of rotation of the cam

$R_r \equiv$ radius of the roller

$R = R_o + f(\theta)$



$\alpha \equiv$ pressure angle
the angle between the axis of the follower and th CN direction

$x_A = R\cos\theta$
$y_A = R\sin\theta$

$x = R\cos\theta - R_r\cos(\theta - \alpha)$
$y = R\sin\theta - R_r\sin(\theta - \alpha)$

$$\alpha = \tan^{-1}\left(\frac{f'(\theta)}{R_o + f(\theta)}\right) = \tan^{-1}\left(\frac{V}{R}\right)$$

$R = R_o + f(\theta)$

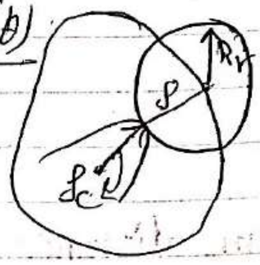
$\rho \equiv$ Radius of curvature of pitch surface

$\rho_c \equiv$ Radius of curvature of cam profile.

$\rho = \rho_c + R_r$

$R = R_o + f(\theta)$

$R = R_o + f(\theta)$



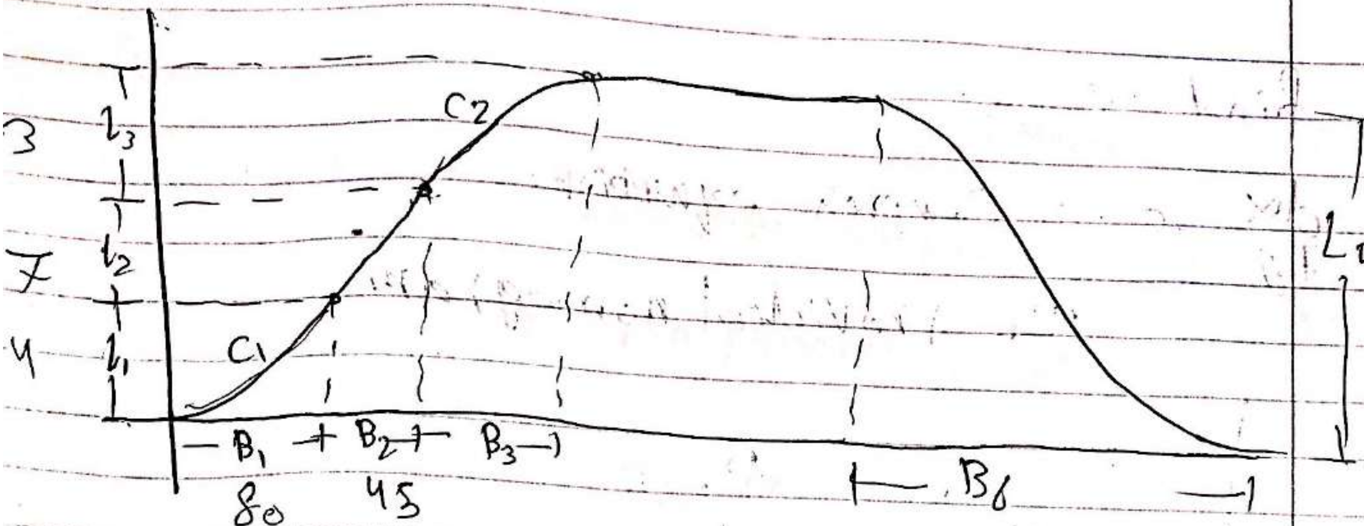
as $R_r \uparrow = \rho_c \downarrow$

$R_r = \rho \Rightarrow \rho_c = 0 \Rightarrow$ cusp, Cam Pointing

$$\rho = \frac{\left[R^2 + (dR/d\theta)^2\right]^{3/2}}{R^2 + 2\left(\frac{dR}{d\theta}\right)^2 - R\left(\frac{d^2R}{d\theta^2}\right)}$$

to avoid cusp insure that $R_r < \rho_{min}$ to find ρ_{min}

$\frac{d\rho}{d\theta} = 0$ complex relation
$\Rightarrow$ use provided case



$R_0 = 5\,cm$

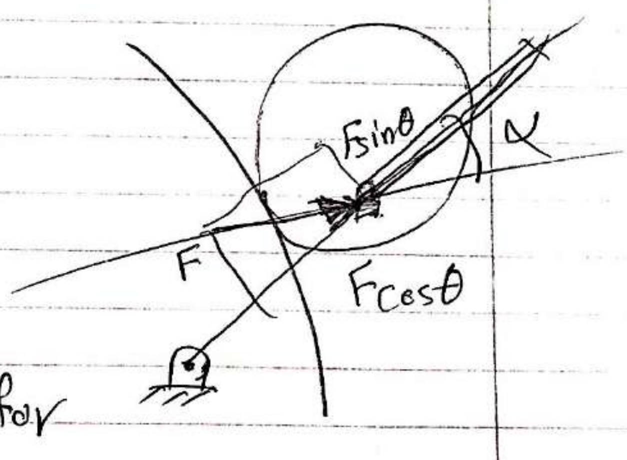
C_1:

$$\frac{L}{R_0} = \frac{4}{5} = 0.8 \Rightarrow \frac{\delta_{min}}{R_0} = 0.75$$

$$\Rightarrow \delta_{min} = 0.75\,R_0 = 0.75(5) = 3.75$$

$\Rightarrow$ maximum $R_r < 3.75$

$\alpha \equiv$ Pressure angle



$F\sin\theta$ perpendicular to the axis of the follower

Keep α as low as possible for design conditions

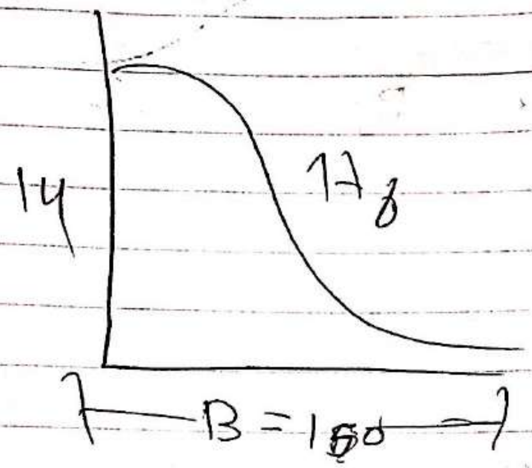
Keep $\alpha \leq 30°$

$$\alpha = \tan^{-1}\left(\frac{f'(\theta)}{R_0 + f(\theta)}\right)$$

To find α_{max}

$\frac{d\alpha}{d\theta} = 0 \Rightarrow$ Complex equation

use provided nomogram



$R_0 = 5$

$\Rightarrow \frac{L}{R_0} = 2.8$

$\Rightarrow \alpha_{max} = 44^0 > 30$

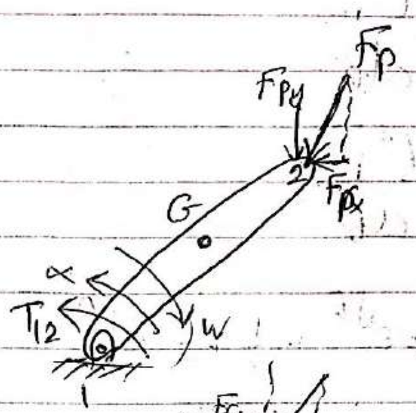
high pressure angle not recommended

Force analysis:

Solution using matrix forces:

- The weight is neglected.

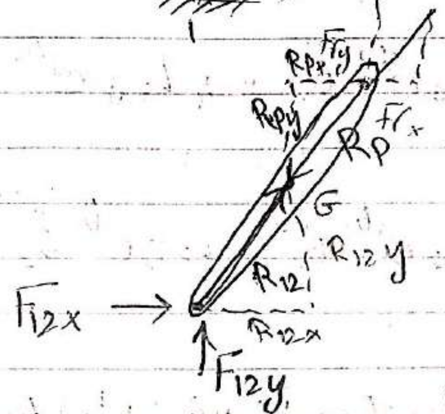
Equation of kinetic equilibriums:



$$\sum \vec{F}_x = m\, a_{Gx}$$

$$\sum \vec{F}_y = m\, a_{Gy}$$

$$\sum M_G = I_G \alpha$$



$R_{12x} = R_{12}\cos\theta_2$

$R_{12y} = R_{12}\sin\theta_2$

$R_{px} = R_p\cos\theta_2$

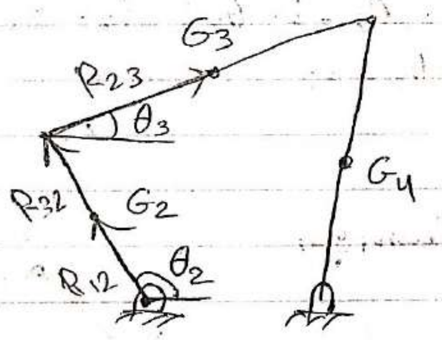
$R_{py} = R_p\sin\theta_2$

$$F_{12x} - F_{px} = m_2\, a_{G_2x} \quad \text{--- (1)}$$

$$F_{12y} - F_{py} = m_2\, a_{G_2y} \quad \text{--- (2)}$$

F_{23} = Reaction force from link 2 on link 3

R_{23} = Position from link 2 to G_3



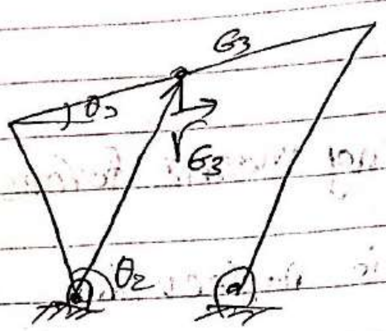
F_{12x}, F_{12y}, T_{12} are unknowns

the moments:

$$F_{12x} R_{12y} - F_{12y} R_{12x} + F_{px} R_{py} - F_{py} R_{px} + T_{12} = I_{G_2}\alpha_2 \quad \text{--- (3)}$$

