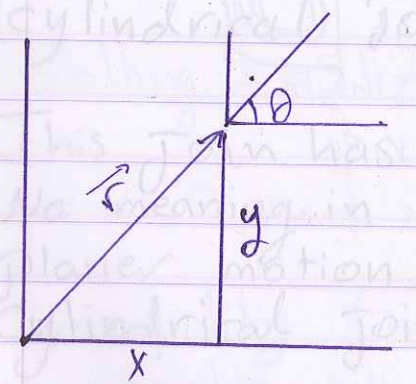
Machine Dynamic
⇓
Mechanism

body Joint

Degress of freedom

number of indepandant parameters need to tataly control the body machine

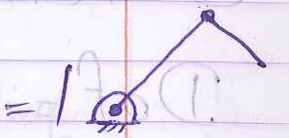


In the Plan 2D each body has 3 degree of freedom

① Revelate Point = Pin

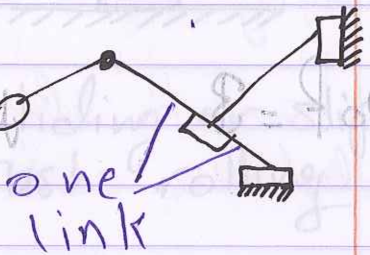
in 3D plane each body has 6 degree

Joints

① Revelute Joint Dof = 1 

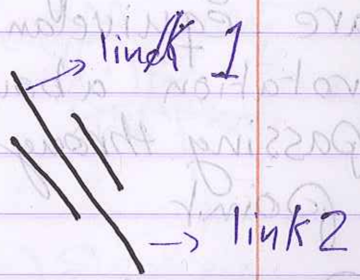
② Prismatic Joint Dof = 1

≡ Slider



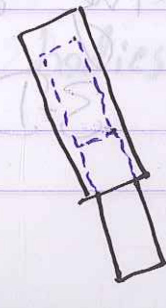
③ cylindrical Joint (3D Space)

This Join has No meaning in planer motion Cylindrical Joint



يحتاج ٣ متغيرات

X , Y , θ



④ Helical Screw Joint

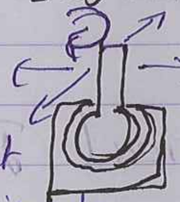
Dof = 1   3D spase

⑤ Spherical Joint

3D - space

Dof = 3

عبارة عن كرة داخل
فنجانة كروية



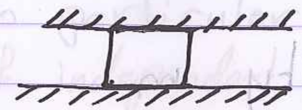
Note: any 3 axics passing through about are equivelant a single rotation about axies passing through the same point

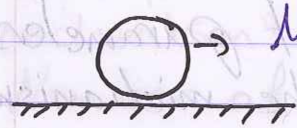
⑥ Sliding on the plane has 3-Dof

⑥ contact

- translation without rolling

DoF = 1





→ No sliding or slipping
Just rolling

(Pure Rolling)

Rolling + Sliding

DoF = 1

mobility (m)

n = number of bodies including the ground

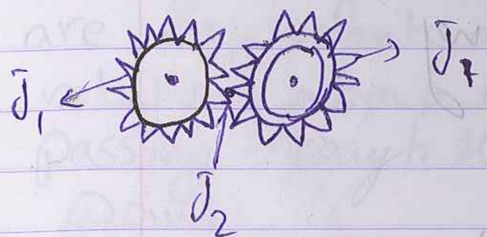
$m = 3(n-1) - 2J_1 - J_2$

J_1 :- number of Joint that have 1 DoF
J_2 :- number of Joint that have 2 DoF

mobility m

Number of independant parameters needed to control the michanism

n = number of bodies including the groud



$n = 3$

$m = 3(n-1) - 2J_1 - J_2$

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

* Mobility [Degree - of - freedom] :-

Number of input that must be control independently to put a mechanism in to particular poition "Namber of independant part required to describe Motion of mechanism"
" Number of indepantant parameters"

* Kutz bach criteria :-

" $m = 3(n-1)\ 2J_1 - J_2$ "

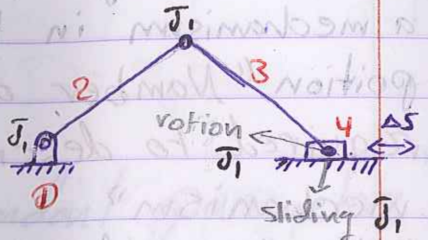
m : mobility (DOF)
n : No. of links including graund
J_1 : No. of single DoF Joints.
J_2 : No. of tow DoF Joints.

if $m = 0 \longrightarrow$ struture ((No motion))

if $m > 0 \longrightarrow$ mechanism ((motion))

if $m < 0 \longrightarrow$ indeterminal struture $\rightarrow$ "No mation"

Ex]



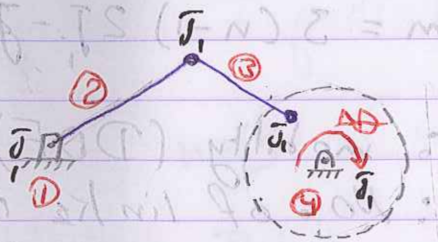
$n = 4$

$J_1 = 4$

$J_2 = 0$

$m = 3(4-1) - 2(4) - 0 = 1$

Ex]



$n = 4$

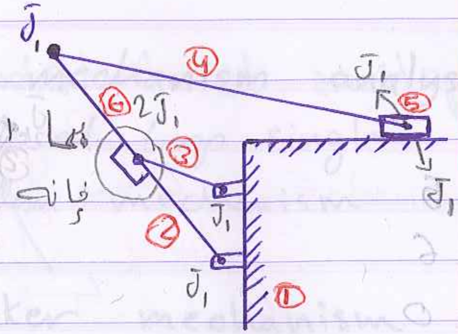
$J_1 = 4$

$J_2 = 0$

$m = 1$

Ex]

بما انه بربط 3 link
فانه يعتبر $2J_1$



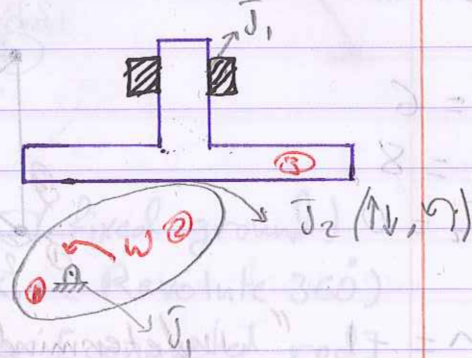
$n = 6$

$J_1 = 7$

$J_2 = 0$

$m = 1$

Ex]



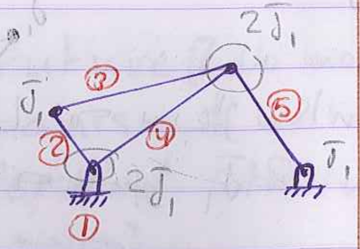
$n = 3$

$J_1 = 2$

$J_2 = 1$

$m = 1$

Ex]



$n = 5$

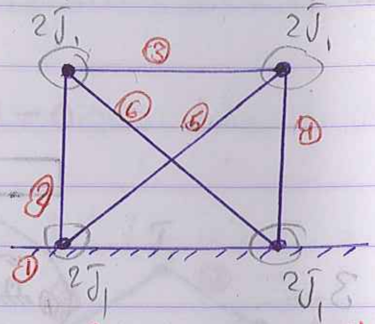
$J_1 = 6$

$J_2 = 0$

$m = 3(5-1) - 2(6) - 0$

$= 0$ "structure"

Ex]



$n = 6$

$J_1 = 8$

$J_2 = 0$

$m = -1$ " indetermind structur"

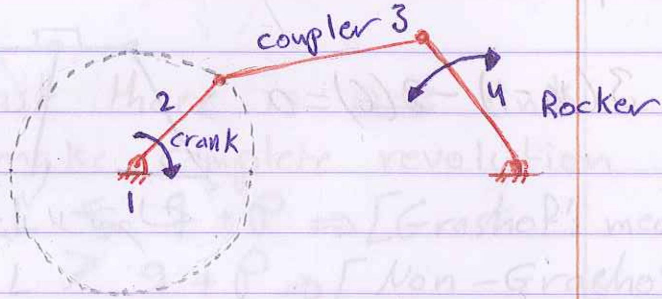
Ch.2

* Four bar mechanism analysis

simplest closed Loop single degree-of-freedom mechanism

* Crank-Rocker mechanism

link



link 1 - from (fixed ground)

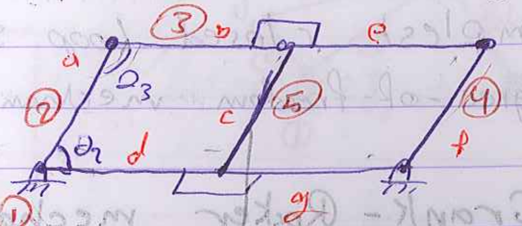
2 - crank (Revolute 360°)

3 - coupler [connected rod]

4 - Rocker [dose not rotate but oscillates]

$m = 1$

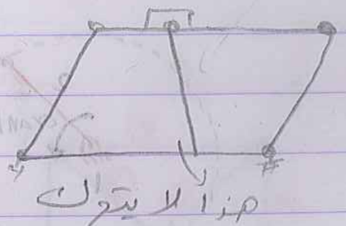
Exceptions to Kutzbach theory



هذا يتحرك لانه موازية
link

$n = 5$

$J_1 = 6$



$3(n-1) - 2(6) = 0$

* Four bar mechanism anylsis

* Grashof's four bar mechanism

S = shortest link
L = longest link
P, q = other link

at least there is one link that make complete revolution

if $S + L \leq q + P \Rightarrow$ [Grashof's mechanism]

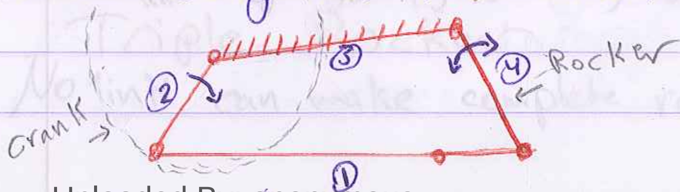
if $S + L > q + P \Rightarrow$ [Non-Grashof's]

Types of 4- bar mechanism

360° oscillat

$\boxed{1-}$ Cranke - Rocker mechanism

Shortest link must be one of the side link "shortest link will make completet revolution"

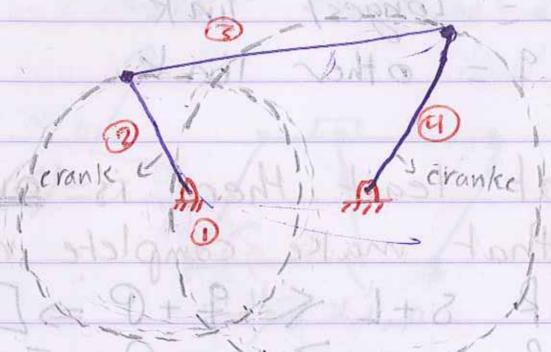


2- Double cranke mechanism

$S + L \leq P + q$

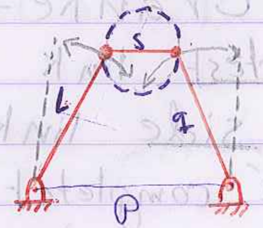
Shortest link is the frame (fixed)

both side link will revolute 360°



3- Double Rocker mechanism

$S + L \leq P + q$

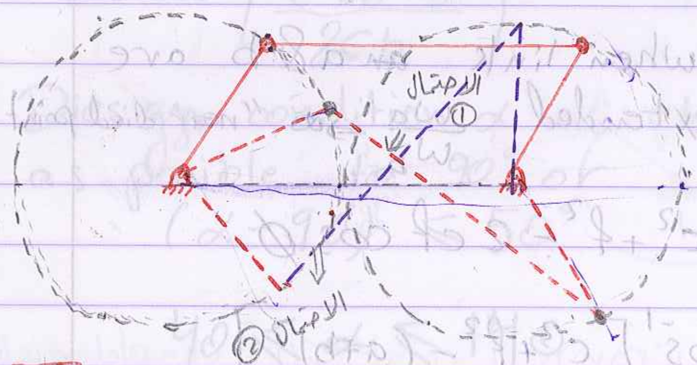


4- chang point mechanism

$P + q = S + L$ على نفس الخط

when all link become aligned

The Interminant motion



5- Triple Rocker mechanism

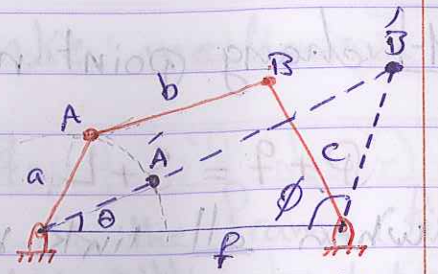
$S + L > P + q$

* Dead Point Configurations

mechanism تعطل مرحلة لا يتحرك فيها

Triple Rocker

No link can make complete revelou tion



when link ~~an~~ a & b become aligned a torque applied on link c will not rotate the mechanism

State 1 :- when link ~~an~~ a & b are completly extended $\frac{\omega_a}{\omega_b} \to \infty$ "near died point"

$$(a+b)^2 = c^2+f^2-2cf\cos\phi$$

$$\therefore \phi = \cos^{-1}\left[\frac{c^2+f^2-(a+b)^2}{2cf}\right]$$

$$\theta = \cos^{-1}\left[\frac{f^2+(b+a)^2-c^2}{2f(b+a)}\right]$$

⇒ the mechanism can be used as velocity magnifier near dead point

☒ Transmissoion Angle

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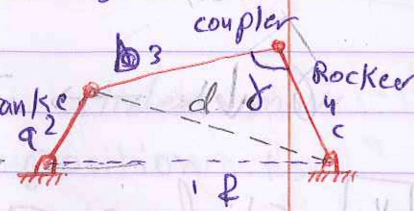


if link 2 = input [crank] cranks
link 4 = output [Rocker]

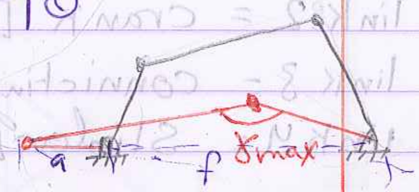
γ is Transmission angle

$$\gamma = \cos^{-1}\left[\frac{c^2+b^2-d^2}{2cb}\right]$$

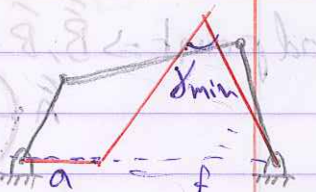
Diesign condition α as closed as possible to 90° or

$$(\alpha-90^\circ) \le 50^\circ$$

$$40 \le \alpha \le 140$$



γ max
$d = d_{max} = f+a$



γ min
$d = d_{min} = f-a$

$T_{out} = f \sin\gamma \cdot (c)$

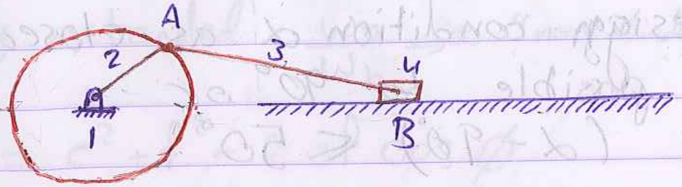
Torqe
T max when $\gamma = 90°$

$\gamma \downarrow \longrightarrow T \downarrow$

$\boxed{*}$ slider crank mechanism :-

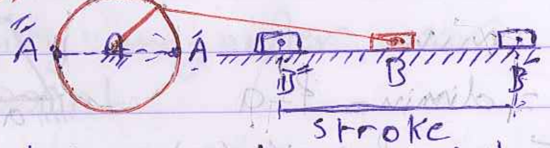
$\boxed{Ex}$

[1] piston in internal combustion engine
[2] pumb



link 2 = crank [rotat 360°] complete revolution
link 3 = connicting rod ترددية
link 4 = Slider [move in reciprocating motion]

Dead point => $\bar{B}, \bar{\bar{B}}$



stroke : distance between extreme point of slider

strocke :-

The distance that the slider move from extrem right position to extream left

$Stroke = X_R - X_L$

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

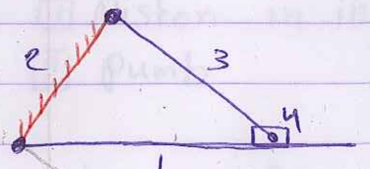
$= 2a$

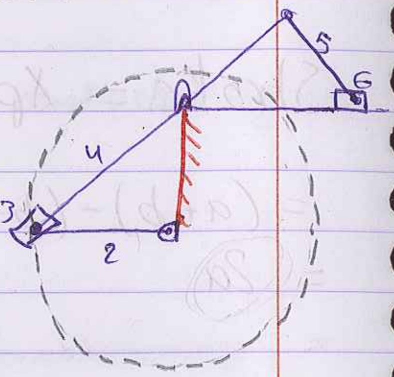
[*] Type of slider crank mechanism

1- Crank is fixed

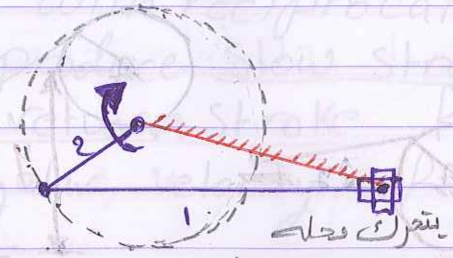
"Rotary engine"

whiter worth quick return mechanism

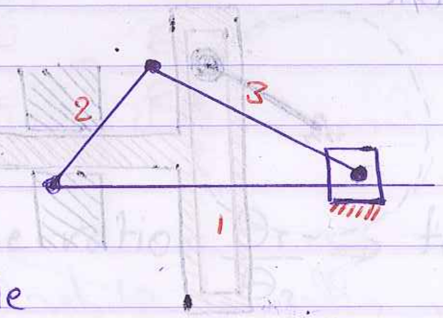




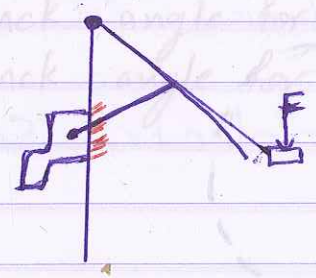
2- Connecting rod fixed



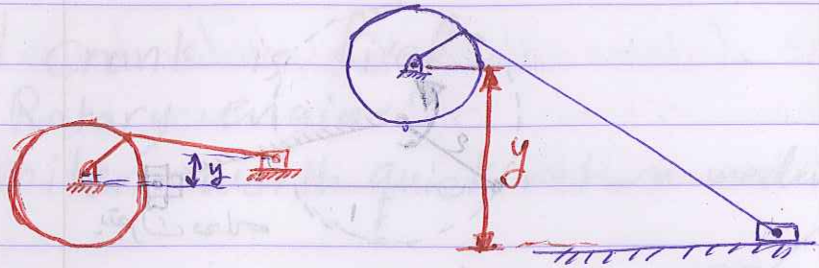
3- Slider fixed



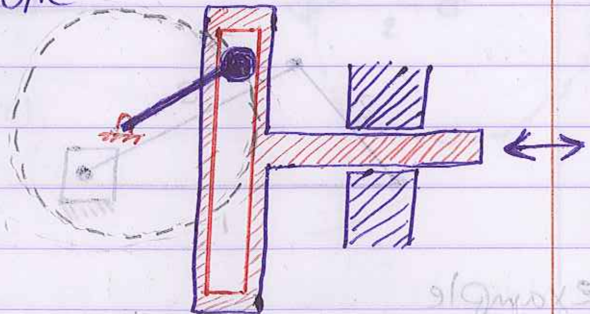
example

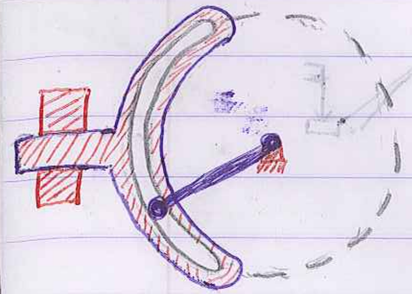


4 oFFset Slider-Cranke mechanism



5 Scotch Yoke





ترددية ⇐ أمام ⇌ خلف

Quick Return mechanism:-

- It is Used with reciprocalling engines to produce Slow strock and quick return stroke for constant angular velocity of crank.