$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ R_{12y} & -R_{12x} & 1 \end{bmatrix} \begin{bmatrix} F_{12x} \\ F_{12y} \\ T_{12} \end{bmatrix} = \begin{bmatrix} m_2 a_{G_2x} + F_{px} \\ m_2 a_{G_2y} + F_{py} \\ I_{G_2}\alpha_2 - F_{px} R_{py} + F_{py} R_{px} \end{bmatrix}$$

$$\vec{a}_{G_2} = \frac{d^2 \vec{r}_{G_2}}{dt^2}$$



$$\vec{a}_{G_3} = \frac{d^2 \vec{r}_{G_3}}{dt^2}.$$

$$\vec{r}_{G_3} = L_2 e^{j\theta_2} + \frac{1}{2} L_3 e^{j\theta_3}$$

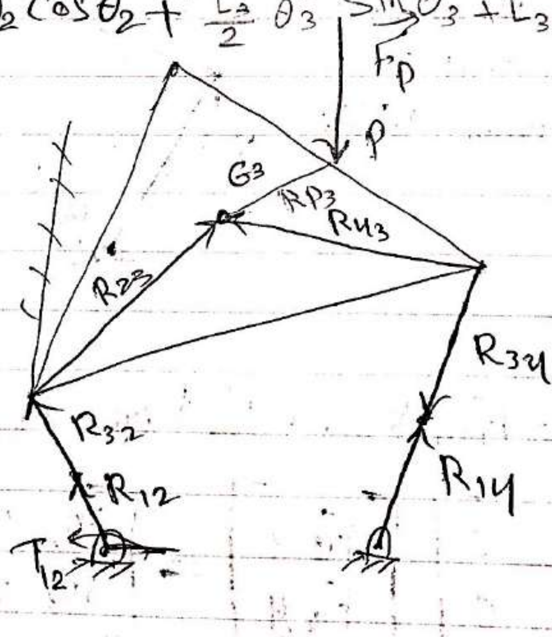
$$\frac{d\vec{r}_{G_3}}{dt} = L_2 j e^{j\theta_2} \dot{\theta}_2 + \frac{1}{2} L_3 j e^{j\theta_3} \dot{\theta}_3$$

$$\frac{d^2\vec{r}_{G_3}}{dt^2} = -L_2 e^{j\theta_2} \underbrace{\dot{\theta}_2^2}_{\omega_2^2} + L_2 j e^{j\theta_2} \underbrace{\ddot{\theta}_2}_{\alpha_2} - \frac{1}{2} L_3 e^{j\theta_3} \underbrace{\dot{\theta}_3^2}_{\omega_3^2} + \frac{1}{2} L_3 j e^{j\theta_3} \underbrace{\ddot{\theta}_3}_{\alpha_3}$$

$$= -L_2 \dot{\theta}_2^2 (\cos\theta_2 + j\sin\theta_2) + L_2 j \ddot{\theta}_2 (\cos\theta_2 + j\sin\theta_2)$$
$$- \frac{L_3}{2} \dot{\theta}_3^2 (\cos\theta_3 + j\sin\theta_3) + \frac{L_3}{2} j \ddot{\theta}_3 (\cos\theta_3 + j\sin\theta_3)$$

$$a_{G_3x} = -L_2 \dot{\theta}_2^2 \cos\theta_2 - L_2 \ddot{\theta}_2 \sin\theta_2 - \frac{L_3}{2} \dot{\theta}_3^2 \cos\theta_3 - \frac{L_3}{2} \ddot{\theta}_3 \sin\theta_3$$
$$a_{G_3y} = -L_2 \dot{\theta}_2^2 \sin\theta_2 + L_2 \ddot{\theta}_2 \cos\theta_2 + -\frac{L_3}{2} \dot{\theta}_3^2 \sin\theta_3 + L_3/2\, \ddot{\theta}_3 \cos\theta_3$$

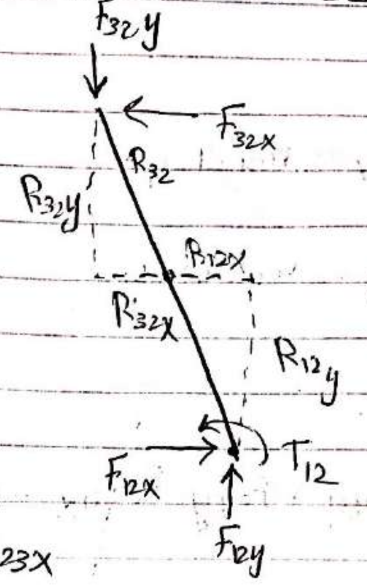
Ex: four bar mechanism



F_{12y} نتعامل + M حول G_2 بس لما اعوض بالارقام ، θ_2 ربع تاني بالتالي

$= \cos\theta$ - وبيعطيني (-) M ؟ عشان أتفادى المشكلة ، بحولها للربع الاول
وبكتب المعادلات تبعوني وباخد θ زي ما هي, بدون مشاكل

link 2:



$$\Sigma F_x = m_2 a_{G_2x}$$

$\cancel{F_{12x}}$

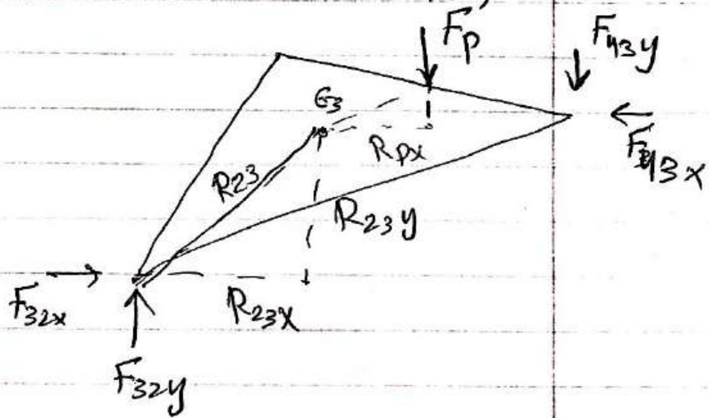
$$F_{12x} - F_{32x} = m_2 a_{G_2x}$$

$$F_{12y} - F_{32y} = m_2 a_{G_2y}$$

$$F_{12x} R_{12y} + F_{12y} R_{12x} + F_{32x} R_{23y} + F_{32y} R_{23x} + T_{12} = I_{G_2} \alpha_2$$

في الربع الأول

link 3:



$$\Sigma F_x \,;\, \Sigma F_y \,;\, \Sigma M_G$$

$$F_{32x} - F_{43x} = m_3 a_{G_3x}$$

$$F_{32y} - F_{43y} = m_3 a_{G_3y}$$

$$\Sigma M_{G_3} = I_G \alpha_3$$

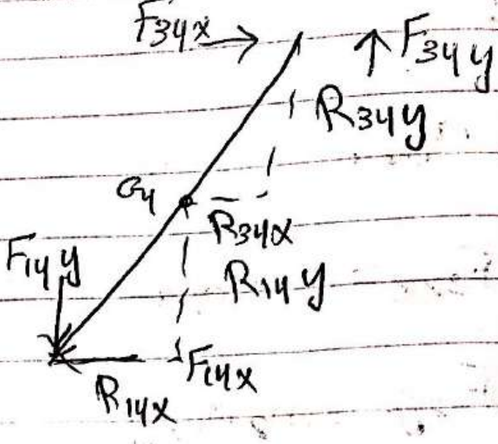
$$F_{32x} R_{23y} - F_{32y} R_{23x} - F_{43x} R_{43y} - F_{43y} R_{43x} - F_p R_{px} = I_{G_3} \alpha_3$$

F_{32} نفسها F_{23} بشرط بحل الاتجاهات صح

link 4:

$F_{34x} - F_{14x} = m_4 a_{G4x}$

$F_{34y} - F_{14y} = m_4 a_{G4y}$



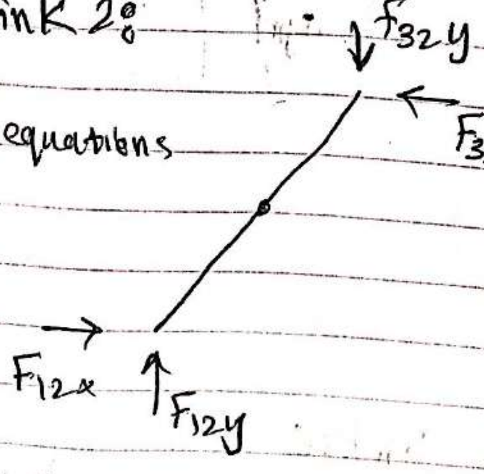
$-F_{34x} R_{34y} + F_{34y} R_{34x} - F_{14x} R_{14y} + F_{14x} R_{14y} + F_{14y} R_{14x} = I_{G}$

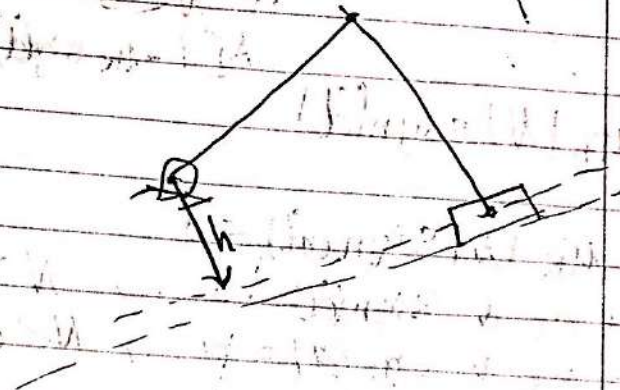
Remarks:

- Slider cranck with friction:

- link 2:

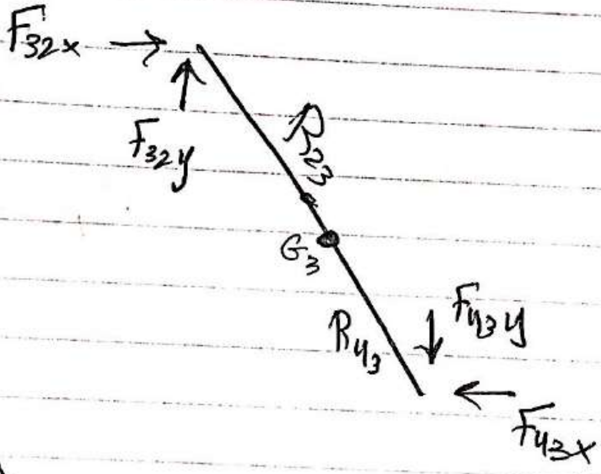
3 equations



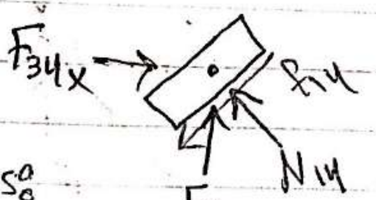


- link 3:

3 equations



Slider:



2 equations:

فش معادلة مومنت لل slider

- No moment equation for slider
- friction can be neglected

$$\Sigma F_x = m_4 a_{G4x}$$

$$\Sigma F_x = f_{14}\cos\theta_1 - N_{14}\sin\theta_1 + F_{34x} = m_4 a_{G4x}$$

$$\Sigma F_y = m_4 a_{G4y}$$

$$\Sigma F_y = F_{34y} + N_{14}\cos\theta_1 - f_{14}\sin\theta_4 = m_4 a_{G4y}$$

$$f = \mu_k N$$

في مشكلة: بقدرش ادخلها ك unknown في ال MatLab ال NW
بعتبر انها + واذا طلعت - بغيرها بالمعادلة

دائماً اتجاه f عكس الحركة

check:

if $N<0$ $\Leftarrow$ $\begin{bmatrix} & & \\ & \mu_k\, sign(\dot{d}) & \\ & & \end{bmatrix}\begin{bmatrix} f \\ N \end{bmatrix}$

$A[1 - \mu_k\, sign(\dot{d})]$

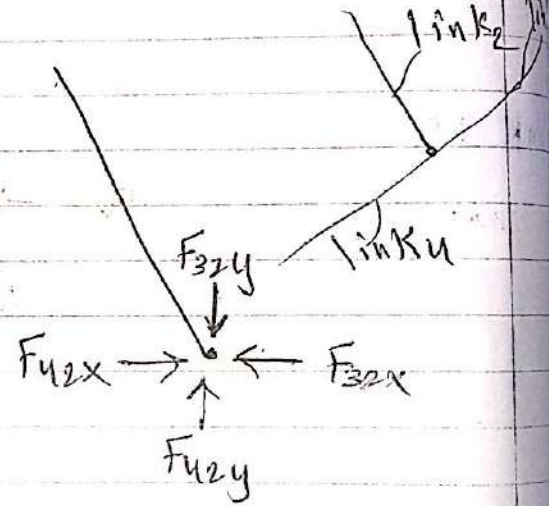
$$f = -\mu_k |N|\, sign(\dot{d})$$

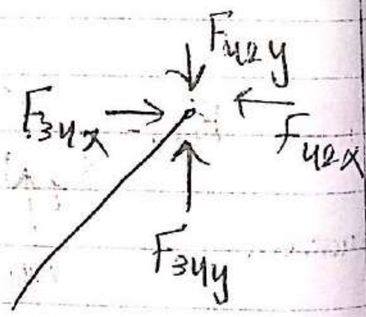
$$f + \mu_k |N|\, sign(\dot{d}) = 0$$

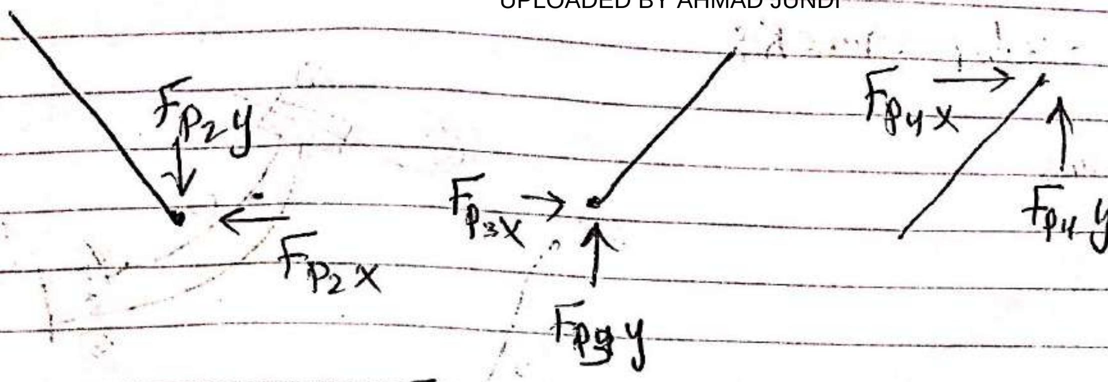
$$f + \mu_k N\, sign(\dot{d}) = 0 \quad , \quad N \geq 0$$

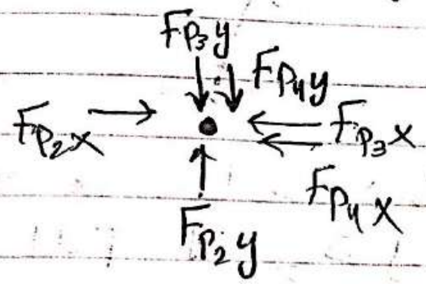
$$f - \mu_k N\, sign(\dot{d}) = 0 \quad , \quad N < 0$$

At pin joint between more than two links:



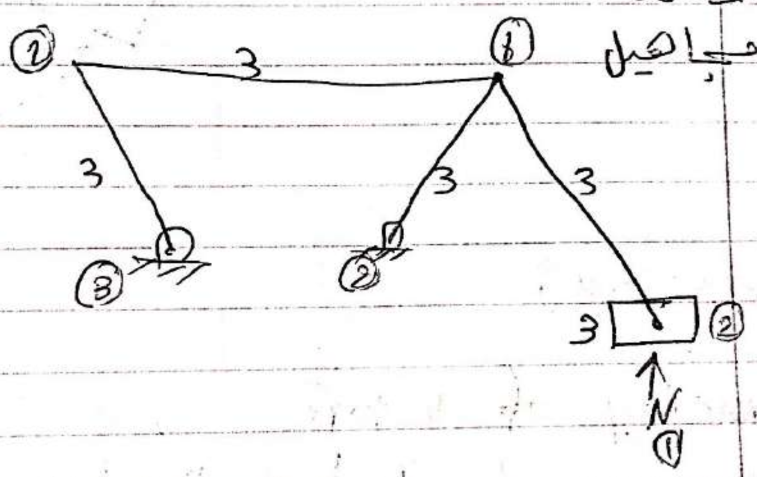






$$\boxed{\begin{aligned}\Sigma F_x &= 0\\ \Sigma F_y &= 0\end{aligned}}$$

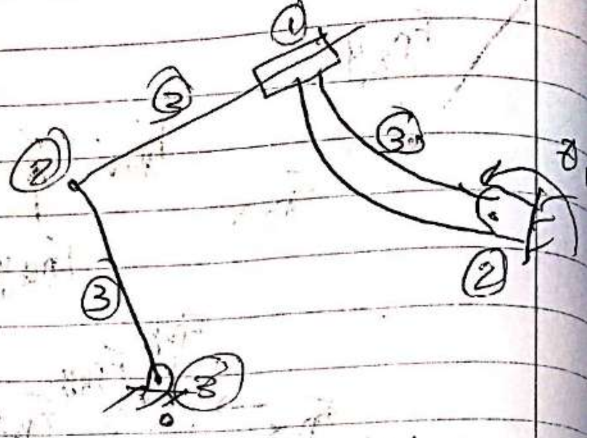
اسوز: معادلات
لحد: مجاهيل



ال Tourque لكل الmechanism لل input بيحسبه
مرة وحدة

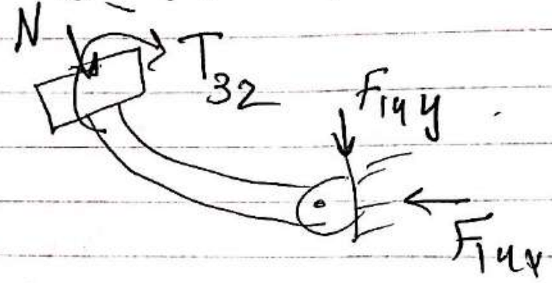
③ Inverted slider crank:

8 unknowns
9 equations.