- Time ratio = $\frac{\text{time of working strock}}{\text{time of return strock}}$

$$= \frac{\frac{\theta_1}{\omega}}{\frac{\theta_2}{\omega}} = \frac{\theta_1}{\theta_2}$$

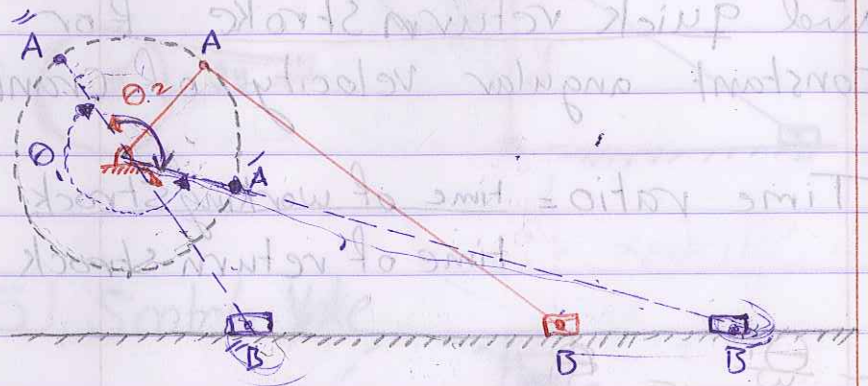
∴ Time ratio = $\frac{\theta_1}{\theta_2}$ ⇒ time ratio > 1

where θ_1 : Cranck angle for working strok

θ_2 : Cranck angle for retern strok

X Quick return mechanism

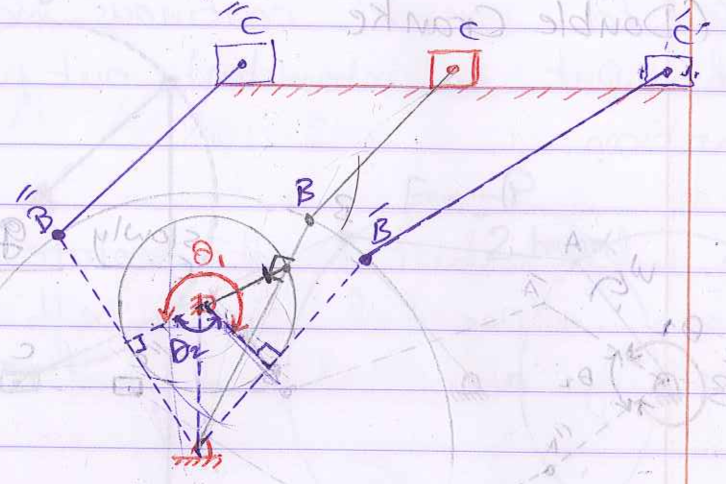
1 Offset slider crank



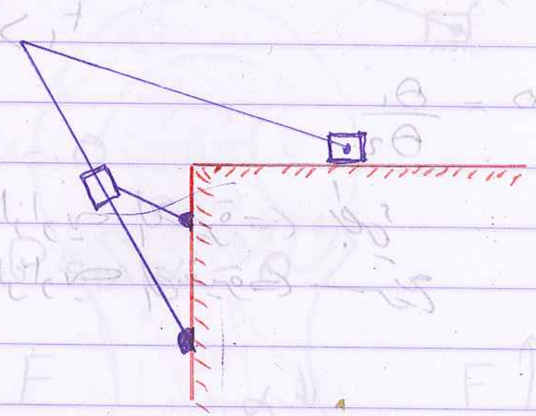
Slider move from $\overset{=}{B} \rightarrow \overset{-}{B}$ with
Slow stroke
Time ratio $\simeq 1.0$
So $\Rightarrow$ Not an effecient slider crank
Mechanism

Example:- electric Saws , shapers

2- Crank shaper mechanism

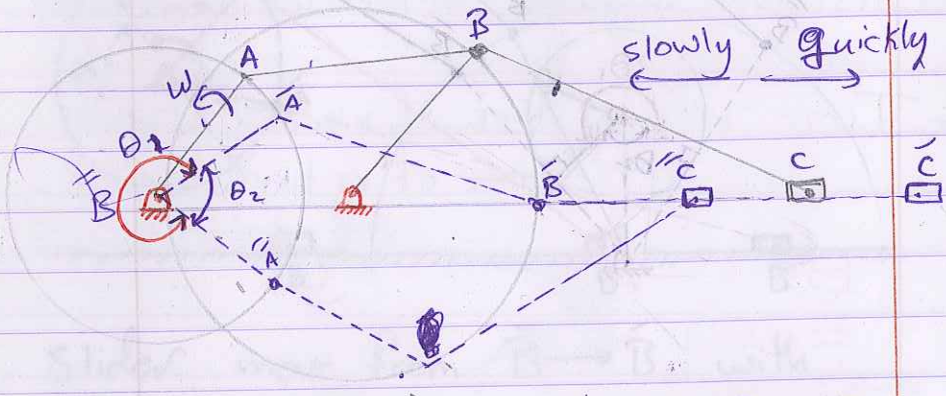


anther



3 Drag link Mechanism :-

(Double Cranke



$\theta_1 > \theta_2$

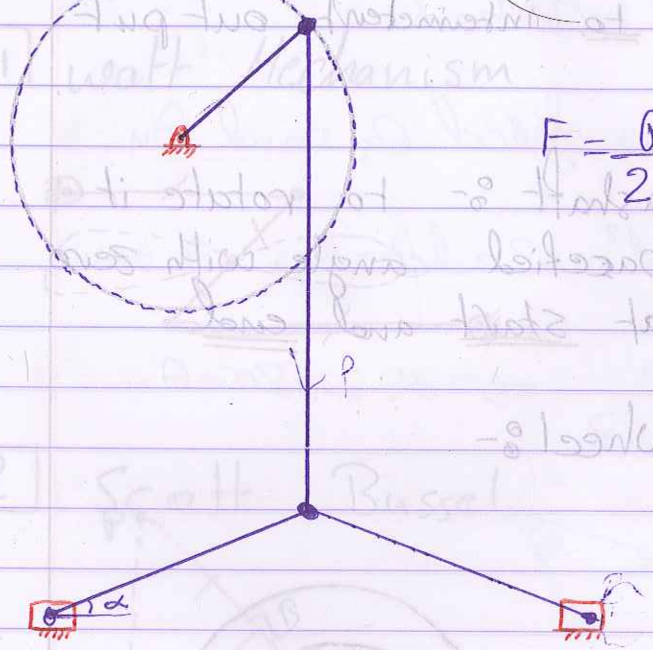
$t_1 > t_2$

time ratio = $\frac{\theta_1}{\theta_2}$

الزاوية الكبيرة ← بطيء

الزاوية الصغيرة ← سريع

4 Toggle



$F = \frac{P}{2\tan\alpha}$

$\sum F_y = 0$

$F - 2P\sin\alpha = 0$

$P = \frac{F}{2\sin\alpha}$

$\alpha \downarrow \quad F \uparrow$

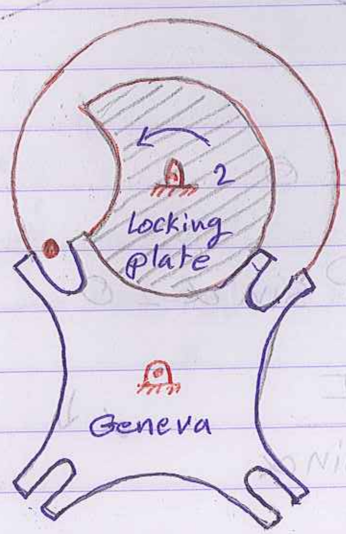
☒ Intermetent motion Mechanism
متقطع

used to convert continous motion of input to intermetent output motion

to index a shaft :- to rotate it into a spacefied angle with zero velocity at start and end

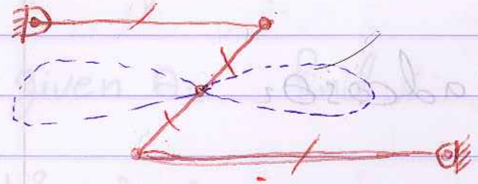
Geneva wheel :-

$$\frac{\omega_2}{\omega_1} = \frac{4}{1}$$

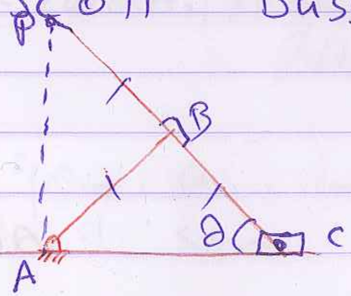


☒ Straight Line Mechanism

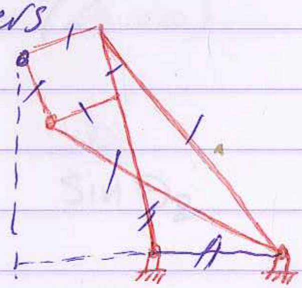
1 watt Mechanism



2 Scott Bussel



3 Peaucelliers



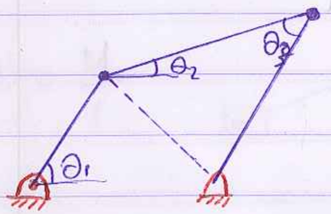
$\boxed{*}$ position Analysis

Graphical Method

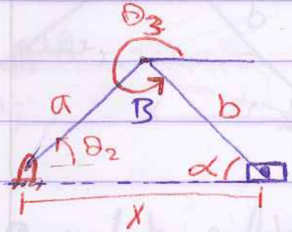
give $\theta_2 \Rightarrow$ fixed θ_3 and θ_4

$$f^2 = a^2 + d^2 - 2ad\cos\theta_2$$

$$\frac{f}{\sin\theta_2} = \frac{a}{\sin B} \Rightarrow \alpha = 180 - \theta_2$$



Example 3:-



given θ_2 find x

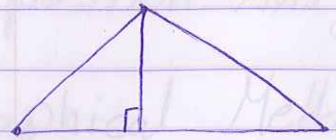
$$b^2 = a^2 + x^2 - 2ax\cos\theta_2$$

$$x^2 - 2a\cos\theta_2 \mp \frac{\sqrt{(2a\cos\theta_2)^2 - 4(1)(a^2-b^2)}}{2(1)}$$

$$\frac{b}{\sin\theta_2} = \frac{a}{\sin\alpha} \rightarrow \alpha$$

$$B = 180 - (\theta_2 + \alpha)$$

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



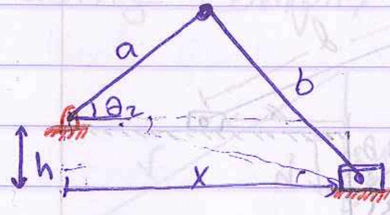
$$X = a\cos\theta_2 + b\cos\alpha$$

$$a\sin\theta_2 = b\sin\alpha$$

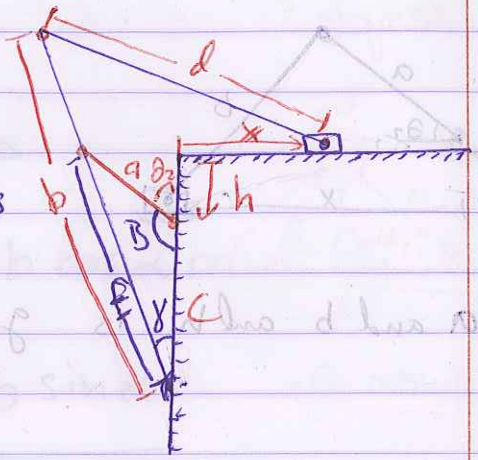
$$\cos\alpha = \sqrt{1-\sin^2\alpha}$$

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

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



a and b and h is given $\Rightarrow X = ??$



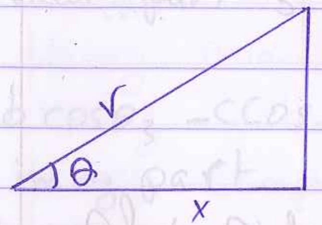
given θ_2 and links length fixed x??

$$\beta = 180 - \theta_2$$

$$\frac{a}{\sin\alpha} = \frac{fr}{\sin B} \qquad \left(\cos\alpha = \sin\left(\frac{a \sin B}{f}\right) \right)$$

$$f^2 = a^2 + c^2 - 2ac\cos B$$

Using complex Number



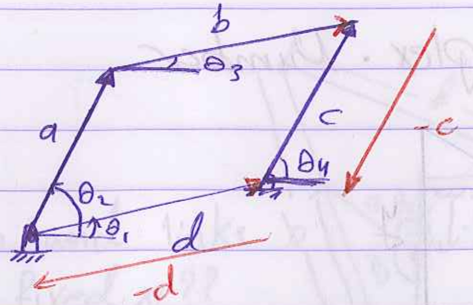
$$\vec{r} = x + jy$$

$$\vec{r} = r e^{j\theta}$$

$$r = \sqrt{x^2 + y^2}$$

$$r = re^{i\theta}$$
$$= x + jy$$

$$r = r\cos\theta + jr\sin\theta$$



given link liength and θ_1 and θ_2
find θ_3, θ_4 ??

Loop equation

$$\vec{a} + \bar{b} - \vec{c} - \vec{d} = 0$$

$$a e^{i\theta_2} + b e^{i\theta_3} - c e^{i\theta_4} - d e^{i\theta_1}$$

$$\frac{d}{dx} = e^{ax} = a e^{ax}$$

$$\frac{d}{dt} e^{ax} = \frac{d}{dx} e^{ax} \frac{dx}{dt}$$

$$\frac{d f(x(t))}{dt} = \frac{d}{dt} f(x) \frac{dx}{dt}$$

$$a(\cos\theta_2 + j\sin\theta_2) + \cdots$$

Real part

$$b\cos\theta_3 - c\cos\theta_4 = d\cos\theta_1 - a\cos\theta_2 \quad \text{---} (1)$$

imag part

$$b\sin\theta_3 - c\sin\theta_4 = d\sin\theta_1 - a\sin\theta_2 \quad \text{---} (2)$$

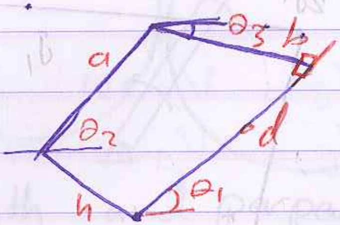
Position analysis $\Rightarrow$ non linear equation

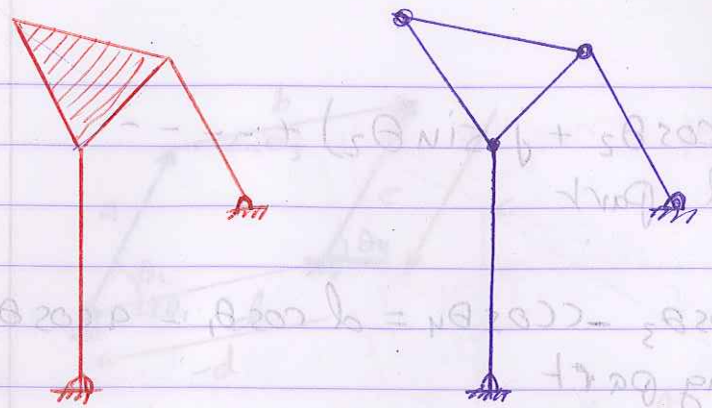
$$(\sin\theta_3)^2 + (\cos\theta_3)^2 = 1 = f_1(\theta_4)^2 + f_2(\theta_4)^2$$

Ex:- given θ_1, θ_2 lingth, h
find $|d|$

$$\vec{h} + \vec{a} + \vec{b} - \vec{d} = 0$$

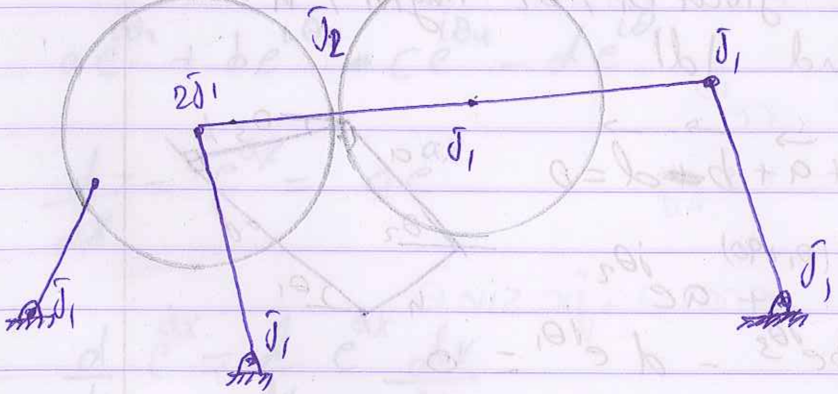
$$h e^{j(\theta_1+90)} + a e^{j\theta_2} + b e^{j\theta_3} - d e^{j\theta_1} = 0$$





if we consider the treangle as one body the mobility is same as the triangle (Three bars))

Gears



Velocity analysis

1- Using velocity polygons
2- Using instant center
3- Using complex number

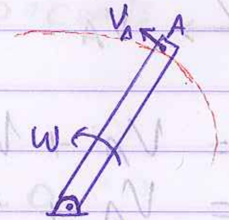
Translation

$\omega = 0$

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

Rotation about fixed axis (O)

$\vec{V}_A = \vec{\omega} \times r_{A/O}$



V_A tangent to path and perpendicular to $\vec{r}$ in the direction of $\vec{\omega}$

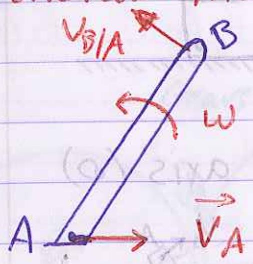
$\vec{V}_{A/O}$ = positive vector of point A with respect to O

from O to A

$+\hat{K}$, $-\hat{K}$ $\vec{\omega}$

direction of $\vec{\omega}$

General motion



عمودي على الخط الواصل
من $\vec{A/B}$ وباتجاه $\vec{\omega}$

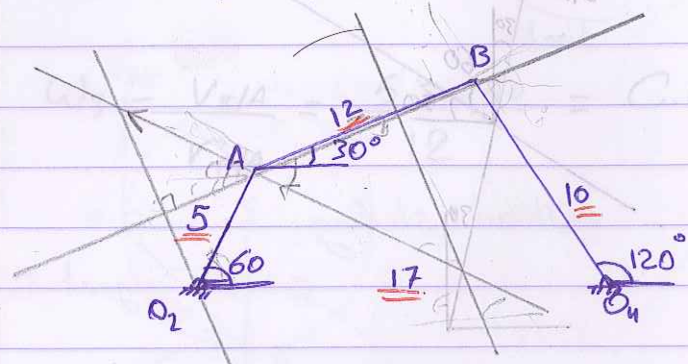
$$V_B = V_A + V_{B/A}$$
$$V_B = V_A + \vec{\omega} \times r_{B/A}$$

$V_{B/A}$ $\perp$ to $r_{B/A}$ in the direction of $\vec{\omega}$

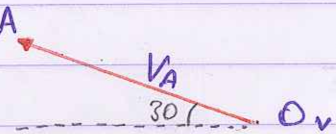
$$V_{B/A} = \omega\, r_{B/A}$$

Four bar mechanism

input ω_2 (given) = 3 rad/s
find ω_3, ω_4 and $\vec{V}_B$?