لحد هلأ في معادلة زيادة

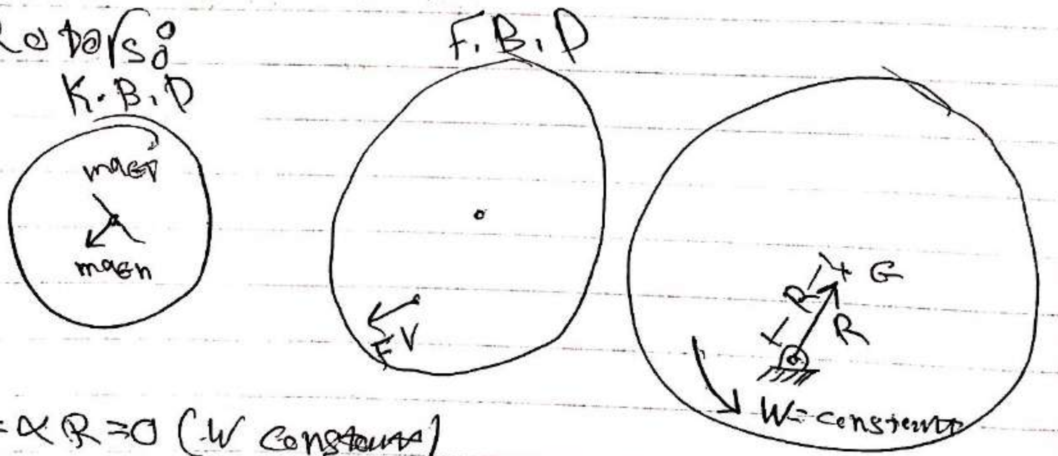
ال slider في ممانعة دوران عليه مش محسوبة
⇐ بضيف ال T للمجاهيل



Balancing:

- Balancing of rotors أي اشي بدور
- " of 4-bar mechanism

Ⓘ Rotors:

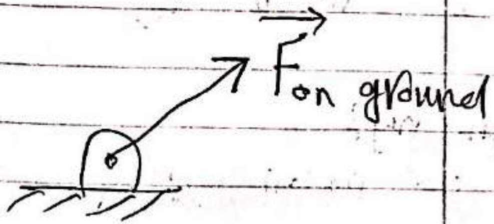


$a_{Gt} = \alpha R = 0$ (W constant)

$a_{Gn} = \omega^2 R$

$\sum \vec{F} = m\vec{a_G} = m\vec{a_G^n} + m\vec{a_{G_t}}$

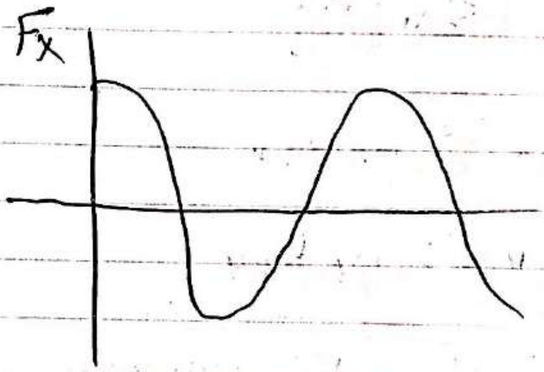
$\vec{F}_{\text{on disk}} = -m\omega^2 \vec{R}$

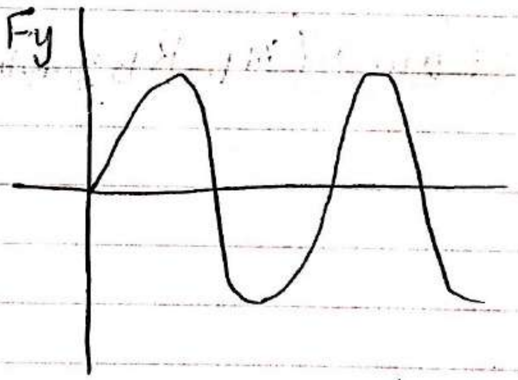


$\vec{F}_{\text{on groun}} = m\omega^2 \vec{R}$

$= m\omega^2 R\left[\cos\theta\, \hat{i} + \sin\theta\, \hat{j}\right]$

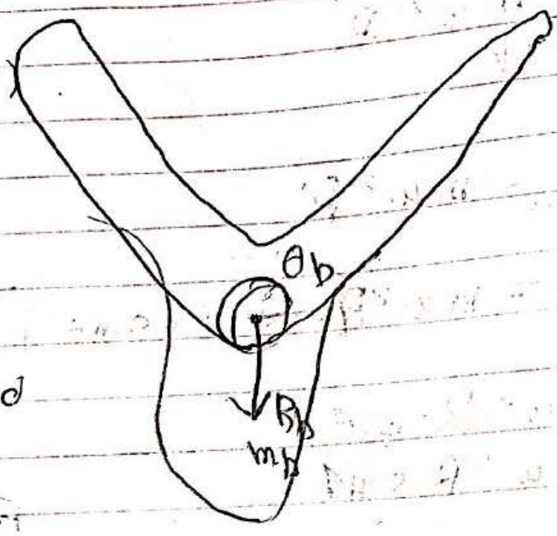
$F_x = m\omega^2 R\cos\theta$
$F_y = m\omega^2 R\sin\theta$





more than one mass on the same shaft:

$$\vec{F_1} = m_1 w^2 \vec{R_1}$$
$$\vec{F_2} = m_2 w^2 \vec{R_2}$$



balancing:

Static balancing:

$$\sum \vec{F} = 0$$
$$\vec{F_1} + \vec{F_2} + \vec{F_b} = 0$$

$$m_1 \vec{R_1} \cancel{w^2} + m_2 \vec{R_2} \cancel{w^2} + m_b \vec{R_b} \cancel{w^2} = 0$$

$$m_b \vec{R_b} = -\sum m_i \vec{R_i}$$

$$m_b \vec{R}_{bx} = -\sum m_i R_{ix}$$

$$m_b R_{by} = -\sum m_i R_{iy}$$

$$m_b R_b = \sqrt{m_b R_{bx}^2 + m_b R_{by}^2}$$

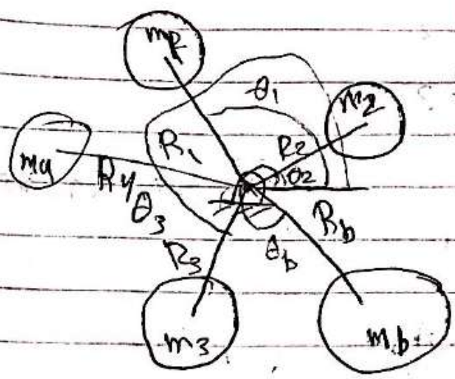
$$\theta_b = \text{atan}2(m_b R_{by}, m_b R_{bx}) \Rightarrow \text{given } R_b \Rightarrow m_b$$

Ex: عنبرهم y موجبة ٣٠°

$R_u = 1$

$\sum m_i R_i \cos\theta_i = -0.133$

$\sum m_i R_i \sin\theta_i = +0.872$



$m_b R_{bx} = +0.13$

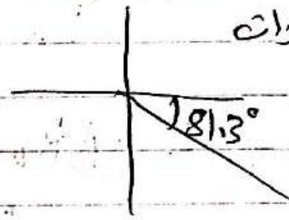
$m_b R_{by} = -0.872$

$\Rightarrow m_b R_b = \sqrt{(m_b R_b)_x^2 + (m_b R_b)_y^2}$

$m_b R_b = 0.882$, Suppose $R_b = 1$

$\Rightarrow m_b = 0.882$

$\theta_b = \tan^{-1}\left(\frac{0.72}{0.133}\right) = 81.3°$



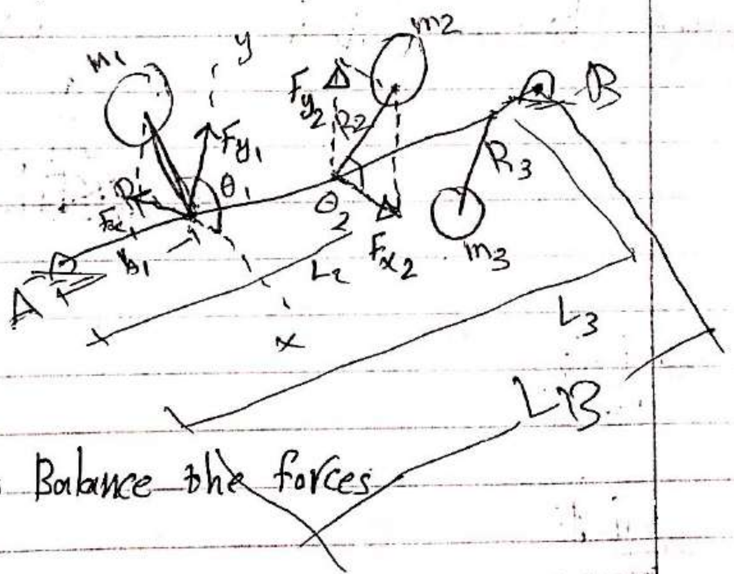
انتبه للإشارات
$\frac{-}{+} = -$
أنا بحالي
بشكل السالب
وبعتمد عالارباع