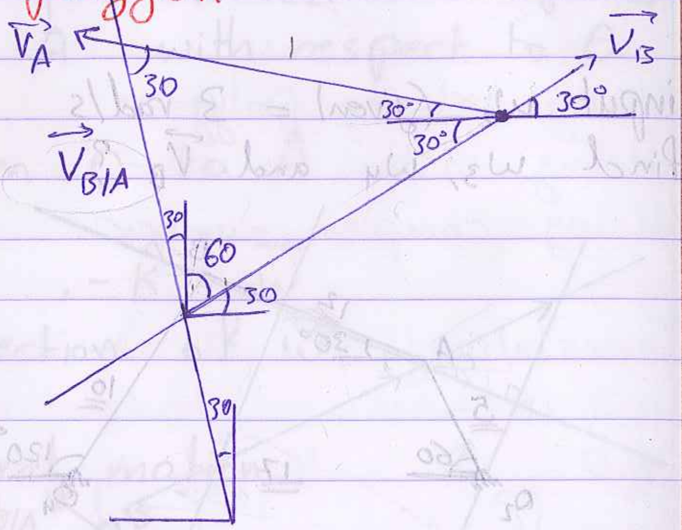
$$\vec{V}_A = \vec{\omega}_2 * \vec{r}_{A/O}$$
$$V_A = 3 * 5 = 15 \text{ cm/s}$$



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

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

Velocity polygon



قاعدة (sin)

$$\frac{V_A}{\sin 90} = \frac{V_B}{\sin 30}$$

$$\frac{15}{1} = \frac{V_B}{0.5}$$

$V_B = 7.5$ cm/s

$$\overset{-\checkmark}{V_B} = \overset{\checkmark\checkmark}{V_A} + \overset{-\checkmark}{V_{B/A}}$$

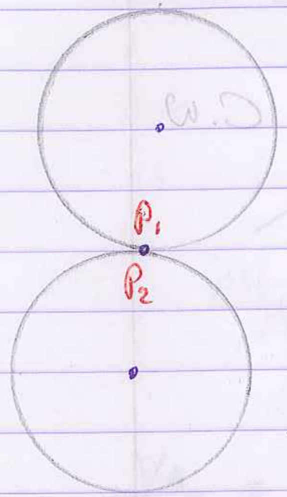
$$\omega_4 = \frac{V_B}{r_{B/O_4}} = \frac{7.5}{10} = 0.75 \text{ rad/s}$$

$V_{B/A} = \omega_3 \; r_{o/A}$

$$\omega_3 = \frac{V_{B/A}}{r_{B/A}} = \frac{5 \sin 60}{12} = \text{C.W}$$

At contact point

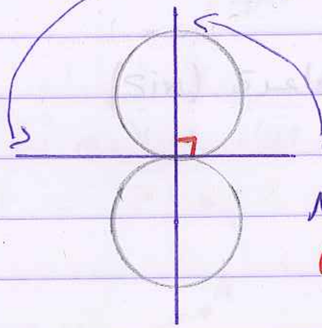
- without sliding: velocity is equal on both bodies

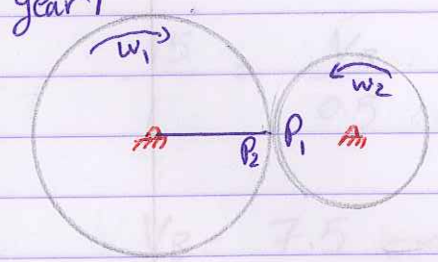


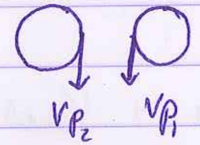
link 1

without sliding

link 2



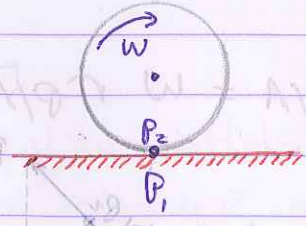




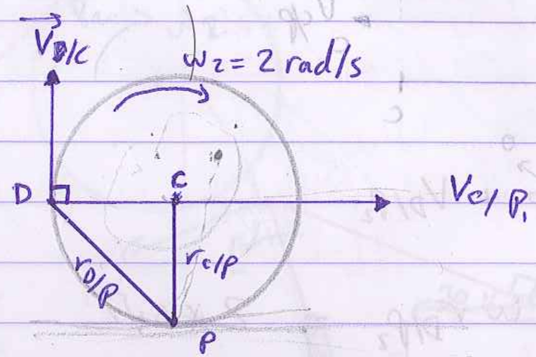
$V_{P_1} = \omega_1 r_1$ (without sliding)

$V_{P_2} = V_{P_1}$

$\vec{V}_{P_2/P_1} = 0$



$V_{P_1} - V_{P_2} = 0$ ((No slipping))



$V_{P_1} = V_{P_2}$

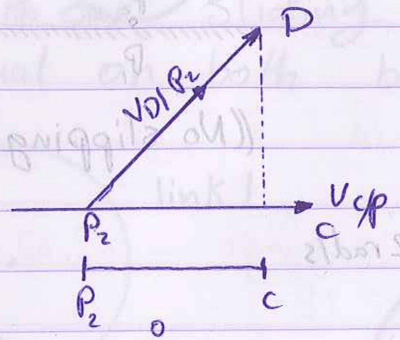
$V_{P_1} = 0 = V_{P_2}$ نستغل سرعة $V_P = 0$

ونعوضها Relative مع ال

$\vec{V}_C = \cancel{\vec{V}_{P_2}}^{\,0} + \vec{V}_{C/P_2}$ ⟵ نقطة

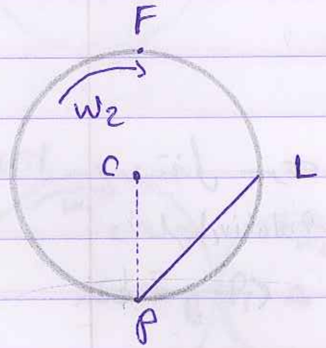
$$\boxed{\begin{aligned} V_{C/P_2} &= \omega_2 \, r_{C/P_2} \\ &= 2 * 5 = 10 \end{aligned}}$$

$$V_{B/A} = w\, r_{P/A}$$



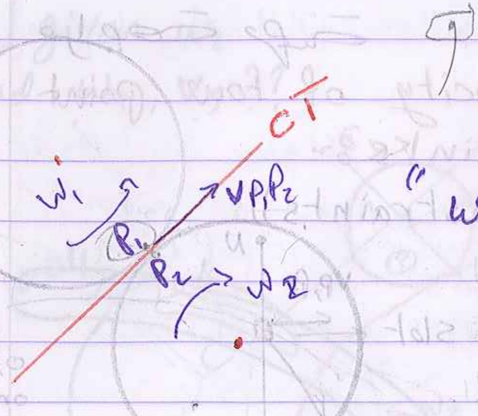
$$V_D = \cancel{V_P}^{\,0} + V_{D/P_2}$$

$$V_{D/P_2} = w\, r_{D/P_2} = 2 * 5\sqrt{2}$$

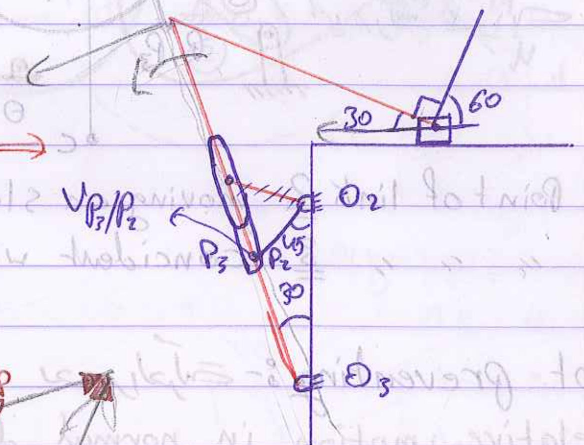


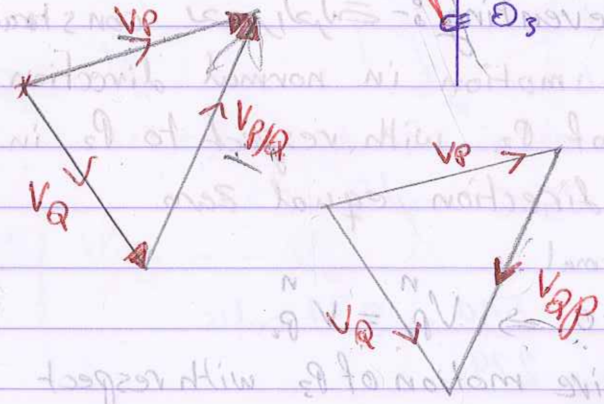
ناخذ نقطة عند الارض
مع أي نقطة في الدائرة

with sliding: the relative velocity is along the common tangent



"with slidding"



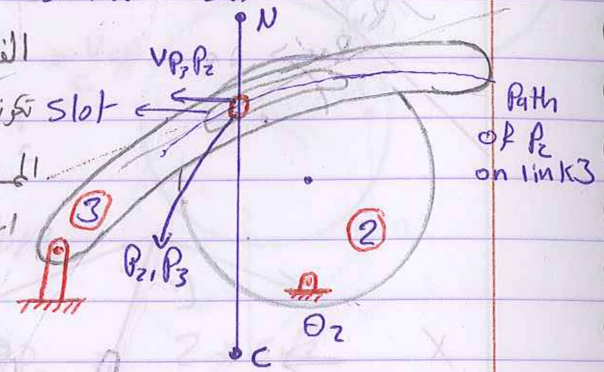


مراجعة مهمة

[*] Relative velocity of tow point on separate links :-

((motion constraints)) قيود

الفكرة الرئيسية هي انه لجسمان slot تكون الحركة النسبية بينهما على المماس لحركتهما ولا تكون هناك اي حركة عمودية



P_2 : Point of link 2 moving on slot of link3

P_3 : " " " 3 concident with poin 2

Slot preventing :- يحصر الحركة constrain

prevent relative motion in normal direction

montion of P_3 with respect to P_2 in normal direction equal zero

$$\overset{\rightarrow \text{normal}}{V^n_{P_3P_2}} = 0 \Rightarrow V^n_{P_3} = V^n_{P_2}$$

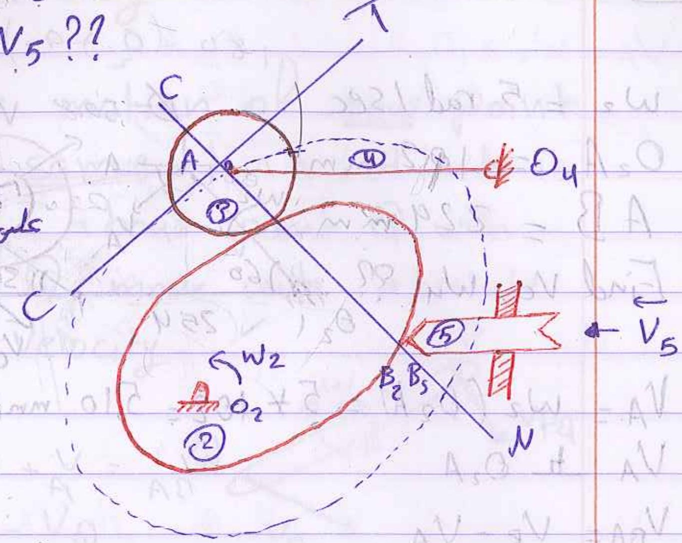
→ relative motion of P_3 with respect to P_2 is only permitted in tangential

$\therefore V^t_{P_2P_3} \neq 0$ tangent

Ex | given w_2

find w_4, V_5 ??

على الدفتر الثاني



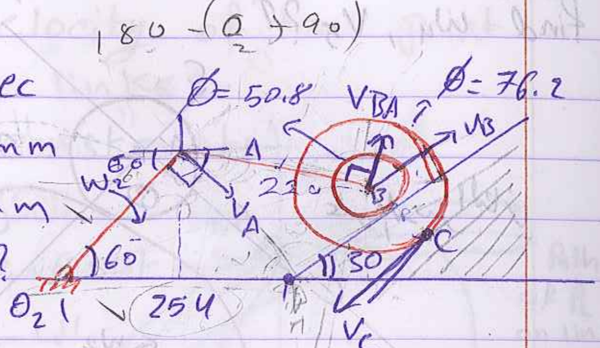
Ex The wheel rolles without slipping

$\omega_2 = 5$ rad/sec

$O_2A = 102$ mm

$AB = 229$ mm

Find V_C; ω_4 ??



$V_A = \omega_2 (O_2A) = 5 * 102 = 510$ mm/s

$V_A \perp O_2A$

$V_{BA} = V_B - V_A$

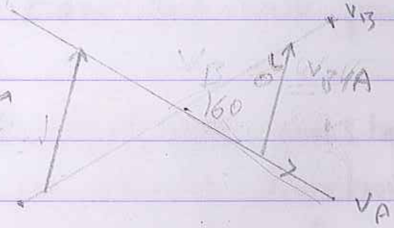
V_B tangent to inclind surface (moving without slipping)

$V_{BA} \perp AB$

$V_{BA} = V_A + \omega_3 r_{A/B}$

$V_B = 650$ mm/s

$V_{BA} = 590$ mm/s



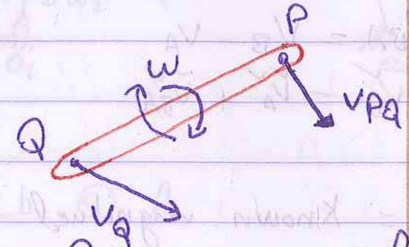
$\omega_4 = \frac{V_B}{50.8/2} = 25.6$ rad/s C.W

$\omega_3 = \frac{V_{BA}}{AB} = \frac{590}{229} = 2.57$ rad/s

$\omega_4 = \frac{V_B}{PB} = \frac{V_C}{PC} \Rightarrow V_C = 650\left(\frac{25.4}{50.8}\right) = 325$ mm/s

2 Analysis by relative motion

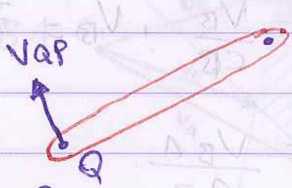
a Relative motion of tow point on the same link. A link is rotating about point Q with ω and Q move with absolute linear velocity



$V_{PQ} = V_P - V_Q$

$= \omega * (QP) \perp QP$ in sense of ω

مع اتجاه دوران ω



$V_{QP} = V_Q - V_P$

$= \omega * (PQ) \perp PQ$ in sense of ω

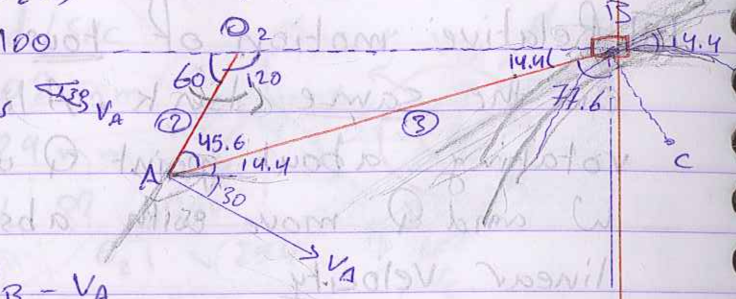
$\therefore \boxed{V_{PQ} = -V_{QP}}$

$\boxed{Ex}$ if $\omega_2 = 1$ rad/s Find V_B, ω_4??

$V_A = \omega_2 * (O_2 A) \perp O_2 A$

$= 1 * 100$

$= 100$ mm/s



$V_{BA} = V_B - V_A$

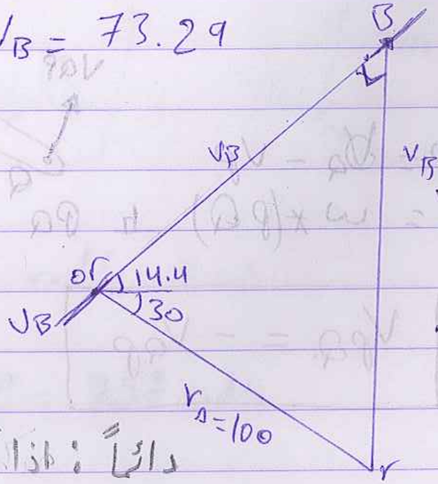
$\therefore \bar{V}_B = \bar{V}_A + \bar{V}_{BA}$

V_B = Known magnitued, direction know $\angle 14.4$

V_{BA} = magnitued is unknown direction know $\perp AB$

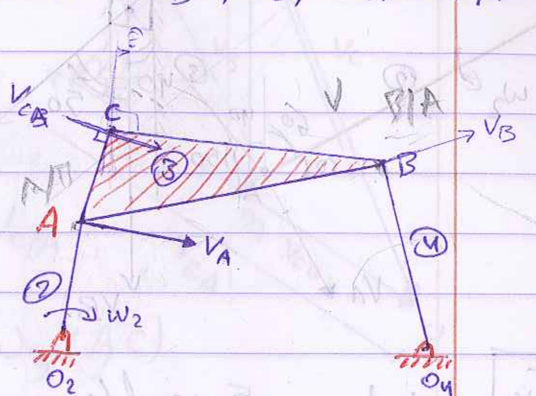
$\therefore \omega_4 = \frac{V_B}{CB}$, $V_B = 73.29$

$\omega_3 = \frac{V_{BA}}{AB}$



دائماً : اذا كان هناك حركة roling with sliping تكون الحركة C.T

$\boxed{Ex}$ given ω_2 find $V_B, V_c, \omega_3, \omega_4$??



Solution

$V_A = \omega_2 (O_2 A) \perp O_2 A$

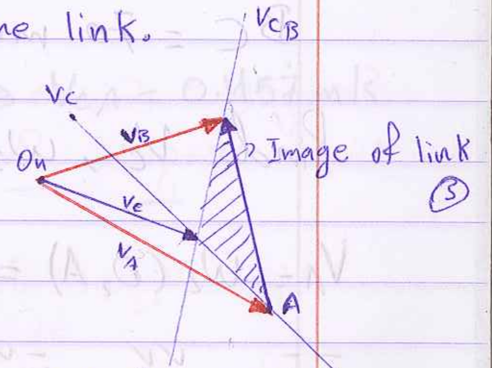
B, A lie on the same link.

$\bar{V}_B = \bar{V}_A + \bar{V}_{BA}$

$V_{BA} \perp AB$

$\bar{V}_c = \bar{V}_A + \bar{V}_{cA}$

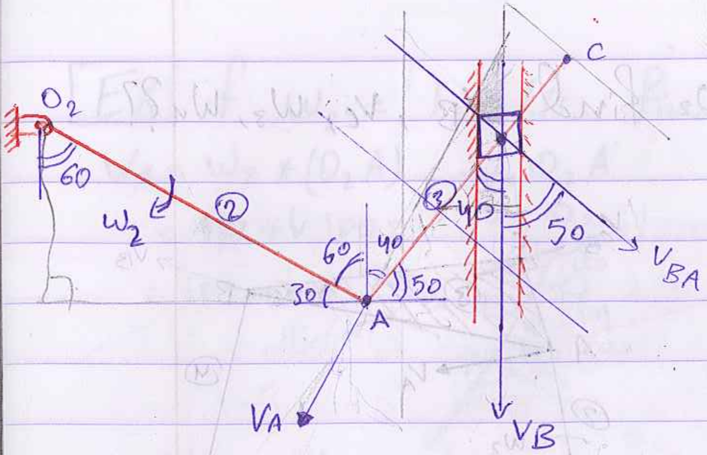
$\bar{V}_c = \bar{V}_B + \bar{V}_{cB}$



Velocity polygon

$V_{BA} = \omega_3 (AB)$, or, $V_{cA} = \omega_3 (CA)$

$\therefore \omega_3 = \frac{V_{BA}}{AB} = \frac{V_{cA}}{AC} = \frac{V_{cB}}{BC}$



$\boxed{Ex}$ $\omega_2 = 5$ rad/s

$O_2A = 76.2$ mm

$AB = 152$ mm

$BC = 70$ mm

Find V_c, ω_3 ??

$V_A = \omega_2 (O_2A) = 5 * 76.2 = 0.381$ m/s

$\bar{V}_c = \bar{V}_A + \bar{V}_{CA}$

$\bar{V}_B = \bar{V}_A + \bar{V}_{BA}$

$$\frac{V_B}{\sin 100} = \frac{V_{BA}}{\sin 30} = \frac{V_A}{\sin 50}$$

Ex $\omega_2 = 5$ rad/s

$O_2A = 76.2$ m

$\therefore V_c = V_A + V_{c/A}$

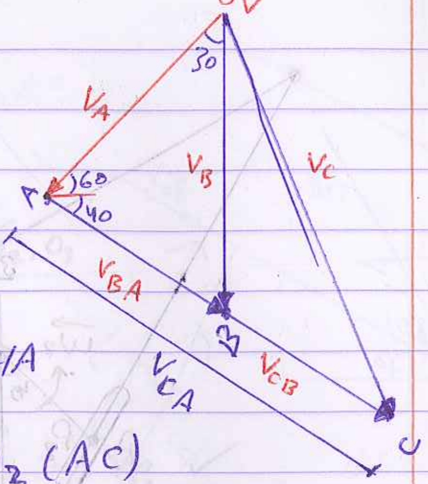
but $V_{CA} = \omega_3 (AC)$

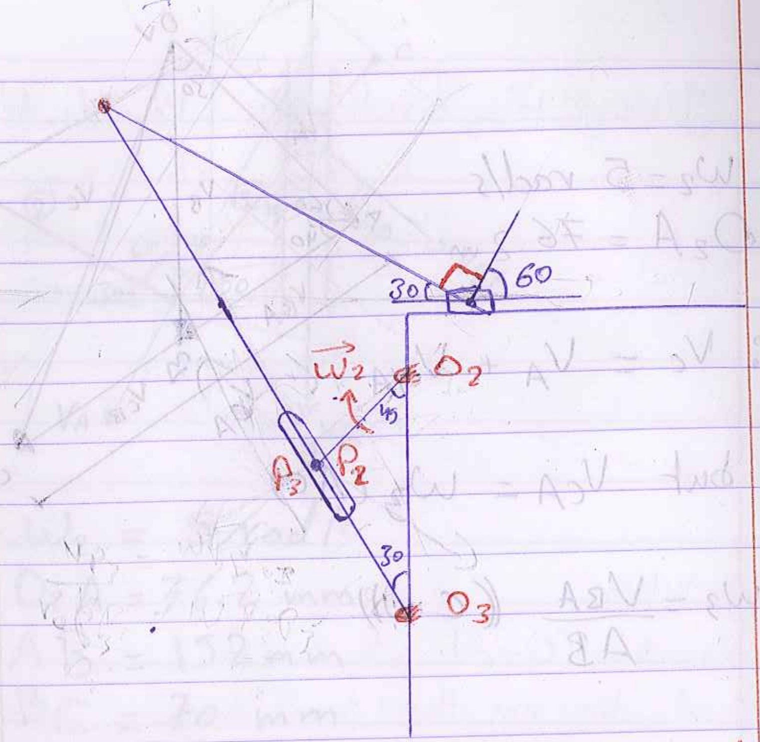
$$\omega_3 = \frac{V_{BA}}{AB} \quad ((C.W))$$

$$\omega_3 = \frac{V_{BA}}{AB} = \frac{V_{CA}}{AC} \Rightarrow V_{CA} = 0.457 \text{ m/s}$$

$\bar{V}_c = \bar{V}_A + \bar{V}_{CA}$

$\bar{V}_c = \bar{V}_B + \bar{V}_{CB}$



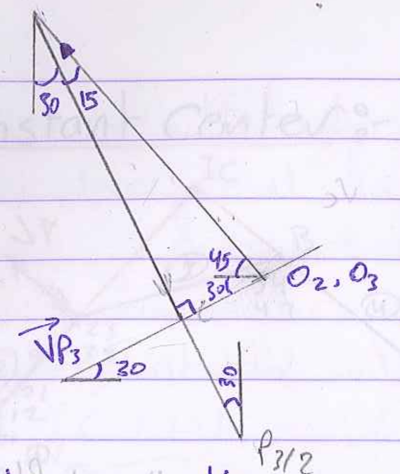


Example: Given $\underline{\omega_2} = 2$ rad/s and link lenghts find $\underline{V_5}$ at this instant

$$V_{P_3} = V_{P_2} + V_{P_3/P_2}$$

$$V_{P_3/P_2} \neq \omega \, r_{P_3/P_2}$$

$$V_{P_2} = \omega_2 * r_{P_3/P_2} = 2 * 5 = 10 \text{ cm/s}$$



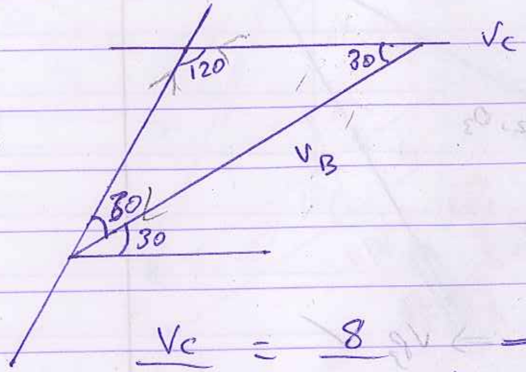
$$\frac{10}{\sin(90)} = \frac{V_{P_3}}{\sin(15)} \rightarrow V_{P_3} \checkmark$$

$$\omega_3 = \frac{V_{P_3}}{r_{3/O_3}}$$

$$\rightarrow \omega_3 = \frac{V_{P_3}}{r_{3/O_3}}$$

$$V_{P_2} = \omega_2 * r_{P/O_2} = 2 * 5 = 10$$

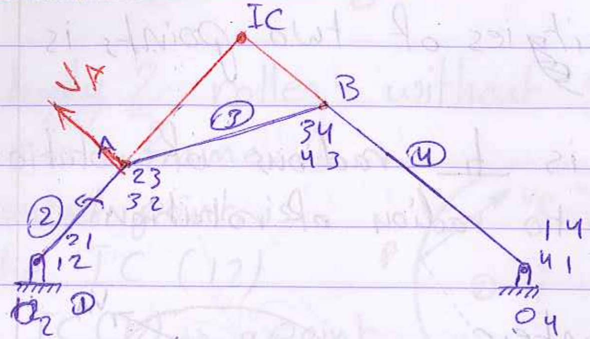
$$V_B = \omega_B \, r_{B/O} = 0.25 * 35 = 8$$



$$\frac{V_C}{\sin 30} = \frac{8}{\sin(120)} \Rightarrow V_C \text{ to the left}$$

$$\cancel{\frac{w_4}{V_{C/B}}}$$

Instant Center:-



a point on a body (link) about wich other link is rotating either at the instant or perminally
<u>OR</u> Point Common to two links with same velocity in magnitude and direction.

Primary instant centers:-

[1] Instant center at pin connection
Instant center (12):- point on link 1 about which link 2 is rotating (link 2 is rotating about link 1 at (12))

12, 14 → Fixed IC, 23, 34 → moving IC

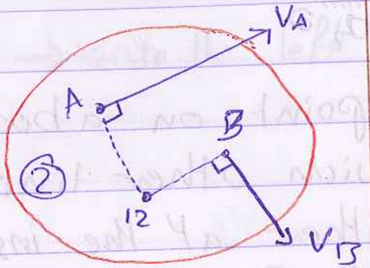
⇒ To find IC when the direction of velocitgies of two points is Known

velocity is ⊥ radious of rotation

∴ V_A ⊥ to radion of rotation

Instant center

Intersection of tow perpendicular at A, B ②



مسافة

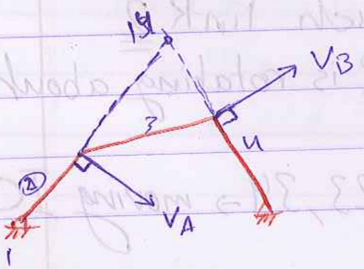
$V_A = \omega_2 (12 - A)$

$V_B = \omega_2 (12 - B)$

$$\frac{V_A}{(12-A)} = \frac{V_B}{(12-B)}$$

(IC : عمودي على السرعة)

⇒ for 4 bar mechanism

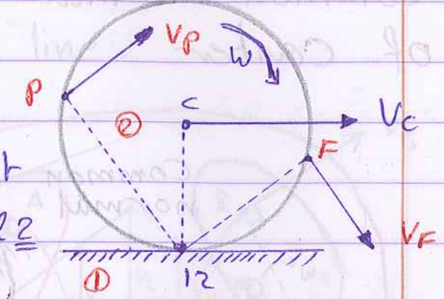


[2] IC of Rolling contact :-

body 2 rolles without Slipping on frame 1

contact point is the IC (12)

∴ IC(12) ⇒ a point common to 1 and 2

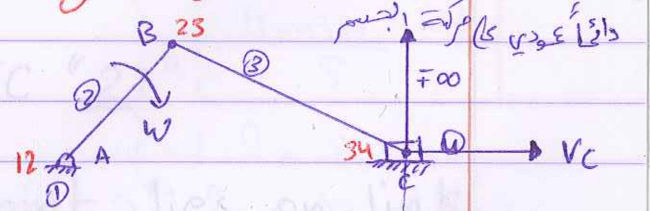


$V_C = \omega\,(12 - C)$

$V_P = \omega\,(12 - P)$

$V_F = \omega\,(12 - F)$

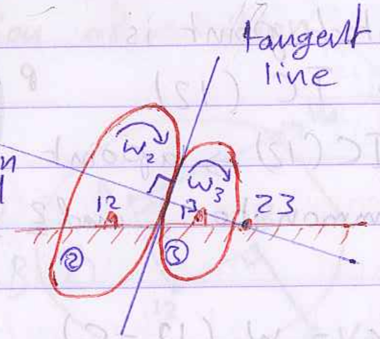
[3] IC of sliding body contact



IC of Sliding link ⊥ Surface of sliding

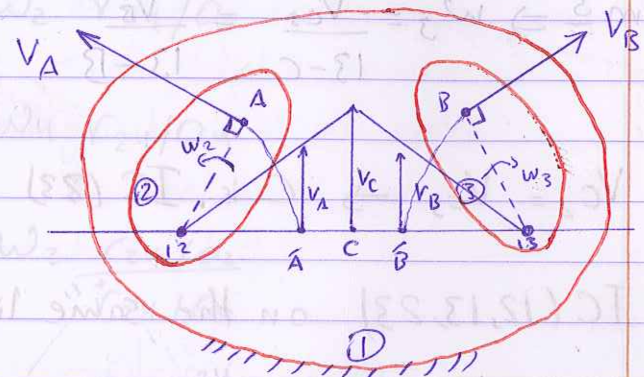
④ IC of Sliding and Rolling contact

IC is the intersection of common normal with line of center



Kennedys Theorem :-

Any three body in motion relative to each other will have IC that lie on straight line.



(12, 13) is the IC of body ① and ② with respect to frame

C is the IC "23"

IC (23) : point lies on link 2 and link 3 of the same velocity

$V_{c_2} =$

$V_{c_3} = \omega_3 (13 - C)$, $V_{c_2} = V_{c_3} \rightarrow$ instant center

from 2 $\Rightarrow \omega_2 = \dfrac{V_{c_2}}{12 - C} = \dfrac{V_A}{12 - A}$

from 3 $\Rightarrow \omega_3 = \dfrac{V_{c_3}}{13 - C} = \dfrac{V_B}{13 - B}$

$V_{c_2} = V_{c_3} \Rightarrow$ C is IC (23)

IC (12, 13, 23) on the same line

$\Rightarrow$ Number of IC of a mechanism:-

$$\boxed{N = \frac{n(n-1)}{2}}$$

n = # of links

(n-1) = # of IC with respect to any link

n(n-1) = # of IC's

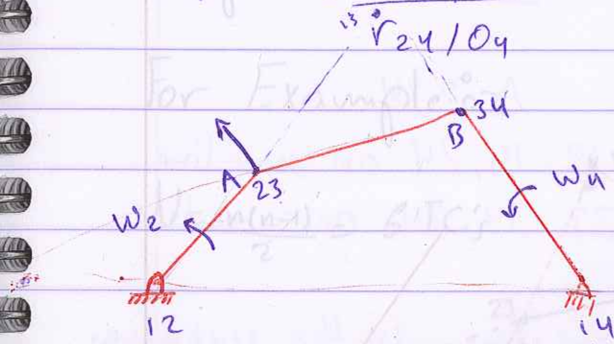
N = # of location of IC's

12	13	23	123
12	14	$\boxed{24}$	124
23	$\boxed{24}$	34	234
13	14	34	134

$V_{24} = \omega_2 \, r_{24/O_2}$

$V_{24} = \omega_4 \, r_{24/O_4}$

$\omega_4 = \omega_2 \dfrac{r_{24/O_2}}{r_{24/O_4}}$

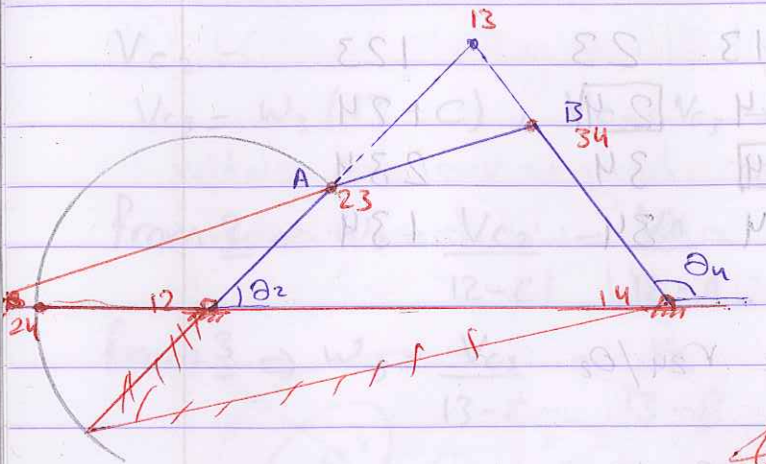


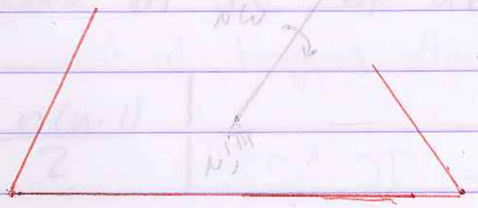
$V_A = \omega_2 \, r_{A/O_2}$

$\omega_3 = \dfrac{V_A}{r_{A/13}}$

$\omega_3 = \dfrac{V_B}{r_{B/13}} = \dfrac{V_A}{r_{A/13}}$

$\vec{V_B} = \vec{V_{13}} + \vec{V_{B/13}}$





Circle diagram to find IC:

Steps :-

① Find # of IC's

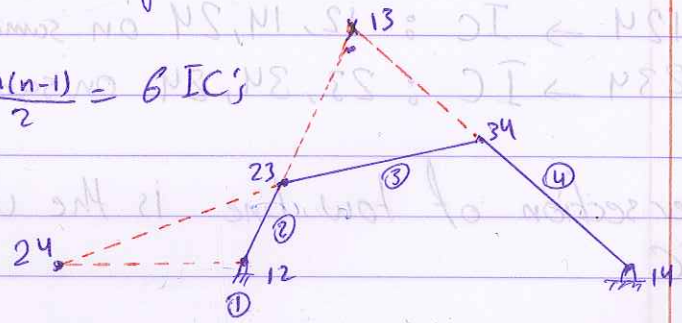
② find all primary IC's

③ draw Circle, lie point's equally Spaced on the circumefrence of circle each point represnt a link
∴ # of point = # of links

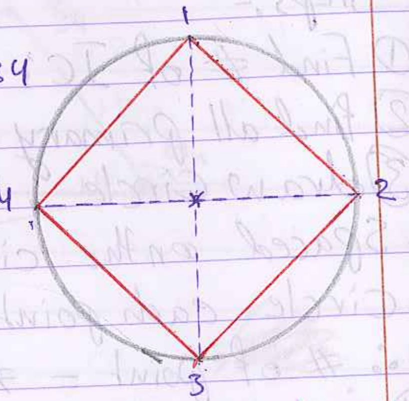
④ each line between these point represent an IC

For Example :-

$N = \frac{n(n-1)}{2} = 6$ IC's



# of point = # of link = 4



IC ((13)) ⇒ Δ 123 , Δ 134

Δ 123 ⇒ IC's

Δ 123 ⇒ IC's : 12, 23, 13 on the same line

Δ 134 ⇒ IC's : 14, 34, 13 on the same line

IC (24) ⇒ Δ 124 Δ 234

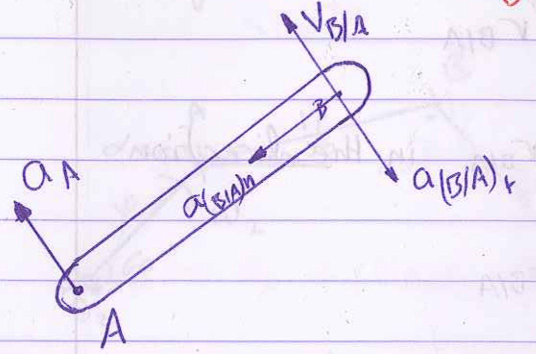
Δ 124 → IC : 12, 14, 24 on same line

Δ 234 → IC : 23, 34, 24 on same line

intersection of tow line is the unknown IC

الامثلة دي بالدفتر الثاني ضروري

Accelaration analysis



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

$(a_{B/A})_n$ $\qquad$ $a_{(B/A)t}$

$-\omega^2 r_{B/A}$ $\qquad$ $\alpha \times r_{B/A}$

$(\vec{a}_{B/A})_n$ = Centripital accelaration of point B relative to A in the oppisit direction of $\vec{r}_{B/A}$

$(a_{B/A})_n$ عكس اتجاه $(r_{B/A} \Leftarrow A \to B)$ ستكون بالعكس $B \to A$

(In the direction towerds the center of rotation A)

أو باتجاه مركز الدوران

$(a_{B/A})_n = \omega^2 r_{B/A}$

$(a_{B/A})_t = \underline{h}\ r_{B/A}$ in the direction of α

$(a_{B/A})_t = \alpha\, r_{B/A}$

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

$a_{B/A} = a_{B/A}^n + a_{B/A}^t$

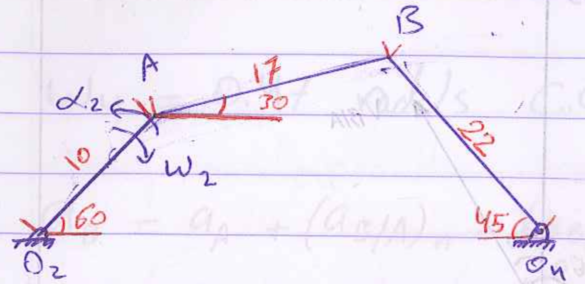
but $a_{B/A}^n = \omega^2 r_{B/A} = \frac{V^2}{BA}$ / (Rotatio about fixed axis)

$a_{B/A}^t = \alpha_2 (BA) \perp AP$ in the direction of α

$\cancel{A_{AB}}$ $a_{AB}^t = -a_{BA}^t$

$a_{AB}^n = -a_{BA}^n$

Example: for the given Mechanism



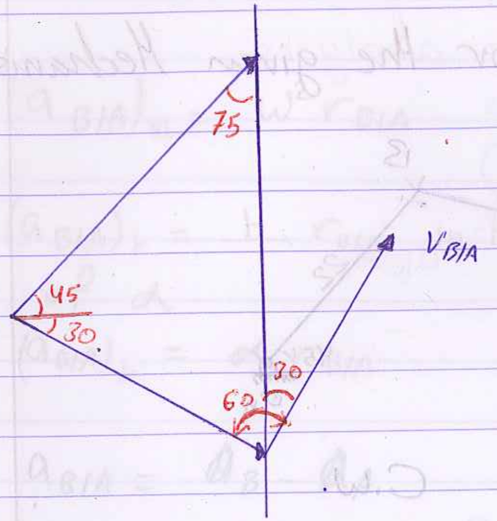
$\omega_2 = 2$ rad/s C.W

$\alpha_2 = 3$ rad/s C.C.W

Determine a_B and α_4, α_3

$V_A = \omega_2\, r_{A/O_2}$
$= 2 * 10 = 20$ cm/s

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



$V_{B/A} = V_A$
$= 20$ cm/s

$\omega_3 = V_{B/A} / r_{B/A} = \frac{20}{17} = 1.18$ rad/s

C.C.W

$\frac{V_B}{\sin 30} = \frac{V_A}{\sin 75}$

$V_B = \frac{20 * \sin 30}{\sin 75} = 10.35$ cm/s

$V_B = \frac{20 \sin 30}{\sin 75} = 10.35$ cm/s

$\omega_4 = 0.47$ rad/s C.W

$a_B = a_A + (a_{B/A})_n + (a_{B/A})_t$

$(a_B)_n + (a_B)_t = (a_A)_n + (a_A)_t + (a_{B/A})_n + (a_{B/A})_t$

$\omega_2 = 2$
$\omega_3 = 1.18$
$\omega_4 = 0.47$

$a_B = \omega_4^2 \, r_{B/O} = (0.47)^2 (22) = 4.85$ cm/s

$(a_A)_n = \omega_2^2 \, r_{A/O_2} = 40$ cm/s

$(a_A)_t = \alpha_2 \, r_{A/O_2} = 3(10) = 30$ cm/s^2

$\vec{a}_{B/A} = \omega^2 r_{B/A} = 23.7$ cm/s

$\alpha_4 = (a_B)_t / r_{B/O_4}$

C.C.W

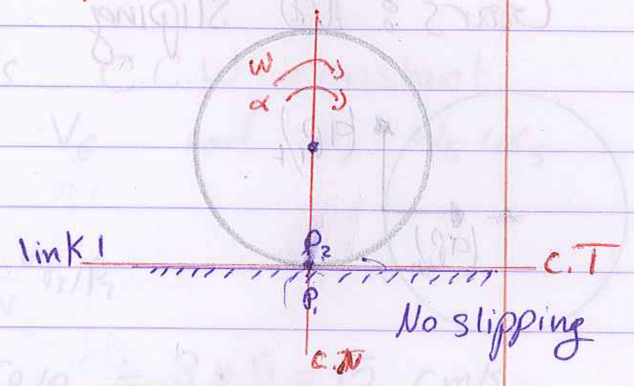
امثلة ع المنستر الثاني

مطلوبين بالامتحان رسم التسارع

At the contact point without Slipping

Remark

Componant of the accelaration a long the common tangent direction is equal on both bodies