Dynamic Balancing:
Masses rotate in different planes

Ex:

$\vec{F} \Rightarrow$ Shaking Forces

add mass b in the indicated plane to balance the momen about the axis of plane A.



add new mass in plane A to Balance the forces

نفرض اتجاه Z axis العزوم احترف ... كل مناقشة الاشارة $M, L, \cos\theta$

$M_{1x} = F_{y_1} L_1 =$

nor $M_{2x} = F_{y_2} L_2$ $\quad F_{y_1} =$ $\quad M_{3x} = F_{y_3} L_3$

$M_{2y} = -F_{x_2} L_2$ $\quad M_{3y} = F_{x_3} L_3$

حول y

$F_{x_1} = m_1 R_1 \cos\theta_1$

$M_{1y} = -F_{x_1} L_1$ بالأصل My يكون (+)

بس لأنه في - داخل F_{x_1} من $\cos\theta$ نعدلها

b $\Sigma M_x = 0$ $\quad M_{bx}$

$\Sigma M_y = 0$

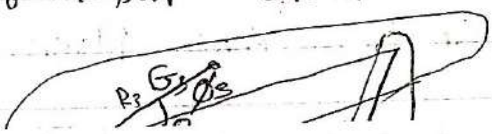
$$m_B R_{By} L_B = -\Sigma m_i R_i \sin\theta_i L_i$$

$$m_B R_{By} = \frac{-\Sigma m_i R_i \sin\theta_i L_i}{L_B}$$

$$m_B R_{Bx} = \frac{-\Sigma m_i R_i \cos\theta_i L_i}{L_B}$$

(II) Balancing Mechanism: 4-bar mechanism

ϕ = angle between L & R



$\bar{x} = \frac{\Sigma m}{\ldots}$

$\bar{y} = \frac{\Sigma}{\ldots}$

$m_{tot}\overline{X} = m_2 R_2 \cos(\theta_2 + \phi_2)$ - - - - -

$m_{tot}\overline{R} = m_2 R_2 e^{j(\theta_2+\phi_2)} + m_3(L_2 e^{j\theta_2} + R_3 e^{j(\theta_3+\phi_3)}) +$
$m_4(L_1 e^{j\theta_1} + R_4 e^{j(\theta_4-\phi_4)})$

$= m_2 R_2 e^{j\theta_2} e^{j\phi_2} + m_3 L_2 e^{j\theta_2} + m_3 R_3 e^{j\theta_3} e^{j\phi_3} + m_4 L_1 e^{j\theta_1} + m_4 R_4 e^{j\theta_4} e^{-j\phi_4}$ ①

Loop equations:

$L_2 e^{j\theta_2} + L_3 e^{j\theta_3} - L_4 e^{j\theta_4} - L_1 e^{j\theta_1} = 0$

$e^{j\theta_3} = \dfrac{L_1 e^{j\theta_1} + L_4 e^{j\theta_4} - L_2 e^{j\theta_2}}{L_3}$ - - ② substitute in ①

$= - - - - - + m_3 R_3 \left(\dfrac{L_1 e^{j\theta_1} + L_4 e^{j\theta_4} + L_2 e^{j\theta_2}}{L_3}\right) e^{j\phi_3}$

$= - - - + m_2 R_2 e^{j\phi_2} + m_3 L_3 - \{m_3 R_3 \frac{L_2}{L_3} e^{j\phi_3}\} e^{j\theta_2} + (m_4 R_4 e^{j\phi_4} + m_3 R_3 \frac{L_4}{L_4} e^{j\phi_3}) e^{j\theta_4}$

Page 619

go to the book, and collect terms

if $(\underset{=0}{\underline{\quad\quad}})\, e^{j\theta_2} + (\underset{=0}{\underline{\quad}})\, e^{j\theta_4}$ $\Rightarrow$ variables $= 0$

I have to add a term here and here

$m_b R_{4x} + j\, m_{4b} R_{4by}$

$\tan^{-1}\left(\dfrac{m_{4b} R_{4by}}{m_{4b} R_{4bx}}\right) = \phi$

$m_b R_{4b} = \sqrt{(m_b R_{4x})^2 + (m_{4b} R_{4b})_y^2}$

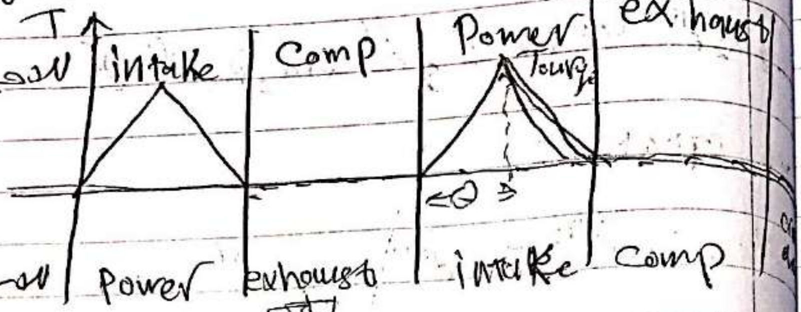
$\phi_{4b} = \tan^{-1}\left(\dfrac{(\quad)y}{(\quad)x}\right)$ الانتباه للإشارات
بالإضافة لبداية ϕ

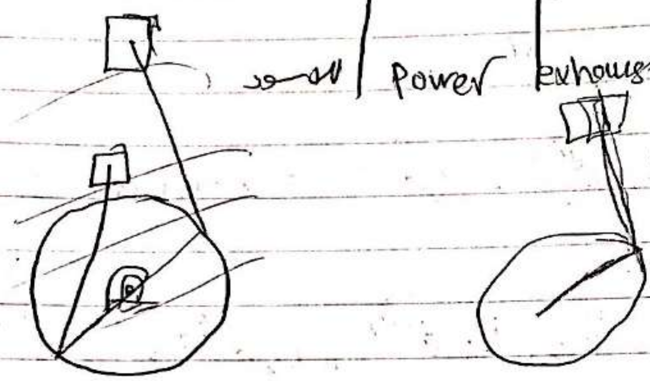
Fly Wheels:

Types of engines:

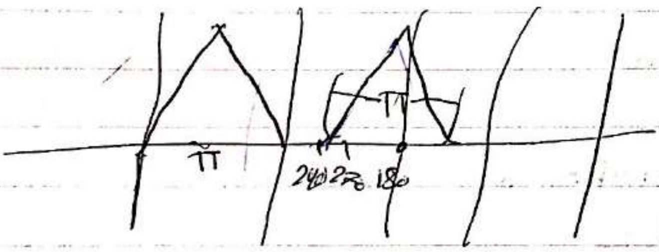
Internal Compustion Engine (4-stroke engine):

Turning Moment Diagram





Crank angle $= \dfrac{4\pi}{\text{number of cylinders}} = \dfrac{\text{Duration of complete}}{\#\text{ of cylinder}}$



240 - angle ⇐

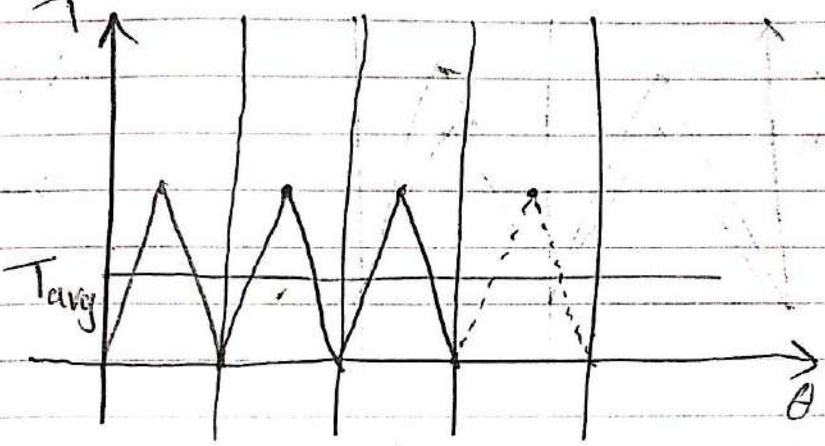
Total energy in one cycle = total work of the engine

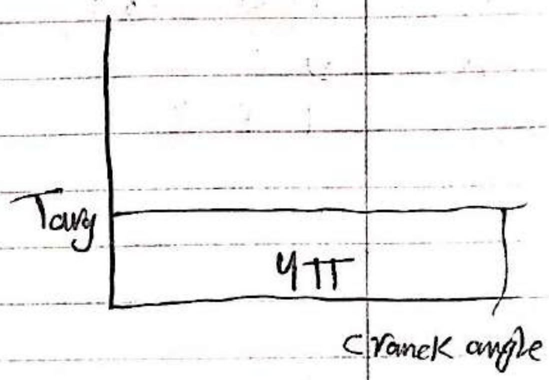
$U_M = \int M\,d\theta = \int T\,d\theta$