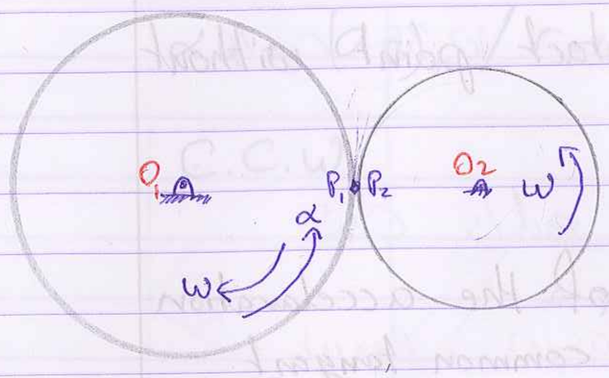


$\vec{a}_{P_1} = 0$

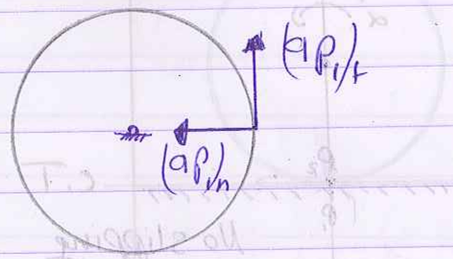
$\vec{a}_{P_1} = 0 = (a_{P_1})_T + (a_{P_1})_n$

$\vec{a}_{P_2} = (a_{P_2})_T + (a_{P_2})_n$

متساويات لانه بدون slipping



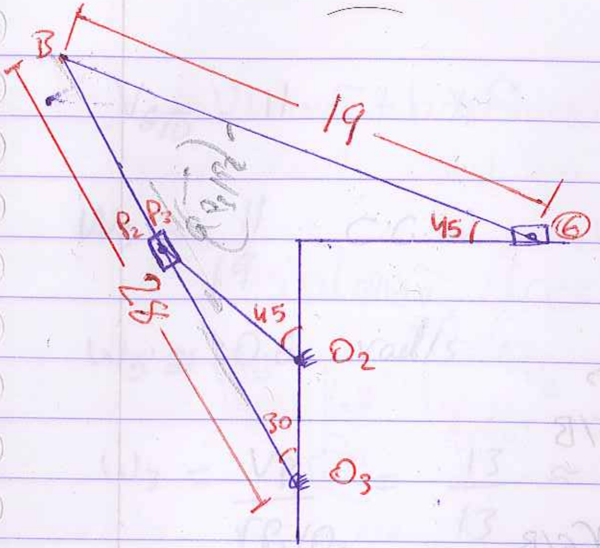
Gears : No sliping



$(a_{P_1})_n = \omega^2 \cdot r_{P_1/O_1}$

$(a_{P_1})_t = \alpha_1 \, r_{P_1/O_1}$

$\alpha_2 r_2 = \alpha_1 r_1$

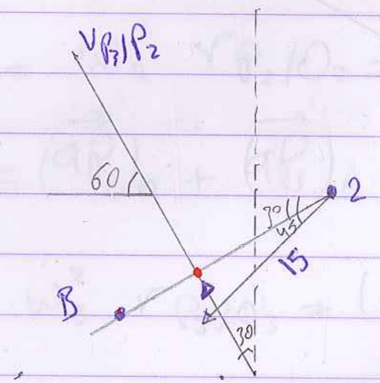


$\omega_2 = 3$ rad/s C.C.W constant

determine V_6 and a_6, ω_5, α_5

$V_{P_3} = V_{P_2} + V_{P_3/P_2}$

$V_{P_2} = \omega_2 \, r_{P_2/O_2} = 3 * 5 = 15$ cm/s

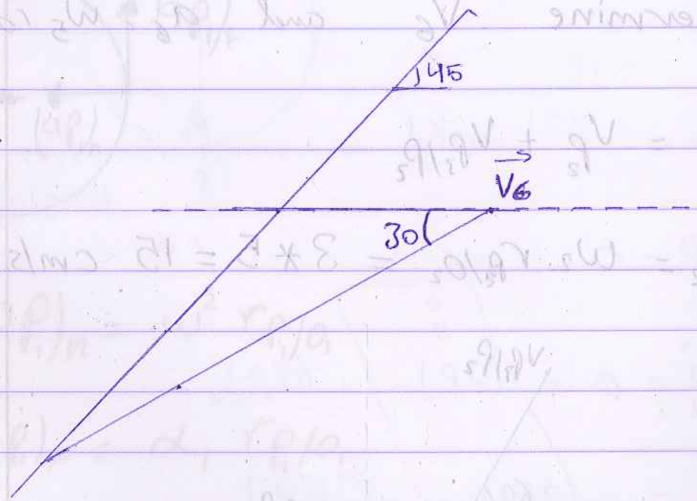


$V_{P_3} = 13$ cm/s

$$\frac{28}{13} = \frac{V_B}{V_{P_3}}$$

$$\vec{V}_6 = \vec{V}_B + \vec{V}_{6/B}$$

$$V_{6/B} = \omega_5 \; r_{6/B}$$



$V_{6/B} = 11$

$$\omega_5 = \frac{11}{19} \quad C.C.W$$

$\omega_5 \cong 0.6$ rad/s

$$\omega_3 = \frac{V_{P_3}}{r_{P_3/O_3}} = \frac{13}{13} \approx 1 \text{ rad/s} \quad C.C.W$$

$V_{P_3/P_2} = 7$

$$\vec{a}_{P_3} = \vec{a}_{P_2} + (a_{P_3/P_2})_{rel} + 2\,\omega_3 \times (\vec{V}_{P_3/P_2})$$

$$a_{P_2} = \vec{(a_{P_2})}_n + \cancel{\vec{(a_{P_2})}_t}^{\,0} = \alpha_2 * r_{P_2/O_2}$$

$$(a_{P_2})_n = \omega_2^2 \; r_{P_2/O_2} = (3)^2(5) = 45 \text{ cm/s}^2$$

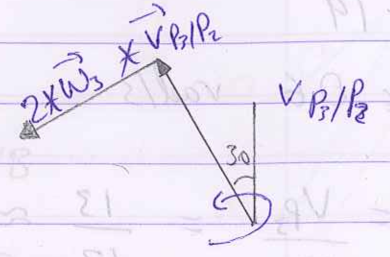
$$(\vec{a}_{P_3}) = (\vec{a}_{P_3})_n + (\vec{a}_{P_3})_t$$

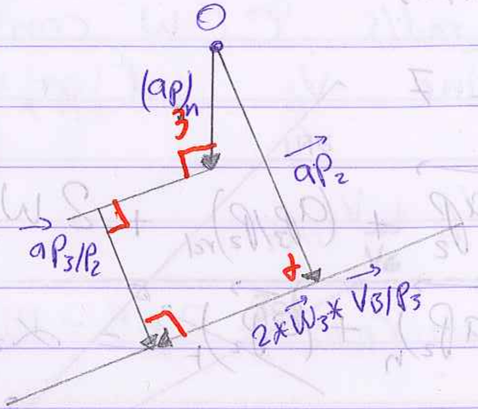
$$a_{P_3} = \omega_3^2 \; r_{P_3/O_3} = (1)^2(13) = 13 \text{ cm/s}$$

$$\left|2\vec{W}_3 \times \vec{V}_{P_3/P_2}\right| = 2 * 1 * 7 = 14\ cm/s^2$$

$W_3 = 1$ rad/s

C.C.W





$$\frac{a_B}{28} = \frac{aP_3}{13} \Rightarrow a_B = \frac{28}{13}\, aP_3$$

$$a_6 = a_B + a_{6/B}$$

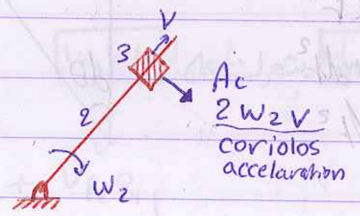
$\boxed{2}$ Relative accelaration of coincident point on separate links:-

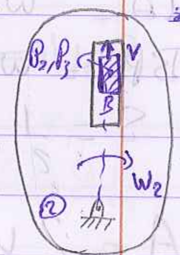
Coriolos Accelaration

$$2\,W_{②} \times V_{P_{③}P_{②}}$$

③ يتحرك على ②

Coriolos accelaration * دائماً عندما يتحرك جسم على آخر يدور ع يتكون





P_3 = Point on moving link $\underline{3}$ along slot of link $\underline{2}$ with linear velocity

P_2 = Concident point on link $\underline{2}$ which is rotating with ω_2

after time dt

displacment of P_3

$P_3 \to \bar{P_3} = P_3\bar{P_2} + \bar{P_2}B + B\bar{P_3}$

الاشتقاق

arc $P_2\bar{P_2}$ with $w_2 = \text{constant}$

$\bar{P_2}B$ = with w_2 = const

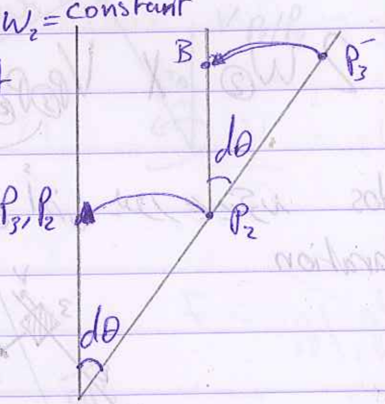
and constant $V = Vdt$

arc $B\bar{P_3} = \bar{P_2}B\,d\theta$

$d\theta = w_2\,dt$

$B\bar{P_3} = w_2\,V dt^2$

$S = \frac{1}{2} A dt^2$



$A = 2\,w_2\,V_{P_3P_2}$

$A \perp V$ in sense of w_2

$A_c = 2 * w_2 * V_{P_3/P_2}$

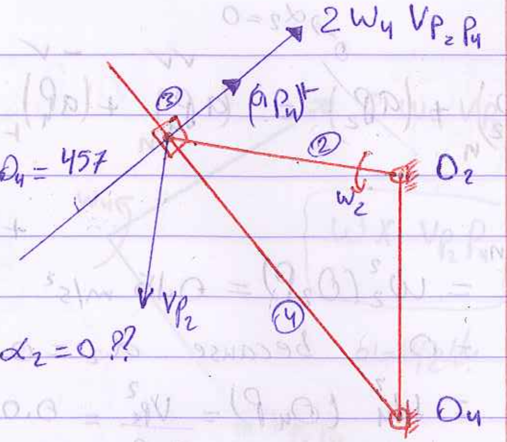
$\boxed{Ex}$ كورس الحل

$O_2P = 152$, $O_2O_4 = 457$

$O_4P = 514$

$w_2 = 9.5$ rpm

find α_4 where $\alpha_2 = 0$??

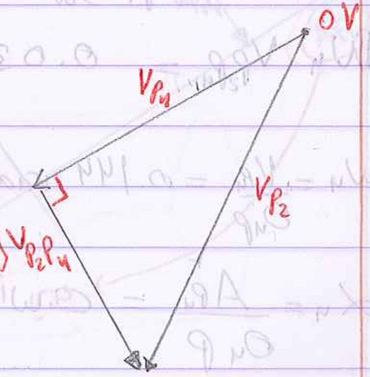


④ بلف و ② يتحرك كله

لا أن $\boxed{\text{link2}}$ يتحرك كل $\boxed{\text{link 4}}$

$$\vec{V}_{P_2} = \vec{V}_{P_4} + \vec{V}_{P_2P_4}$$

tangent لكلة



$V_{P_2P_4}$ in direction of link 4

$V_{P_4} = 0.074$ m/s

$V_{P_2P_4} = 0.131$ m/s

$V_{P_2} = w_2\,(O_2P)$

$= 151$ mm/s $\perp O_2P_2$

$\alpha_2 = 0$

$$\underbrace{(A_{P_2})_n}_{} + \overset{0}{(a_{P_2})_t} = \overset{\checkmark\checkmark}{(a_{P_4})_n} + \overset{-\checkmark}{(a_{P_4})_t} + \overset{\checkmark\checkmark}{(a_{P_4P_2})_n} + (a_{P_{42}})_t$$

$$+ 2\omega_4 V_{P_2P_4}$$

$a_{P_2}^n = \omega_2^2 (O_2P) = 0.15 \ m/s^2$

$a_{P_2}^t = 0$ because $\alpha_2 = 0$

$a_{P_4}^n = \omega_4^2 \ (O_4P) = \dfrac{V_{P_4}^2}{O_2P} = 0.0007 \ m/s$ $P \to O_4$

$A_{P_4}^t \perp O_4P$

$A_{P_4P_2}^t$ along link 4

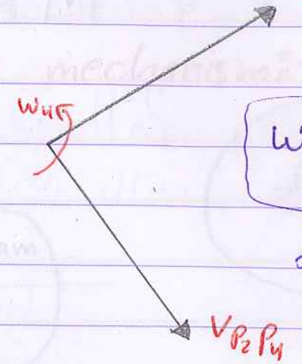
فش مركز

$A_{P_2P_4}^n = \dfrac{V_{P_2P_4}}{R \to \infty} = 0$

$2\omega_4 V_{P_2P_4} = 0.038 \, m/s^2$

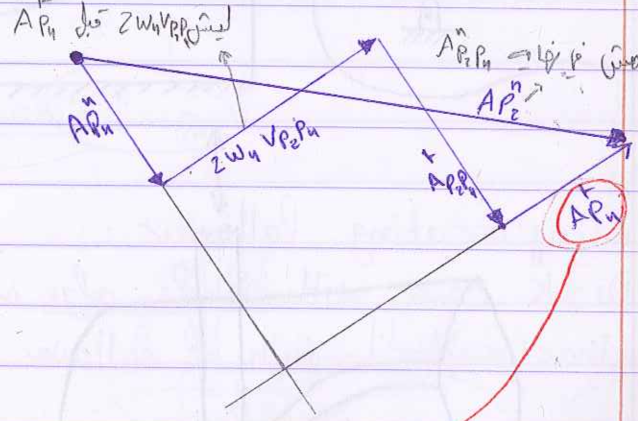
$\omega_4 = \dfrac{V_{P_4}}{O_4P} = 0.144$ rad/s $\underline{ccw}$

$\alpha_4 = \dfrac{A_{P_4}^t}{O_4P} = C.W$



$\boxed{\omega \times V_{P_2P_4}}$

بطلع الاتجاه



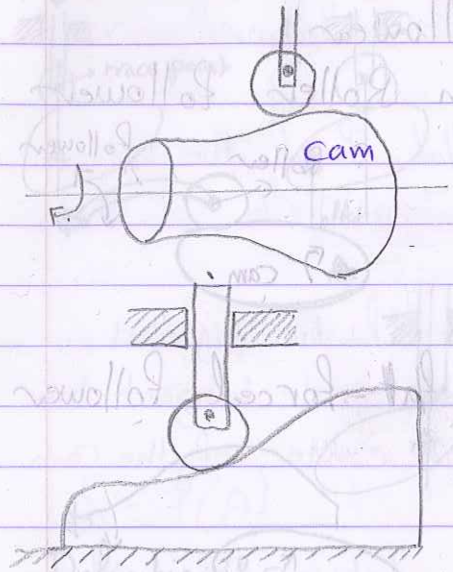
بدي أوجده عشان ه

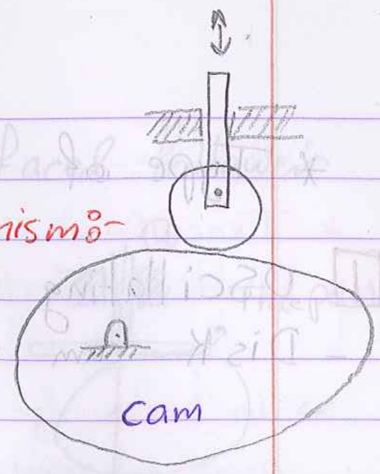
$\alpha_4 = \dfrac{A_{P_4}^t}{O_4P}$

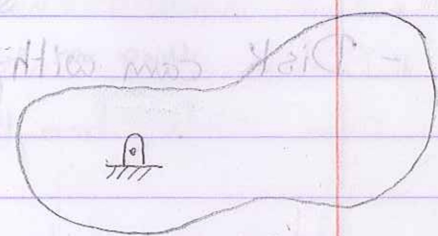
C.W

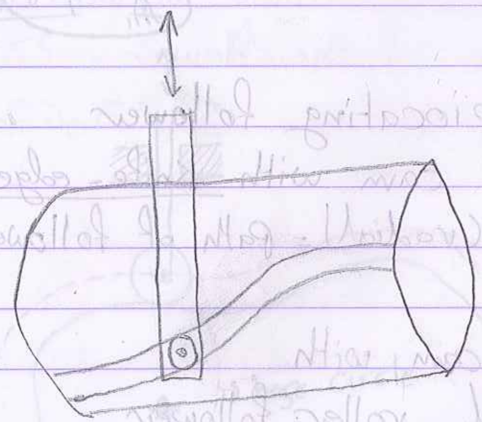
"CAM"

Cam follower mechanism:-





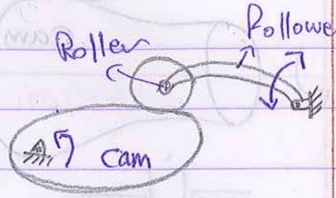




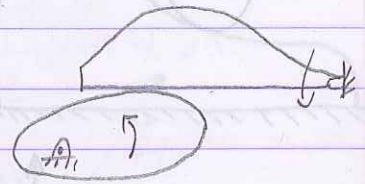
* Type of follower :-

[1] Oscillating follower

- Disk cam with Roller follower



- Disk cam with flat-forced follower



[2] Recipiocating follower

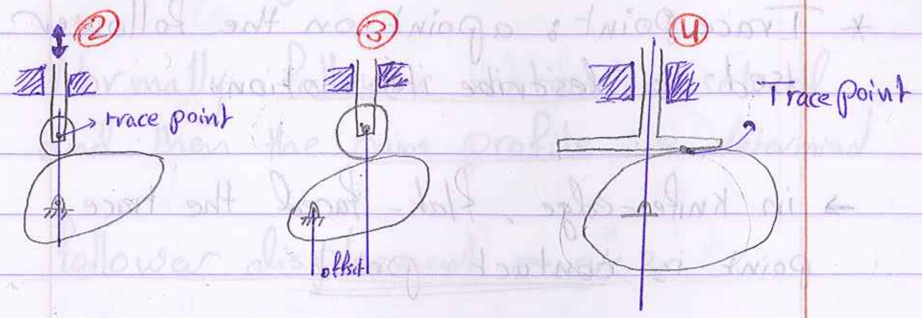
1 Disk cam with Knife-edge in line follower

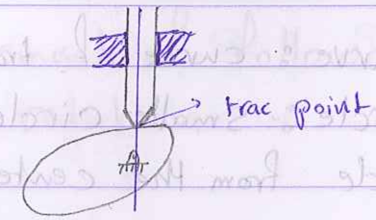
In-line (radial) = path of follower motion

2 Disk cam with radial roller follower

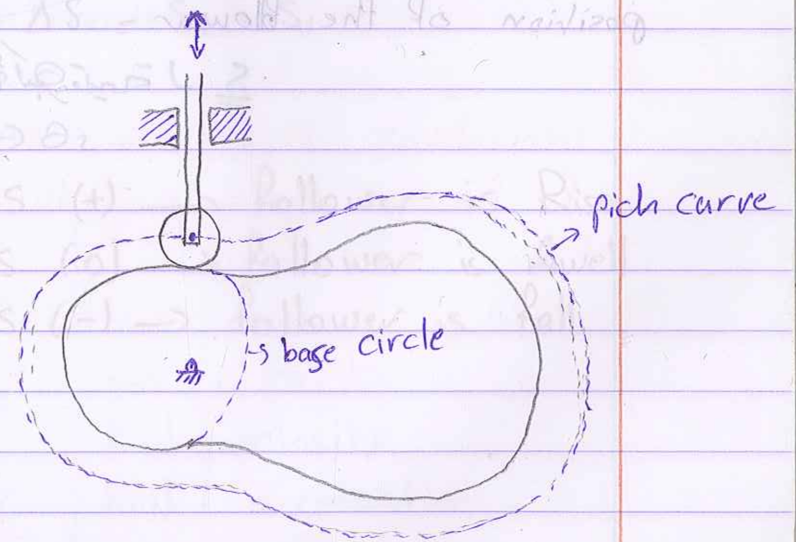
3 Disk cam with radial offset roller follower

4 Disk cam with flat-faced follower





Definition :-



Defintion:-

* Trace point: apoint on the follower used to describe it's motion.

→ in Knife-edge, flat-faced the trace point is contact point

* Pich curve: curve of trace point
* Base circle:- smalle circle tangant to cam circle from the center of the cam

* stroke:- distanc between two extrem position of the flower

أكبر قيمة لـ S

Cam Design:-

Normally follower motion is selected and then the cam profile is determind

follower displacment curve:-

S = displacment of follower
θ = cam rotation

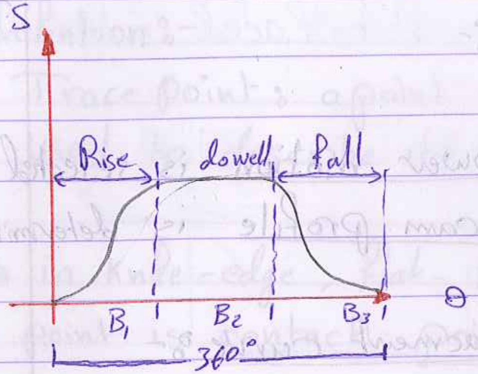
$$S = f(\theta)$$

lift $= \Delta S = S_2 - S_1$

$S_1 \to \theta_1$

$S_2 \to \theta_2$

if ΔS (+) → follower is Rise
if ΔS (0) → follower is dwell
if ΔS (-) → follower is fall



B_1, B_2, B_3
is cam interval angle

$V = \frac{ds}{d\theta}$

$a = \frac{d^2s}{d\theta^2}$

Dowell $\Rightarrow S =$ constant

$\frac{ds}{d\theta} = 0 = V$; $a = 0 = \frac{d^2s}{d\theta^2}$

Design condition

$\Rightarrow$ continous S, V, a

$F = ma \rightarrow F$ is continous

other wise $\rightarrow$ hiegh internal force
$\rightarrow$ vibration
$\rightarrow$ noise
$\rightarrow$ cracks تشقق

$V = \frac{ds}{dt}$ finit velocity

$a = \frac{dv}{dt}$ finit accelaration

$\frac{da}{d\theta}$ = Jerk "vaibration"

Displacment Curve

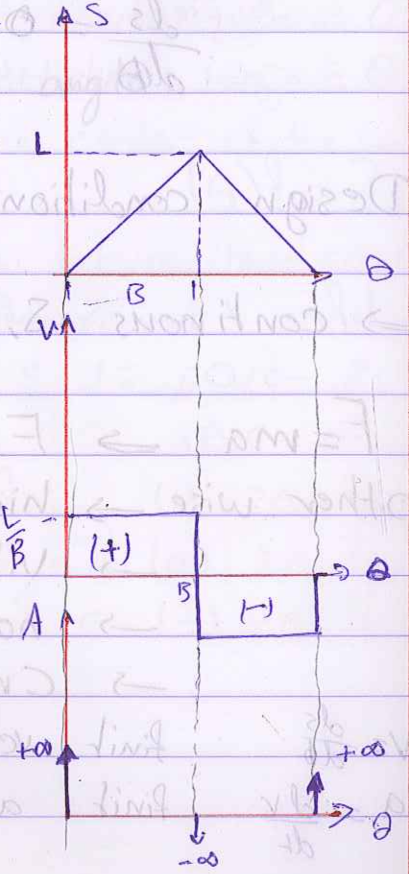
1. Straight line diagram (constant velocity) gives infinite accelaration at inflection point

$A \to \infty \Rightarrow$ high stresses and Inertia Force

$S = V\theta$

$\frac{ds}{d\theta} = V$

$\therefore V = \frac{L}{B}$



⊠ Jerk :- derivative of accelaration gives indication of impact loading

Jerk $\to \infty$: high impact loading and high stress and vibration

2. constant accelaration.

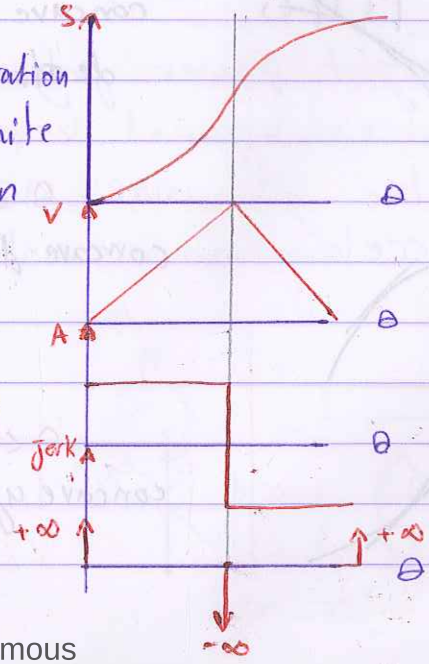
$S = K\theta^2$ $\quad S = \frac{1}{2}A\theta^2$

$\dot{S} = 2K\theta$ $\quad \dot{S} = A\theta$

$\ddot{S} = 2K$ $\quad \ddot{S} = A$

constant accelaration curve give infinite Jerk at infliction point.

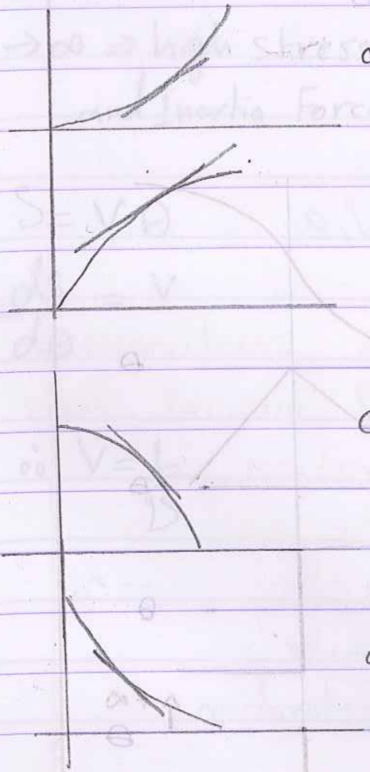
is not stable for high speed cam



3 Curves that give continous accelaration and velocity

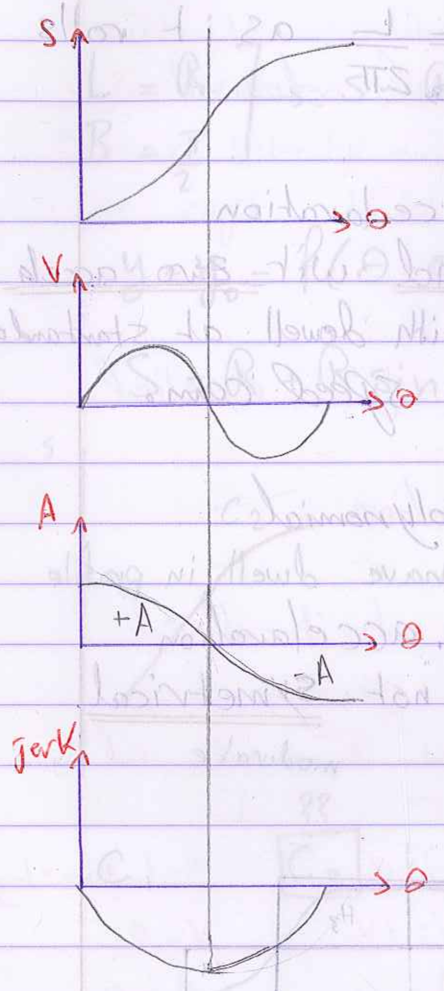
Standard Displacment Diagram

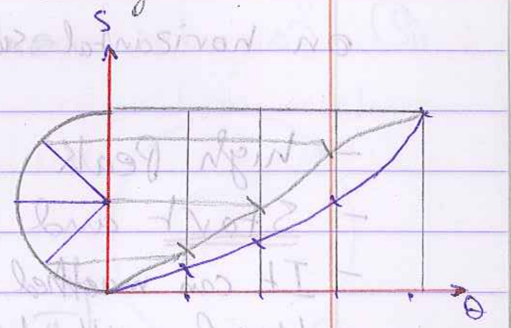
1) simple harmonic motion
2) cycloidal
3) Eight power polynomial



1 Simple Harmonic motion ((SHM))

- give lowest peak accelaration
- Used to match accelaration at start and end with high velocity





SHM

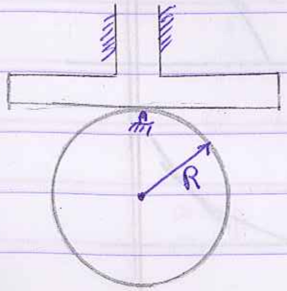
2 Cycloidal

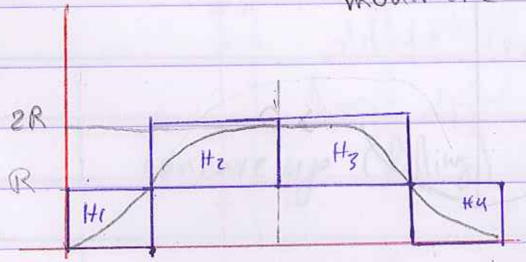
The horizntal distanc transvered by apoint on circumfrances of a circle of $r = \frac{L}{2\pi}$ as it rolls on horizantal surfaces

- high Peak accelaration
- Start and end wit zero accela
- It can matched with dowell at start and end
- Used with high speed cam.
  Low

3 Eight Power polynomial

cycle motion and have dwell in profile
- value of max accelaration
- accelaration is not symetrical
  modirate





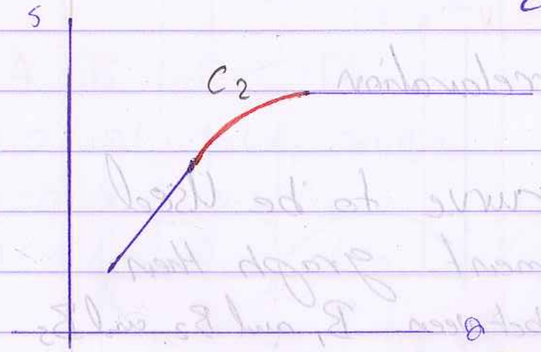
$h = R - R\cos\theta$

$H_2 \Rightarrow S = L \sin \frac{\pi\theta}{2B}$

$\left.\begin{array}{l} L = R \\ B = \frac{\pi}{2} \end{array}\right] \rightarrow S = R\sin\theta$

$y - y_0 = f(\theta - \theta_0)$

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

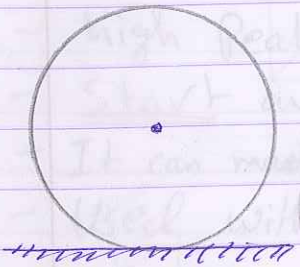


C_1 ?? $\boxed{C_2}$?? $\boxed{C_5}$

$\propto$ becaus the velocity at the begin $= 0$

C_1		C_2		C_5	
في البداية	في النهاية	البداية	النهاية	البداية	النهاية
$V=0$		$V=+V$	$V=0$	$V=0$	
$a=0$		$a=0$	$a=0$	$a=0$	

② can be matched dowell



$y(\theta) =$ cycloid

① Modarate accelaration

Recommand the curve to be Used for the displacment graph then find the relative between B_1 and B_2 and B_5

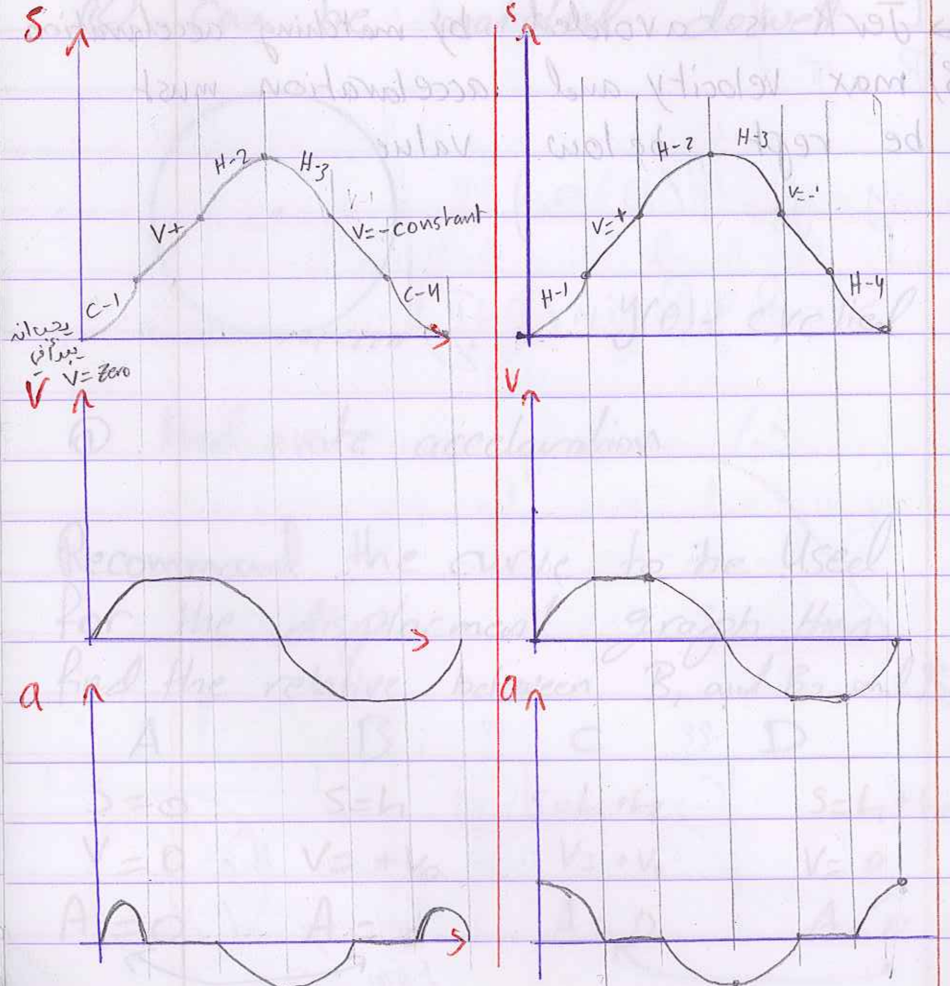
A	B	C	D
$S=0$	$S=L_1$	$S=L_1+L_2$	$S=L_1+L_2+L_3$
$V=0$	$V=+V_0$	$V=+V_0$	$V=0$
$A=0$	$A=0$	$A=0$	$A=0$

C_1 C_2

☒ Matching displacment curve:-

1) motion requirment must be met
2) displacment, velocity, accelaration must be continous at control point
→ Jerk is avoided by matching accelaration
3) max velocity and accelaration must be kept below value

$\boxed{Ex}$ a follower is to have a period of
يشترط السؤال constant velocity during out ward
انه نضع and returns travel, Select curve
const veloc to be matched with these constant
بالصعود والنزول velocity curve for infinit Jerk.



$\boxed{Ex}$ follower motion

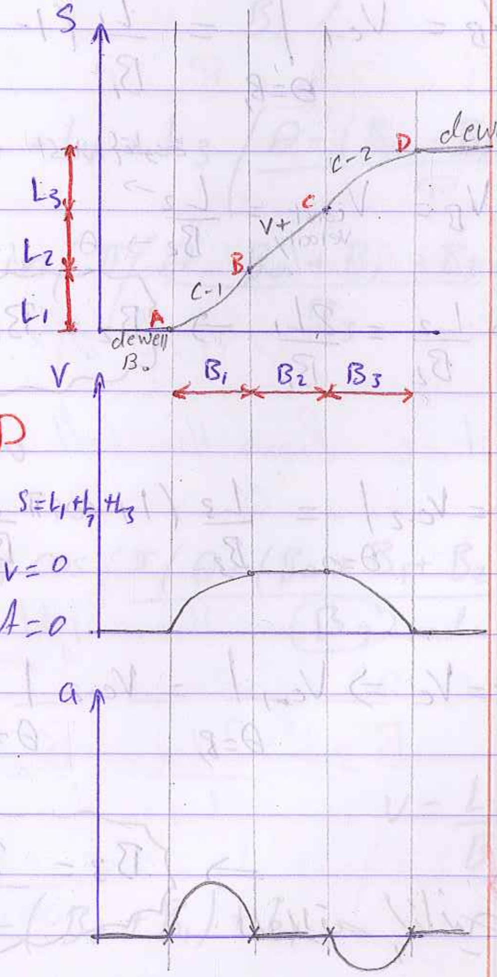
O-A :- dwell

A-B :- rise with acc

B-C :- rise with const velocity

C-D : rise with decelaration

D-> : dwell motion



A	B	C	D
$S=0$	$S=L_1$	$S=L_1+L_2$	$S=L_1+L_2+L_3$
$V=0$	$V=V_1$	$V=V_1$	$V=0$
$A=0$	$A=0$	$A=0$	$A=0$

a) find standerd curve to be matched (Displacement diagram)??

b) relation between $\beta_1, \beta_2, \beta_3$ to match velocity at B, C??

b) $V_B = V_{c-1} \Big|_{\theta=\beta_1} = \frac{L_1}{\beta_1}\left(1-\cos\pi\left(\frac{\theta}{\beta_1}\right)\right) = \frac{2L_1}{\beta_1}$

الكانه أفقيه

$V_B = V_{\substack{const \\ Velocity}} = \frac{L_2 \rightarrow}{\beta_2 \rightarrow \theta}$

$\therefore \frac{L_2}{\beta_2} = \frac{2L_1}{\beta_1} \Rightarrow \boxed{\beta_2 = \beta_1 \frac{L_2}{2L_1}}$ ✓

العلاقة الأولى

$V_c = V_{c-2} \Big|_{\theta=0} = \frac{L_3}{\beta_3}\left(1+\cos\pi \frac{\theta}{\beta_3}\right) = \boxed{\frac{2L_3}{\beta_3}}$

$V_B = V_c \Rightarrow V_{c-1} \Big|_{\theta=\beta_1} = V_{c-2} \Big|_{\theta=0}$

$\Rightarrow \boxed{\beta_3 = \frac{\beta_1 L_3}{L_1}}$

العلاقه الثانيه

حل الاستاد نضال

C_1

$S_1 = L_1\left(\frac{\theta-\beta_0}{\beta_1}\right) - \frac{1}{\pi}\sin\left(\pi\left(\frac{\theta}{\beta_1} - \beta_0\right)\right)$

$V = \frac{L_1}{\beta_1}\left(1-\cos\pi\left(\frac{\theta-\beta_0}{\beta_1}\right)\right)$

$C_2 \Rightarrow S = L_1 + L_2 + L_3\left(\frac{\theta-(\beta_0+\beta_1+\beta_3)}{\beta_3}\right) + \frac{1}{\pi}\sin\left(\pi\left(\frac{\theta-\beta_0+\beta_1+\beta_3}{\beta_3}\right)\right)$

$\cancel{S = L_1 + L_2}$

$$\boxed{V = \frac{L_3}{\beta_3\,\text{rad}}\left(1+\cos\left(\frac{\pi\left(\theta-(\beta_0+\beta_1+\beta_2)\right)}{\beta_3\,\text{rad}}\right)\right)}$$