= Total area under the curve

= Area under T-θ diagram of one cylinder $\times$ # of cylinders

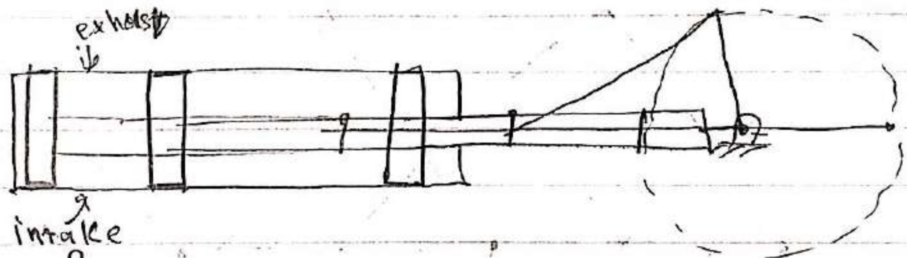
$T_{avg} = \dfrac{\text{Total area under the curve}}{\text{duration of one cycle}}$



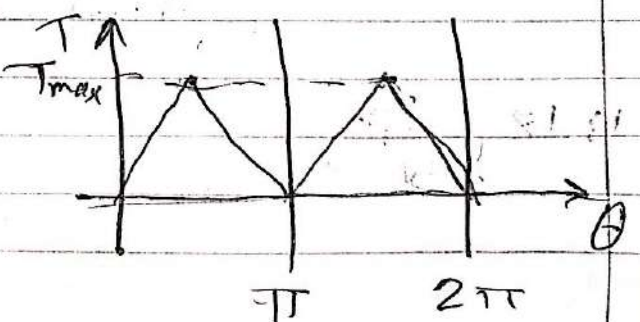


* Steam Engines:

① Single acting cylinder



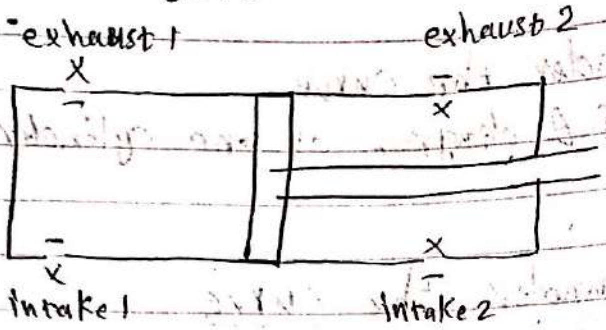
Duration of one cycle = 2π



② Double acting Cylinder:

Single:

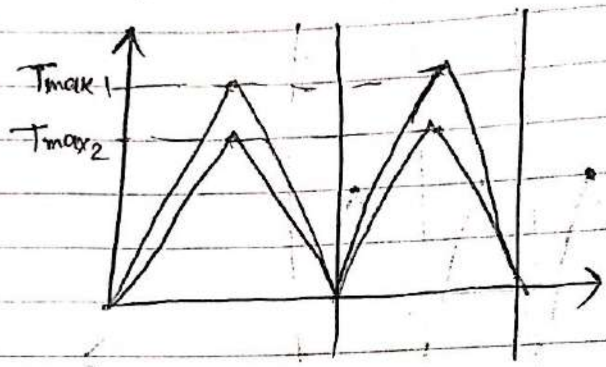
Duration of one cycle $= 2\pi$



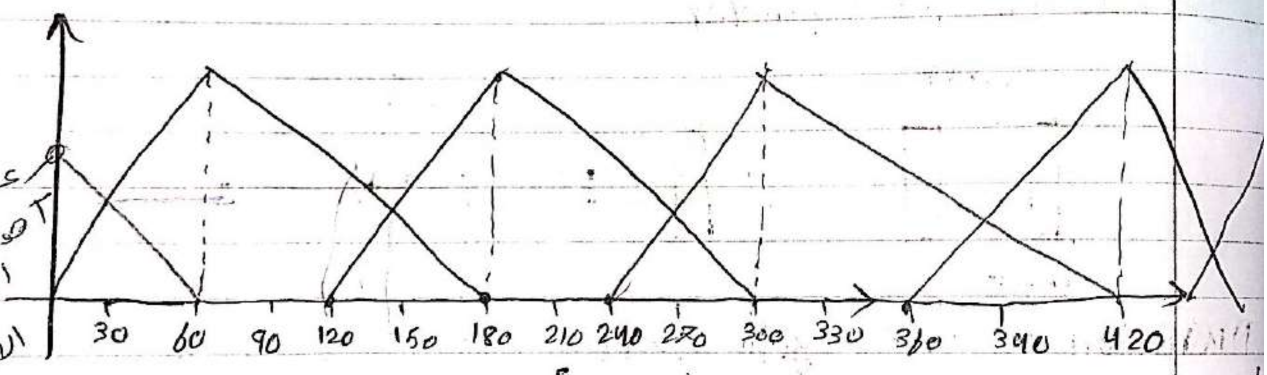
T وهو راجع > T وهو رايح

بسبب اختلافات ال A

$F = \frac{P}{A}$ p نفسه عالجهتين



3 Cylinders crack angle $= \frac{2\pi}{3} = 120°$



لحد 360 واللي بزيد بخليه أول اشي

عرض كل مثلث 180°

crack angle $= 120°$

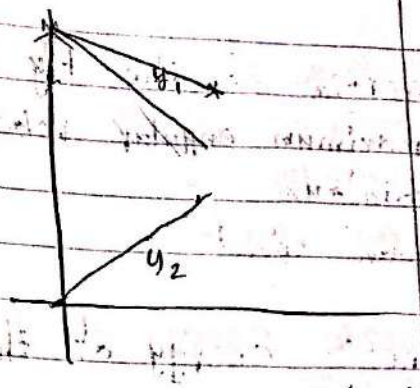
Ex 13.17 مهم في الرابط

$y_1 = m_1 x_1 + b_1$

$y_2 = m_2 x_2 + b_2$

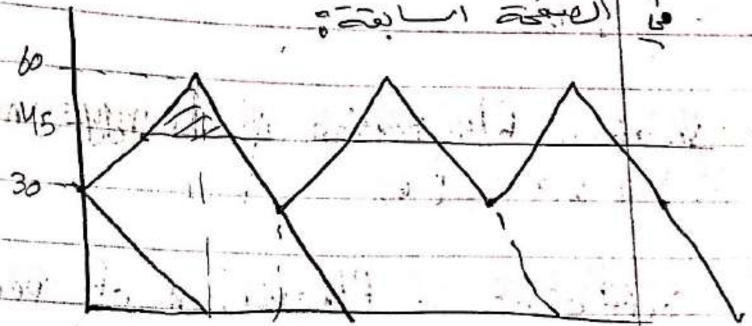
$$\boxed{y_{total} = y_1 + y_2 = (m_1 + m_2)x + (b_1 + b_2)}$$

$y_{tot} = m_{tot} X + b_{tot}$



في الصفحة السابقة

اجت بالنص عند 30 لأنه
البداية 60 والنهاية 180 وجاية
120 بيصير يعني النص بالتالي $\frac{1}{2}$ الطول



مصور عالتلفون

Find the maximum fluctuation of energy = e (Energy Provided by flywheel)

Identify the points at intersection between the T_{avg} & T_{rot}

المعادلات ثابتة عالدوسيات ، اسم الصحيح عشان توجد الطاقة ، طبعه القوانين المطلوبة بتكون حليت السؤال

$I \equiv$ inertia of the fly wheel

$w_1 =$ maximum angular velocity of the flywheel (max speed)

$w_2 \equiv$ minimum " " " " " (min speed)

$w \equiv$ mean speed.

$E \equiv$ Kinetic energy of the flywheel at mean speed
$= \frac{1}{2} I w^2$

$e \equiv$ maximum fluctuation of energy $\equiv$ energy supplied by the flywheel
$= \frac{1}{2} I w_1^2 - \frac{1}{2} I w_2^2$

$K \equiv$ Coefficient of fluctuation of speed
$= \frac{w_1 - w_2}{w} * 100\%$

Coefficient of fluctuation of energy $= \frac{e}{\text{Total work in one cycle (total area under } T\text{-}\theta \text{ curve)}}$

(ii) 13.17

بنا نطلع علاقة مباشرة E & K & e

~~13.18~~

$$e = \frac{1}{2} I (w_2^2 - w_1^2) = I \underbrace{\boxed{\frac{(w_1 - w_2)}{w}}}_{K} \underbrace{\boxed{\frac{(w_1 + w_2)}{2}}}_{w} * w$$

$$e = I K w^2 = \underbrace{\boxed{\frac{1}{2} I w^2}}_{E} K (2) \Rightarrow e = 2EK$$

$$\Rightarrow \boxed{K = \frac{e}{2E} = \frac{e}{I w^2}} = \frac{2.5\pi}{(m K_G^2)\, w^2} = \frac{2.5\pi}{(6)\underbrace{(0.088)^2}_{\text{given}}\left(400 \times \frac{2\pi}{60}\right)^2}$$

K_G: radius of gyration

rpm to rad

(iii) Coef. of fluc. of energy $= \frac{e}{\text{Total work}} = \frac{2.5\pi}{3 \times \frac{1}{2} \times \pi \times 60}$