$\beta \rightarrow C$

$V = \frac{L_2}{\beta_2}$

$S = \frac{L_2}{\beta_2}\left(\theta-(\beta_0+\beta_1)\right) + L_1$

at B from the right $V_B = \frac{L_2}{B_2}$

" " left $V_B = \frac{2L_1}{B_1}$

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

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

a/ Accelaration ما أخذنا علاقة فيه لانه في البدايه والنهايه صفر

at C from the left $V_C = \frac{L_2}{B_2}$

from the right $V_C = \frac{2L_3}{B_3}$

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

Determine the maximum accelaration

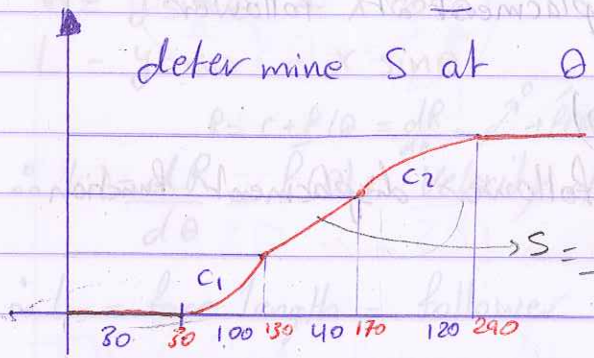
a max at $\theta = \frac{B_1}{2} = \frac{\pi L_1}{B_1^2} (\sin \frac{\pi}{2})$

a min $= -\frac{\pi L_3}{B_3^2}$

max absolute accelaration

$|a_{min}| \; (\gtreqless) \; |a_{max}|$

determine S at $\theta = 120°$



$\rightarrow S = \frac{L_2}{B_2} (\theta - (B_0 + B_1)) + L_1$

$\Rightarrow S = L_1 \left(\frac{120-30}{100} - \frac{1}{\pi} \sin\left(\frac{\pi (120-30)}{100} \right) \right)$

problem [17, 22, 36, 37, 40, 43, 44]

[*] Cam profile Desigin (Analytical method)

[1] Disk Cam with Radial Flat - faced Follower

we have to determine, [Design Requrment]

1) Profile of the cam [Parametric Eq of cam Profile]
2) min follower Length [contact Point]
3) min. cam Radius [base circle]

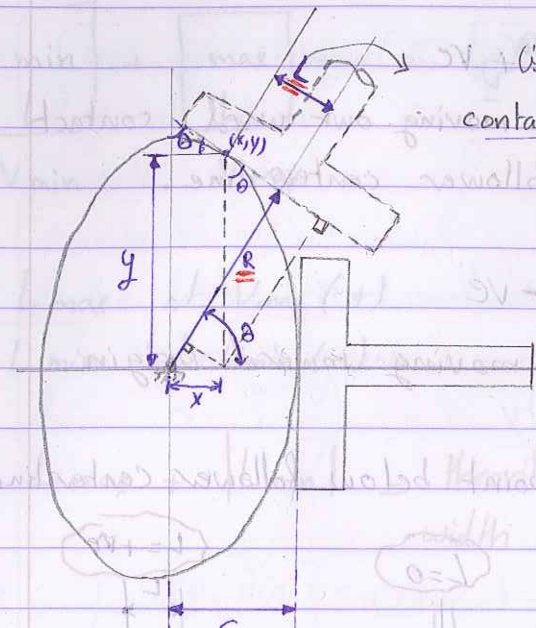
C : min cam Radious (base circle)

R : Radial displacment at follower

$$R = C + f(\theta)$$

where $f(\theta)$ = follower displacment function

المسافه العموديه بين contact Point و center



اصغر مسافه بين contact Point و center الافقيه

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

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

$$R = c + f(\theta) \Rightarrow \frac{dR}{d\theta} = \cancel{c'}^{\,0} + f'(\theta)$$

$$\therefore L = \frac{dR}{d\theta} = f'(\theta) = \text{Velocity of follower}$$

$\therefore L$ = face length = follower velocity

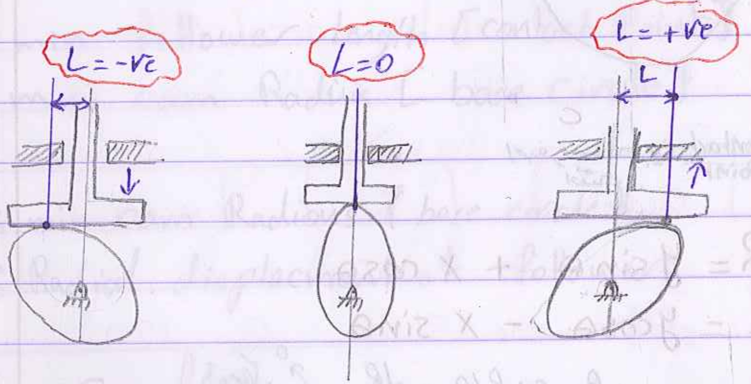
$\Rightarrow$ if $f'(\theta) = +ve$

$\therefore$ follower moving out ward contact above follower center line.

$\Rightarrow$ if $f'(\theta) = -ve$

$\therefore$ follower moving toward origin of cam

- contact point below follower centerline



$L = V$

$V = +ve \Rightarrow L = +ve$

$\Downarrow$

the follower is rising

dwell $\Rightarrow V = 0, \; L = 0$

$\boxed{\begin{matrix} \text{min} \\ L \end{matrix}} + \boxed{\begin{matrix} \text{max} \\ L \end{matrix}}$

V_{min} V_{max}

طول flat فيس
force

L_{max} at V_{max} (+)

L_{min} at V_{min} (−)

$L_{max} + |L_{min}| =$ theoritical face width of the follower

المثال [illegible] موجود في امتحانات عند الاستاذ

$$V_{max} = \frac{5\pi}{2\left(120 \times \frac{\pi}{180}\right)} = 3.75 = L_{max}$$

$$V_{min} = -\frac{\pi L}{2\beta} = \frac{-\pi L}{2\beta} = -5$$

Theoritical face width $= 3.75 + |-5|$
$= 8.75$ cm

$C_{min} \Rightarrow [F + F''']$ is min in negative

$L = f'(\theta)$

∴ face length = follower velocity

∴ min face length → max velocity + min velocity

$t_{min} \longrightarrow$

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

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

but $R = c + f(\theta)$ and $L = f'(\theta)$

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

$y = [c + f(\theta)]\sin\theta + f'(\theta)\cos\theta$

$R \Leftrightarrow y$ عوضنا محل

$L \Leftrightarrow x$

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

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

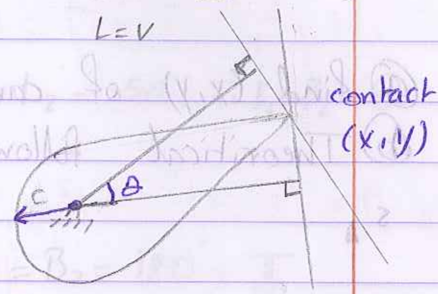
$\boxed{X}$ Cam Pointing [Cusp]:-

A point on cam surface, for small rotation of cam, the contact point will not change (& the follower not move)

الكام يوجد حركة مع ثبات ال follower

$\frac{dx}{d\theta} = 0$, $\frac{dy}{d\theta} = 0$ ($\underline{\underline{L}}$ يوجد)

$L = V$



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

$\frac{dy}{d\theta} = [c + f(\theta) + f''(\theta)]\cos\theta$

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

عندما يكون مجموعهم صفر بيكون

هناك cusp

to avoid cusp $\Rightarrow c + f(\theta) + f''(\theta) > 0$

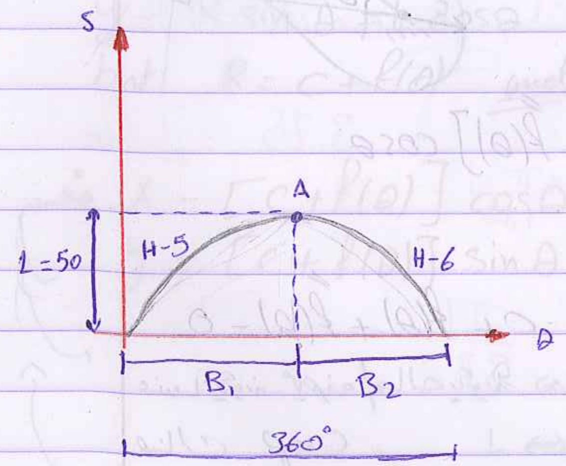
$\Rightarrow c > -[F + F'']$ $c = -ve$ has no significant meaning

in graph by graphical method

$\therefore$ C largest cam Radious when $[f+f'']$ is min
C mimums cam Radious when $[f+f'']$ is max
بالسالب اكبر قيمه بالسالب

Ex: Disk cam with flat-faced follower
37 follower moves with (SHM) for rise and return in one revolution of the cam ($\theta = 360^\circ$) $L_{rot} = 50$ mm, $C_{min} = 25$ mm

(a) find (x, y) of cam contour (profile)
(b) Theoritical follower face length



we make equality of accelaration

$$\therefore a_{H-5}\Big|_{\theta=0} = a_{H-6}\Big|_{\theta=B_2}$$

حتى يكون constant accelaration يجب ان تكون a في البداية تساوي a في النهاية

$$\frac{\pi^2 L_1}{2B_1^2}\left(\cos\frac{\pi(0)}{B_1}\right) = \frac{-\pi^2 L_2}{2B_2^2}\left(\cos\frac{\pi B_2}{B_2}\right)$$

$$\frac{L_1}{B_1^2} = \frac{L_2}{B_2^2} \quad \text{but } L_1 = L_2 = 50 \quad \therefore B_1 = B_2 \;-\; (1)$$

$$B_1 + B_2 = 360^\circ \quad \therefore B_1 = B_2 = 180^\circ = \pi$$

[H-5] $\Rightarrow f(\theta) = S = \frac{L}{2}\left(1 - \cos\frac{\pi\theta}{\pi = B}\right) = 25(1-\cos\theta)$

$$\therefore f(\theta) = 25(1-\cos\theta)$$

$$f'(\theta) = 25(\sin\theta)$$

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

$$= [25 + 25 - 25\cos\theta]\cos\theta - 25\sin\theta\sin\theta$$

$$= 50\cos\theta - 25\cos\theta^2 - 25\sin^2\theta$$

$$= 50\cos\theta - 25[\cos^2\theta + \sin^2\theta]$$

$$\therefore \cos\theta = \frac{X+25}{50}$$

$y = [c + f(\theta)]\sin\theta + \acute{f}(\theta)\cos\theta$

$= [25 + 25 - 25\cos\theta]\sin\theta + 25\sin\theta\cos\theta$

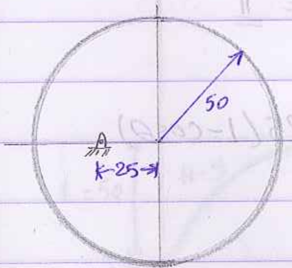
$\therefore y = 50\sin\theta$

$\therefore \sin\theta = \frac{y}{50}$

but $\cos^2(\theta) + \sin(\theta)^2 = 1$

$\left(\frac{y}{50}\right)^2 + \left(\frac{X+25}{50}\right)^2 = 1$

$\therefore y^2 + (X+25)^2 = 50^2 \Rightarrow$ Circle Equation with radiou of $\underline{\underline{50}}$ and far from center $\underline{\underline{25}}$



b) $L_{min} = \acute{f}(\theta)_{max}$ → max velocity

from the Eq of velocity of H-5

$v = \frac{\pi L_1}{B_1}\left(\sin\frac{\pi\theta}{B}\right) \Rightarrow v_{max} = \frac{\pi L_1}{2B_1}$ when $\theta = \frac{B}{2} = \frac{\pi}{2}$

$\therefore L_{min} = \frac{\pi L_1^{50}}{2B_{1 \to \pi}} = 25$

or from $\acute{f}(\theta)$

$\Rightarrow L_{min} = \max$ of $(25\sin\theta) = 25$ at $\frac{\pi}{2}$

$\therefore L_{tot} = 25 + 25 = 50$ mm

Harmonic معادلة دائرة

اذا كانت مستمرة complete أو جزء من دائرة

اذا كان بيضاوي revelouhion

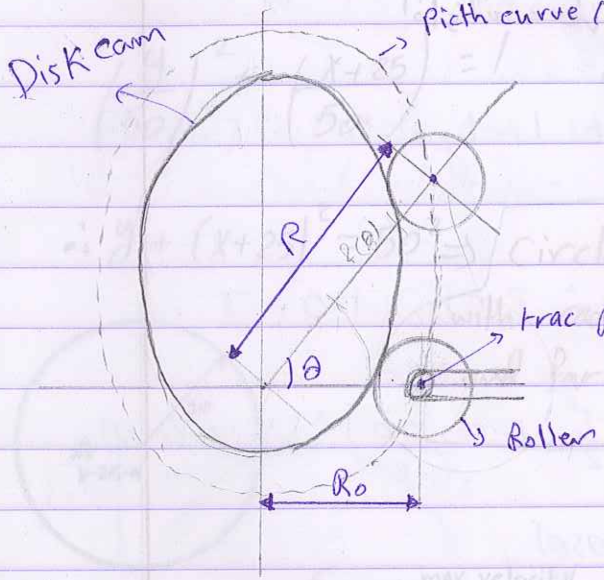
2 Disk cam with Radial Roller follower

R_o = min pitch radius

R = radial follower displacment

$R = R_o + f(\theta)$

$f(\theta)$ = follower displacment function



⊛ Cam Pointing [Cusp]:-

ρ_c = radious of curvetur of cam surface

ρ = radious of curvetur of Pitch surface

R_r = roller radious

$\rho \equiv \rho_c + R_r$

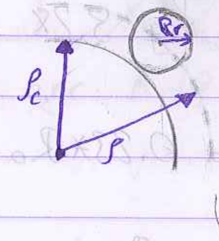
for constant ρ $\quad R_r \uparrow \rightarrow \rho_c \downarrow$

$R_r = \rho \rightarrow \rho_c = 0$ ((cusp))

$R_r = \rho \rightarrow$ cam pointing

⇒ for no pointing ((to avoid it))

$R_r < \rho_{min}$



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

$\rho_{min} \rightarrow \frac{d\rho}{d\theta} \rightarrow 0$ الطريقة صعبة ولكن نجدها

جاهزة من الجداول

Fig 3.27, 28, 29 for SHM, cyc, Power

Fig 3.30

سؤال [illegible]

$\rightarrow \left(\frac{\rho_{min}}{R_o} \text{ vs } \beta\right) \xrightarrow{\text{for}} \frac{L}{R_o}$

Ex :- Radial roller follower

$L = 0.75''$

SHM

$B = 30^\circ$

$R_r = 0.25''$

$R_o = 1.875''$

Check for pointing??

$$\frac{L}{R_o} = \frac{0.75}{1.875} = 0.4$$

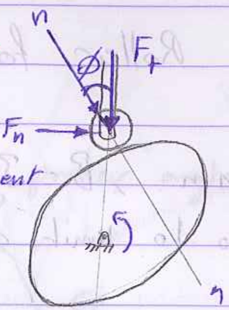
from fig 3.28 $\Rightarrow \frac{\rho_{min}}{R_o} = 0.23$

$$\rho_{min} = 0.23 * R_o = 0.23 * 1.875 = 0.43$$

$R_r < \rho_{min}$ ∴ No pointing

$$x_A = R\cos\theta$$
$$y_A = R\sin\theta$$
$$x_P = x_A - R_r\cos(\alpha+\theta)$$
$$y_P = y_A - R_r\sin(\alpha+\theta)$$

Pressure Angle :-

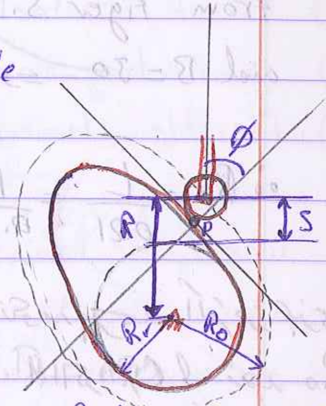


F_n = undisiearble component

$\phi \downarrow \longrightarrow F_n \downarrow$

$F_n \downarrow \longrightarrow T \downarrow$

ϕ must be small as possible



$$R = R_o + f(\theta)$$

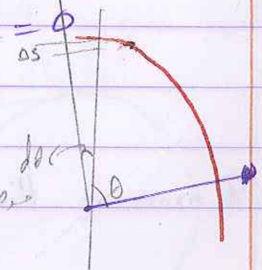
$$\frac{dR}{d\theta} = f'(\theta) \Rightarrow \boxed{\tan\phi = \frac{F'(\theta)}{R_o + R}}$$

for Small $d\theta \rightarrow$ the arc $R\,d\theta \approx$ throug line

$$\tan\phi = \frac{\Delta S}{R\,d\theta}$$

$$\Delta S = dR \rightarrow \tan\phi = \frac{dR}{d\theta}\,\frac{1}{R}$$

$\rightarrow$ to find $\phi_{max} \rightarrow \frac{d\phi}{d\theta} = 0$



$\boxed{5.31}$ من عنده

EX :- Radial Roller follower

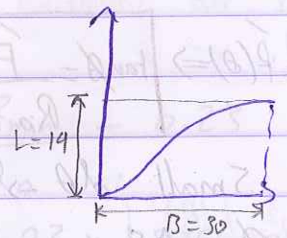
$L = 19\ mm$, $B = 30$, SHM

find R_o to limit $\alpha_{max} = 30$??
max presser Angle

from figer 3.B1 at $\alpha_{max} = 30$

and $B = 30$ $\Rightarrow \frac{L}{R_o} = 0.21$ for SHM

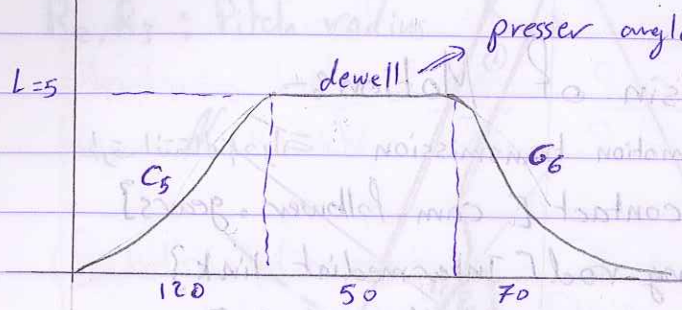
$\therefore R_o = \frac{L}{0.21} = \frac{19}{0.21} = 90.5\ mm$



عندما تكون لدي أكثر من جزء مثل
(Cyclo, SHM , Poly) نجد Ro
لكل جزء منها ونأخذ اكبر Ro
لأنه نفس الشيء في حال α_{max}

Presser angle in dewll = zero

Example



$R_o = 8$, $R_r = 2$

for C_5

$\frac{L}{R_o} = \frac{5}{8} = 0.625$, $B_1 = 120$

$\alpha_{max} = 26°$ for C_5

$\frac{L}{R_o} = \frac{5}{8} = 0.625$, $B_2 = 70$

$\alpha_{max} = 38$ for C_6

$\alpha > 30$ so we will increase R_o

GEAR

chapter 7

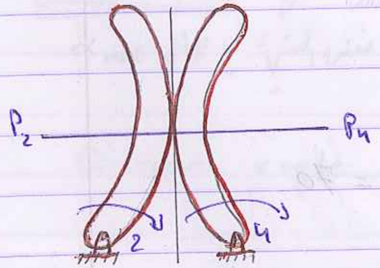
Transmissin of Motion:-

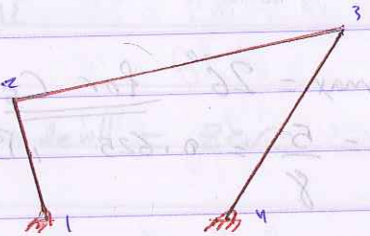
ways of motion transmission طرق انتقال الحركة

1) Direct contact [cam-follower, gears]
2) connecting rod [Intermediat link]
3) Flexible element [belt, chain]
   حزام سلسلة