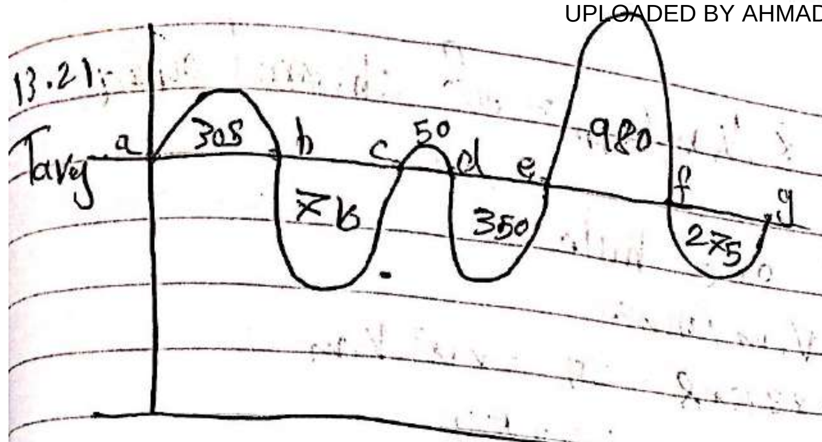
(iv) maximum Tourqe

دائما أعلى

نقطة ماهو عامل

Ex 13.21

13.21:



$\omega = 1800$ rpm

$K = ?$

$I = m k_G^2 = 40 \times (0.14)^2$ $\qquad K = \frac{e}{I\omega^2}$

to find e:

assume the energy of a = H

" " " " $\boxed{b = H + 305}$ Max energy

" " " " $c = H + 305 - 710 = H - 405$

$d = H - 405 + 50 = H - 355$

$\boxed{e = H - 355 - 350 = H - 705}$ min energy

$f = H - 705 + 980 = H + 275$

$g = H + 275 - 275 = H$ هاد check $\int$

$e = H_{max} - H_{min}$

$= H + 305 - (H - 705) = 1010 \text{ mm}^2$ $\qquad$ 1mm = 6N.m

$= 1010 \text{ mm}^2 \left(\frac{6 N.m}{mm}\right)_{\text{ارتفاع}} \times \left(\frac{1° \times \frac{\pi}{180°}}{mm}\right)_{\text{عرض}}$ $\qquad 1° = 1mm$ لكل

$= 105.8 N.m$

$K = \frac{105.8}{40 (0.14)^2 \times \left(1500 \times \frac{2\pi}{60}\right)^2} = 5.454 \times 10^{-3} = 0.55\%$

Ex 13.27

الفترة اللي بقص فيها بتكون طويلة

13.27: The Plate requires 8 N.m/mm² of sheared area

Energy required to shear one hole
= Shear area × 8 N.m/mm²
$= 2\pi r t \times 8 = 2\pi \times 20 \times 35 \times 8 = 35.2 \times 10^3$ N.m
thickness
= 35.2 kJ

% Without the flywheel the power of the required motor
تعليمه

time to shear one hole = $\frac{1 \text{ min}}{6} = \frac{60 s}{6} = 10$ s

Power $= \frac{\text{Energy}}{\text{time}} = \frac{35.2 \text{ kJ}}{10 s} = 3.52$ kW (With flywheel)

actual cutting time $= \frac{35}{2 \times 95} \times 10 = 1.84$ sec
بتقطع بس 35 من ال 95
وبس يقطع وهو نازل بس

Power without flywheel required motor $= \frac{35.2 \text{ kJ}}{1.84} = 19.13$ kW
كزززززوة ؟

The energy supplied by the motor in 1.84 s = 35.2 × 1.84 = 6.48
" " " " flywheel = 35.2 − 6.48 = 28.7 kJ

V = 20 m/s , m = ?
$V = W$
مجال
$I = m$

$K = \frac{w_1 - w_2}{w}$

$(0.03)(w) = (\Delta w + w) - \cancel{(w - \Delta w)}$

$K = \frac{e}{I w^2} = \frac{e}{m v^2}$

m = 2390 kg

Force Analysis Using Polygons:

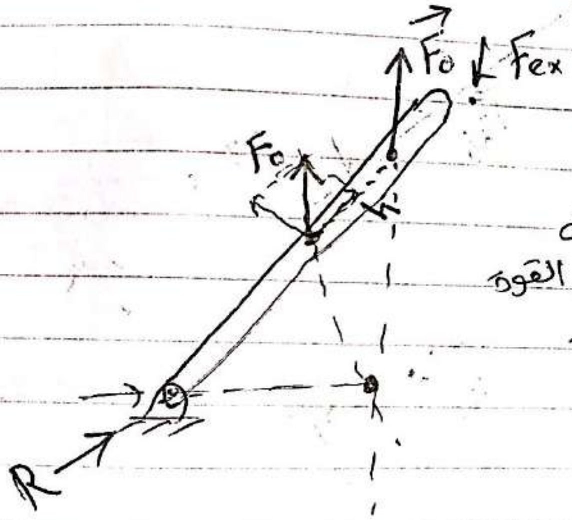
$\sum \vec{F} = m\vec{a} \Rightarrow \sum \vec{F} + \vec{F_o} = 0$

$\vec{F_o} = -m\vec{a}$ عشان يشكل ال Polygon

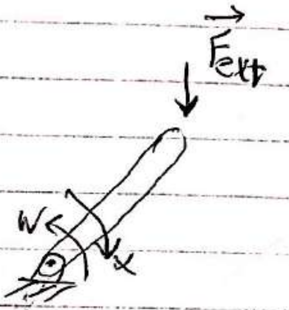
$\sum M_G = I_G \alpha \Rightarrow \sum M_G + M_o = 0$

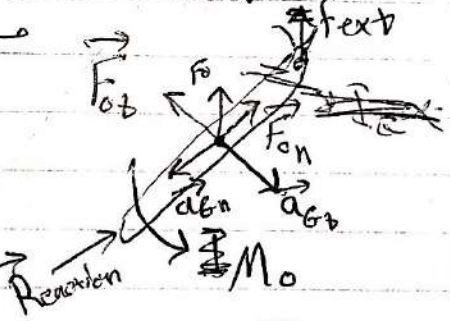
~~$\sum M_G - I_G \alpha = 0$~~ $M_o = -I_G \alpha$

1) Ex: Find reaction force



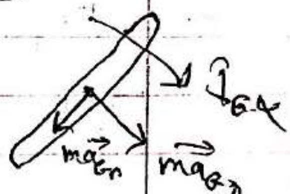
بدنا نضيع المومنت
من خلال تحريك القوة
مسافة معينة

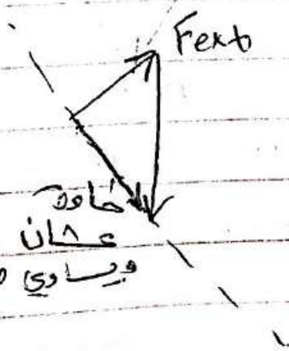




Suppose $\omega = 0 \Rightarrow a_n = 0$

$h = \frac{I_G \alpha}{m a_G}$ $\quad h = \frac{I_G \alpha}{m r \alpha} \Rightarrow h = \frac{I_G}{m r}$





$F_o h = M_o$

$m a_G h = I_G \alpha$

$h = \frac{I_G \alpha}{m a_G}$

إضافة
عشان يسكر
ويساوي صفر

Force Analysis Using Polygons:

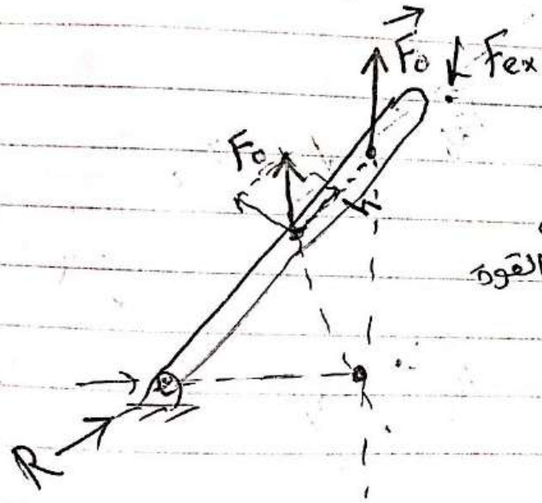
$\sum \vec{F} = m\vec{a} \Rightarrow \sum \vec{F} + \vec{F_o} = 0$

$\vec{F_o} = -m\vec{a}$ علشان يسكر ال Polygon

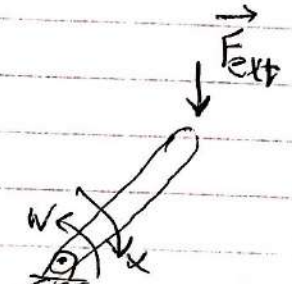
$\sum M_G = I_G \alpha \Rightarrow \sum M_G + M_o = 0$

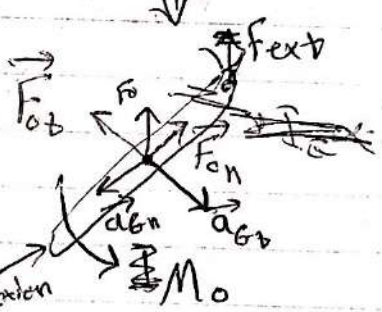
$\cancel{\sum M_G - I_G \alpha = 0}$ $M_o = -I_G \alpha$

Ex: Find reaction force



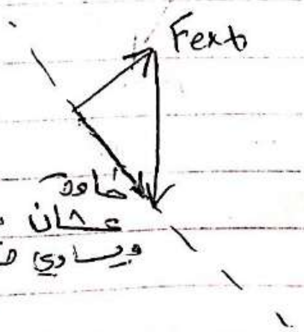
بدنا نضيع المومنت
من خلال تحريك القوة
مسافة معينة

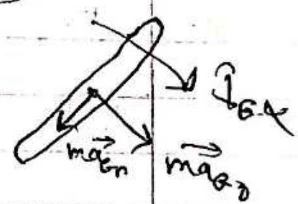




$h = \frac{I_G \alpha}{m a_G}$ Suppose $\omega = 0 \Rightarrow a_n = 0$

$h = \frac{I_G \alpha}{m r \alpha} \Rightarrow h = \frac{I_G}{m r}$





$F_o h = M_o$

$m a_G h = I_G \alpha$

خاطئة
علشان يسكر
ويساوي صفر

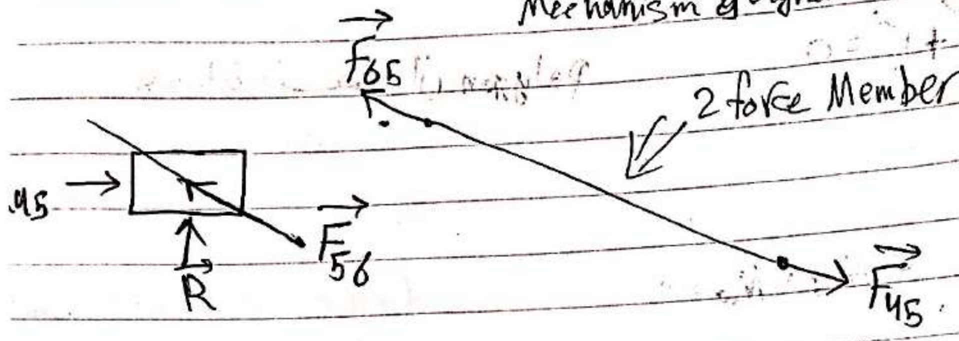
$h = \frac{I_G \alpha}{m a_G}$

سؤال من 485 في الكتاب

Mechanism & dynamic Machinery

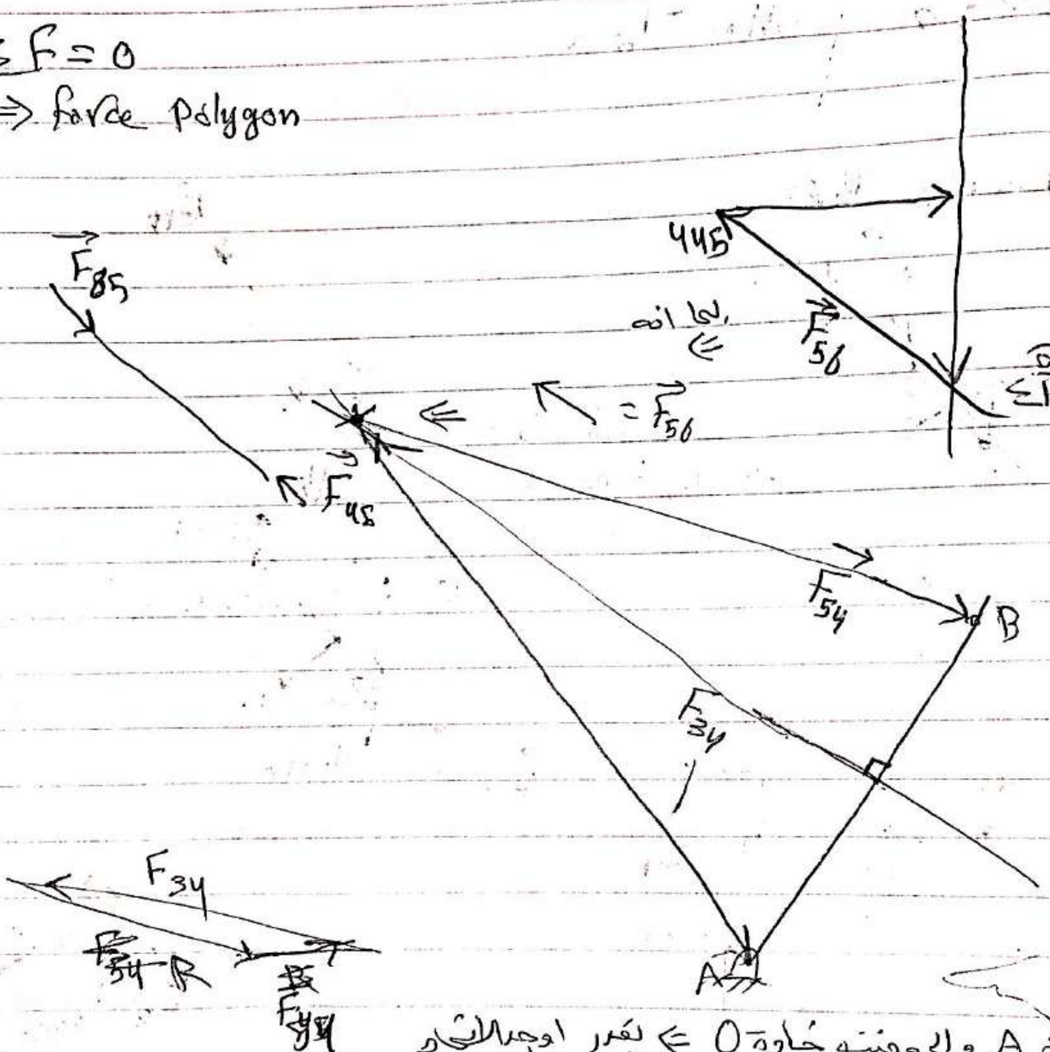
No a_G

No α



$\Sigma F = 0$

$\Rightarrow$ force Polygon

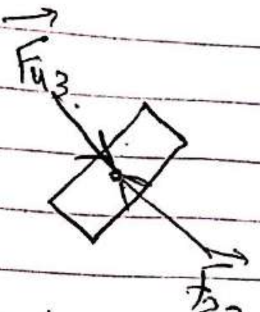


خاوة $\Sigma F = 0$ لأنه $\vec{r}_1+\vec{r}_2+\vec{r}_3$

بعرف اتجاه R

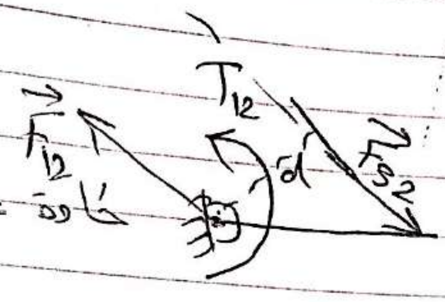
اتجاه F_{34} : امسك A والحوفته خاوة O ⇐ بقدر اوجد الاتجاه

اتجاه R : امسك B : " O ⇐ " " "



واتجه اللينك الافقي لأ حطيت الفورس افقي

كافة لانه مش محدد فيها تفاصيلها هاذا pin ممكن يأثر بأي اتجاه

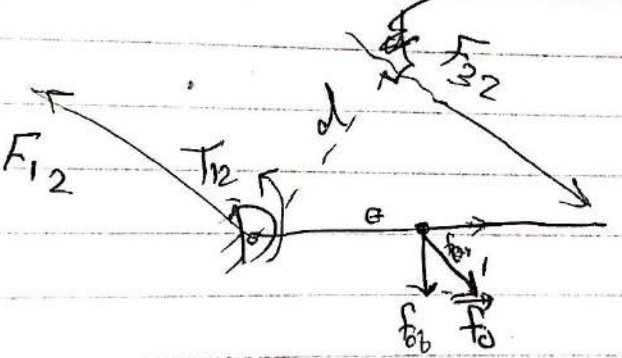


كاوة عشان تعكس $\vec{F}_{32}$ مش عارفين

$\Sigma M_o = 0$

$\vec{T}_{12} + (\vec{F}_{32}\vec{d}) = 0$

$+T_{12} - F_{32}d = 0$



اذا كان في α

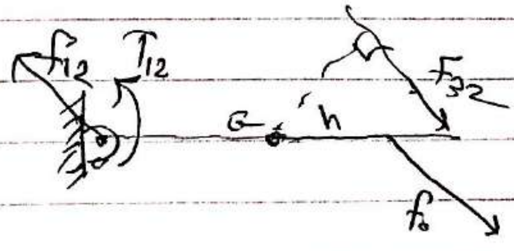
Dynamic

3 forces without Torque (external moment)

use h

$\Sigma M_o = 0$

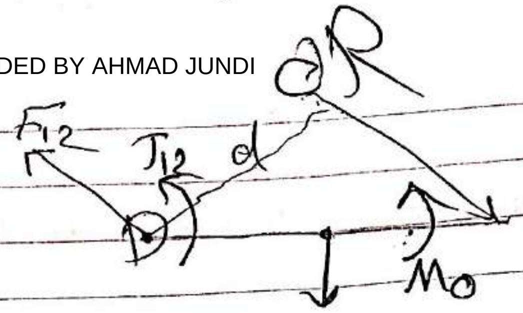
$\Rightarrow T_{12} + (\vec{f_o}\vec{h}) + \vec{F}_{32}\vec{d} = 0$



$T_{12} \oplus f_o h \oplus F_{32}d = 0$

مستعمل — مش عارف

تحريك f_o ألغى M_o اللي هو $I_G\alpha$



أو ما بحرك اشي فبعطي M_o وبحطه بالمعادلة

$$T_{12} - M_o - F_{o} \, r_{G_2/O_2} - F_{32} d = 0$$