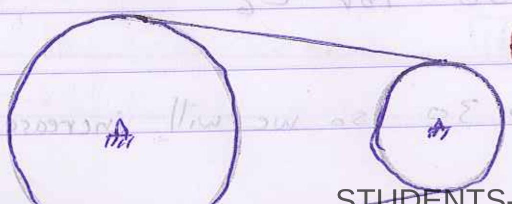
line of transmission:-

motion is transmetted from driver to driven machin along line of transmission





① common normal P_2P_4 ② along connecting rod



③ flixible element

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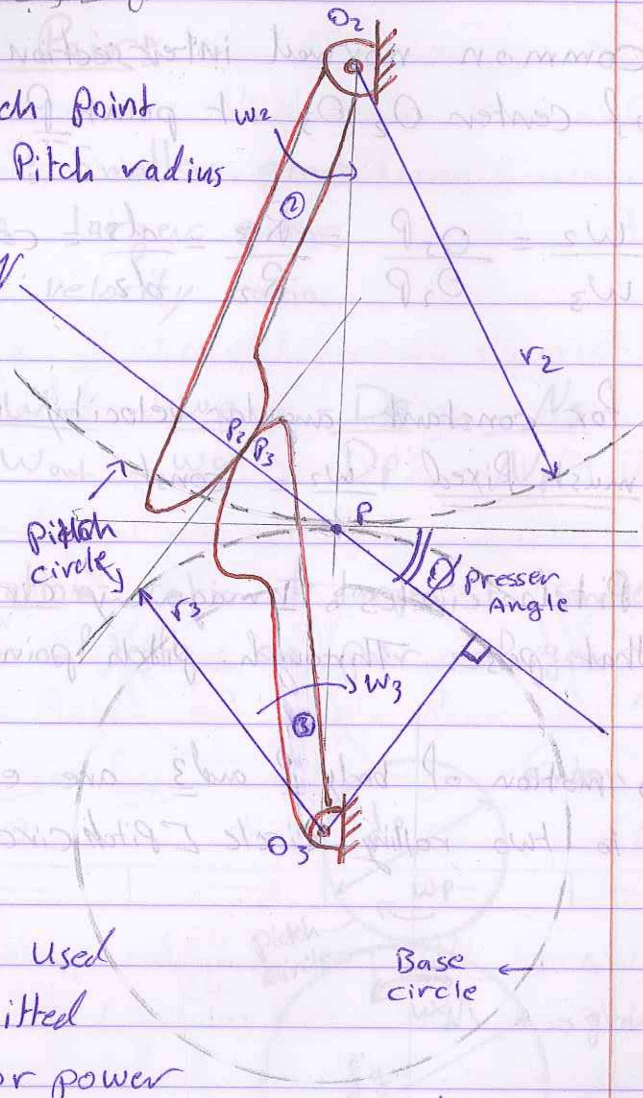
P: Pitch Point

R_2, R_3 : Pitch radius



Gears are Used to transmitted motion or power between two shaft (rotating shaft) common normal intersection line of center $O_2 O_3$ at point $\underline{P}$

$$\frac{W_2}{W_3} = \frac{O_3P}{O_2P} = \frac{R_3}{R_2} = \frac{d_3}{d_2} = \text{constant}$$

For constant angular velocity ratio, $\underline{P}$ must fixed $\frac{W_2}{W_3} = \text{const}$

Pitch circles : Imageneny circles that parses through pitch point $\underline{P}$

$\Rightarrow$ motion of body $\underline{2}$ and $\underline{3}$ are equivalant to two rolling circle [Pitch circle]

Gear Pair:

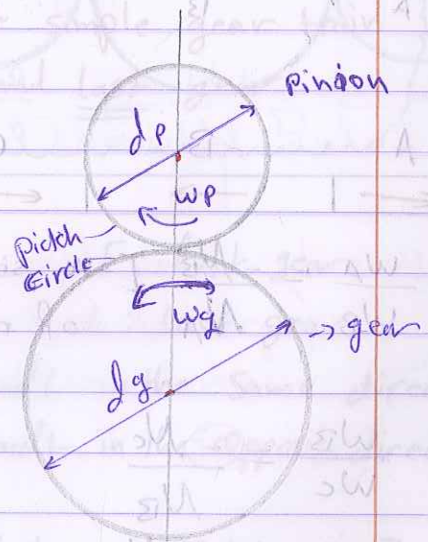
Pinion : Smaller gear

Gear : larger gear

Angular velocity ratio

$$(V_R) = \frac{W_{in}}{W_{out}} = \frac{W_P}{W_g} = \frac{-D_g}{D_P} = \frac{-N_g}{N_P}$$

gear ratio : ratio of larger to smaller number of teeth on pair of gear



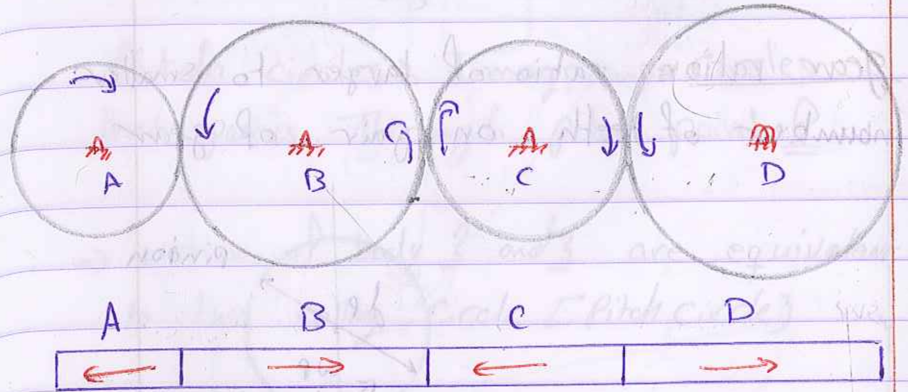
Gear Trains :-

Two or more gear in mesh to transmit motion form one shaft to anther

[1] Simple gear train :-

one gear in each shaft

[a] External Gears



$$\frac{W_A}{W_B} = \frac{-N_B}{N_A}$$ [-ve sing for oppitise direction of rotation]

$$\frac{W_B}{W_C} = \frac{-N_C}{N_B}$$

$$\frac{W_C}{W_B} = \frac{-N_B}{N_C}$$

$$\text{velocity ratio} = \frac{W_{in}}{W_{out}} = \frac{W_A}{W_D} = \frac{W_A}{W_D}$$

$$= \frac{W_A}{W_B} * \frac{W_B}{W_C} * \frac{W_C}{W_D} = \frac{W_A}{W_D}$$

$$= \frac{-N_B}{N_A} * \frac{-N_C}{N_B} * \frac{-N_D}{N_C} = -\frac{N_D}{N_A}$$

V_R = +ve if input and output gear rotat in the same direction

V_R = -ve if input and output gear rotat in the opposit direction

> Velocity Ratio for simple gear train depend on first and last gear

$$\therefore V_R = \frac{W_F}{W_L} = \frac{N_L}{N_F}$$ F : first gear, L : last gear

$V_R \Rightarrow$ +ve if F and L in the same direction

$V_R \Rightarrow$ -ve if F and L in the opposit direction

tooth no of intermeadiat gear [Idele gear] are Cancle

Idler gear فولاذ

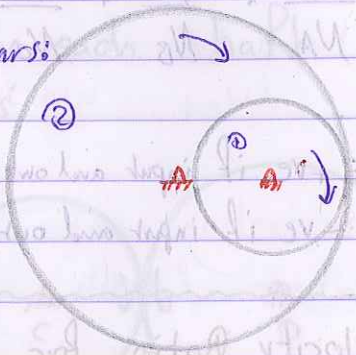
⇒ Purpose of Idder gear:-

1) To increase the center distance
2) To chang direction of rotation

[b] Internial gear's:

Pinion with internal gears:

$$V_R = \frac{W_{in}}{W_{out}} = \frac{W_1}{W_2} = +\frac{N_2}{N_1}$$

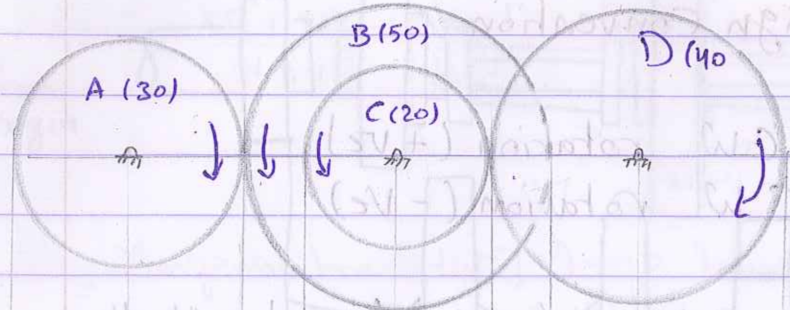


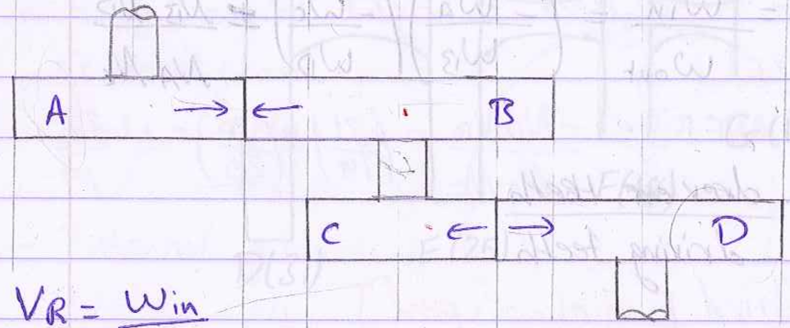
$$V_R = \frac{W_{in}}{W_{out}} = \frac{W_{driver}}{W_{driven}} = \frac{\text{Product of teath of driven gear}}{\text{Product of teath of driver gear}}$$

Velocity ratio depend on no. of teeth of indep and out put gear (First, last)

[2] Compound Gear train:-

Two or more gear have the same axis (on Same shaft)





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

$$= \frac{W_A}{W_D} = \frac{\text{Prouduct of no. dreven}}{\text{Prouduct of no. driver}}$$

$$= +\frac{N_B\,N_D}{N_A\,N_C}$$

$$= \frac{(50)(40)}{(30)(20)} = +\frac{20}{6}$$

نعتبر gear A, B Train
gear C, D Train
$W_C = W_B$

if $\omega_A = 1600$ rpm (ccw)

$\therefore \omega_B = \frac{+6}{20}(1600) = +480$ rpm C.C.W

Sign Convention

CCW rotation (+ve)

CW rotation (-ve)

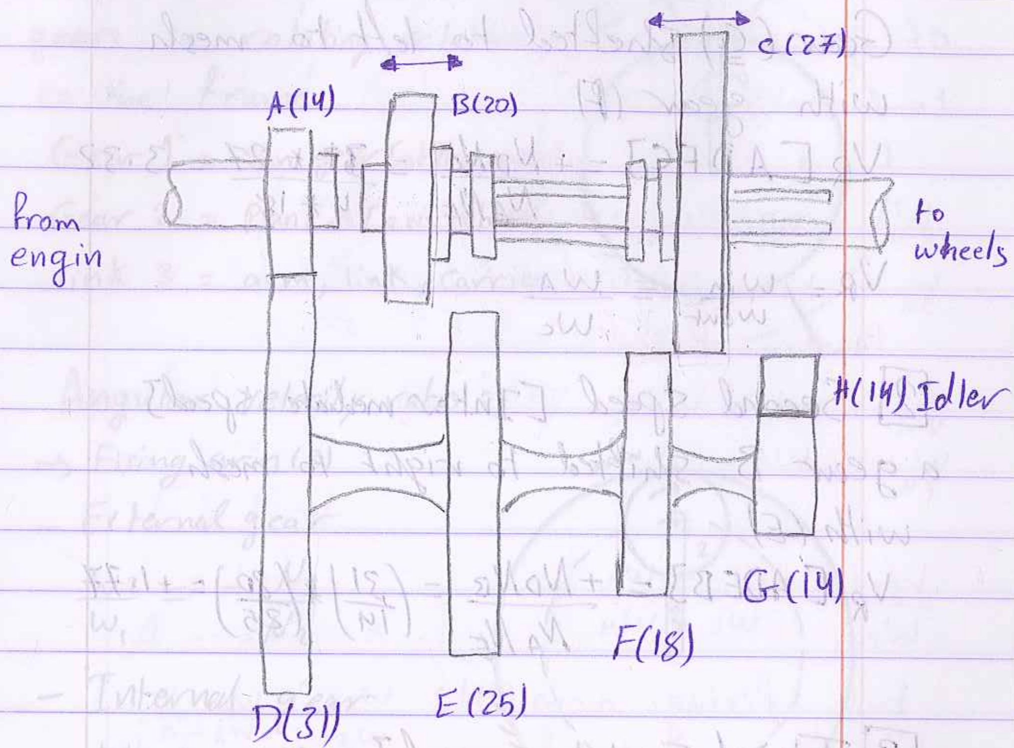
$$V_R = \frac{W_{in}}{W_{out}} = \left(\frac{-W_A}{W_B}\right)\left(\frac{-W_C}{W_D}\right) = \pm \frac{N_B\, N_D}{N_A\, N_C}$$

$= \dfrac{\text{drev} ~~\text{er}~~ \text{teeth}}{\text{driving teeth}}$

Train Value $(e) = \dfrac{W_{out}}{W_{in}} = \dfrac{\text{Product of teeth driving}}{\text{Product of teeth driver}}$

$$e = \frac{1}{V_R}$$

Automotive transmission :-



Gear A : driven by engin

Gear B, E, F, G : rotat as one Unit

Gear H : Idler that mesh with G

Gears A, D, E, F, G, H are in motion if gear A in motion

[1] First speed [low speed]

Gear ($\underline{C}$) shefted to left to mesh with gear (F)

$$V_R[ADFC] = +\frac{N_D N_C}{N_A N_F} = \frac{31 * 27}{14 * 18} = 3.32$$

$$V_R = \frac{W_{in}}{W_{out}} = \frac{W_A}{W_C}$$

[2] Second speed [Intermediate speed]

a gear B shifted to right to mesh with (E)

$$V_R[ADEB] = \frac{+N_D N_B}{N_A N_E} = \left(\frac{31}{14}\right) * \left(\frac{20}{25}\right) = +1.77$$

[3] Third [higher speed]

Gear (B) shifted to left to eingen (contact) with gear A by mean of clutch teeth $V_R = \underline{\underline{1}}$

[4] Reverse :- يعكس الحركة

gear (c) shifted to right to mesh with Idler (H)

$$V_R[ADGHC] = -\left(\frac{31}{14}\right)\left(\frac{14}{14}\right)\left(\frac{27}{14}\right) = -4.27$$

[3] Planetary Gear trains :-

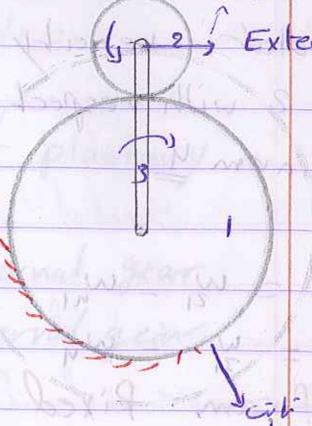
$V_B = W_a * r_{B/P}$

The axis of one or more gears is rotating relative to the frame

Gear 1 = sun gear [at the center]

Gear 2 = Plant → [axis rotate]

link 3 = arm, link, carrier



Angular velocity ratio :-

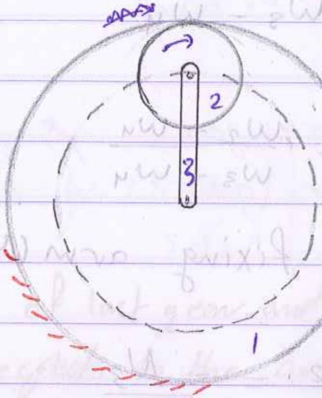
⇒ Fixing arm (3)

- External gear

$$\frac{W_2}{W_1} = -\frac{N_1}{N_2}$$

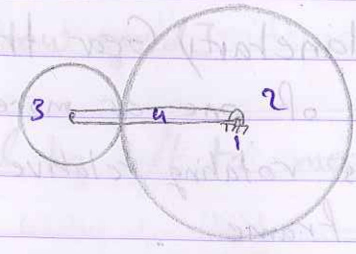
- Internal gear

$$\frac{W_2}{W_1} = +\frac{N_1}{N_2}$$



⇒ when all member are free to rotat velocity of 2 with respect to arm $\underline{4}$

⇒ when all free to rotat velocity of 2 with respect to arm $\underline{4}$



$$\frac{\omega_2 - \omega_4}{\omega_3 - \omega_4} = \frac{-N_3}{N_2}$$

$$\omega_{24} = \omega_{21} - \omega_{41}$$

$$\omega_{34} = \omega_{31} - \omega_4$$

fram fixed

$$\omega_{24} = \omega_2 - \omega_4$$

$$\omega_{34} = \omega_3 - \omega_4$$

$$\frac{\omega_{24}}{\omega_{34}} = \frac{\omega_2 - \omega_4}{\omega_3 - \omega_4}$$

but fixing arm (4): $\dfrac{\omega_{24}}{\omega_{34}} = \dfrac{\omega_2 - 0}{\omega_3 - 0}$

$$= \frac{\omega_2}{\omega_3} = \frac{-N_3}{N_2}$$

train value $= (e) = \dfrac{-N_3}{N_2}$

$$\Rightarrow \frac{\omega_{24}}{\omega_{34}} = \frac{\omega_2 - \omega_4}{\omega_3 - \omega_4} = e$$

$$\frac{\omega_{24}}{\omega_{34}} = \frac{\omega_2 - \omega_4}{\omega_3 - \omega_4} = \frac{-N_3}{N_2}$$

⇒ applied only for plantary

$$\therefore\ e = \begin{cases} \dfrac{-N_3}{N_2} & \text{---- External gear} \\ \dfrac{N_3}{N_2} & \text{--- Internal gear} \end{cases}$$

⇒ for any planterary gears :-

F = First

L = last

A = Arm

$\dfrac{\omega_{LA}}{\omega_{FA}}$ = velocity ratio of last gear and first with respect to the arm

ω_F = velocity of the first gear with respect fixed link

ω_L = 〃 〃 〃 last 〃 〃 〃 〃 〃

ω_A = 〃 〃 〃 Arm with respect to fixed link

$$\frac{W_{LA}}{W_{FA}} = \frac{W_L - W_A}{W_F - W_A} = e$$

sing CCW (+)
CW (-)

$$e = \frac{\text{Product of driver gear}}{\text{Product of driven gear}}$$

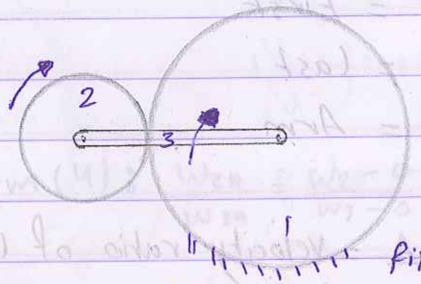
$e = +ve$ if F and L rotat in the same direction

$e = -ve$ if F and L " " " opsitie "

~~[illegible]~~

Example: External

first gear = gear 1
last gear = gear 2
Arm = link 3

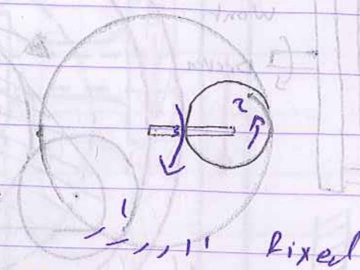


$$\therefore \frac{W_{LA}}{W_{FA}} = \frac{W_L - W_A}{W_F - W_A} = -\frac{N_1}{N_2}$$

$$\left.\begin{aligned} W_L &= W_{21} = W_2 \\ W_F &= W_1 = 0 \\ W_A &= W_{31} = W_3 \end{aligned}\right\} \Rightarrow -\frac{N_1}{N_2} = \frac{W_2 - W_3}{0 - W_3} \Rightarrow W_2 = W_3\left(1 + \frac{N_1}{N_2}\right)$$

Internal

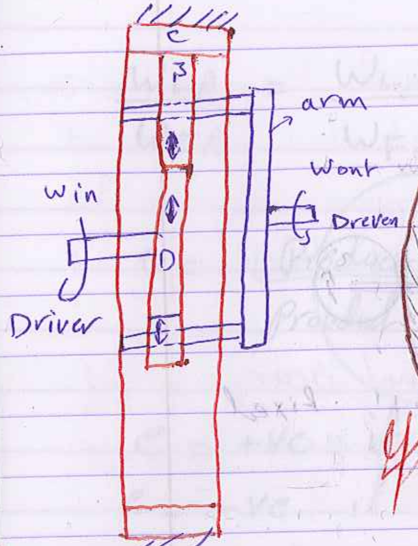
First = 1
last = 2
Arm = 3

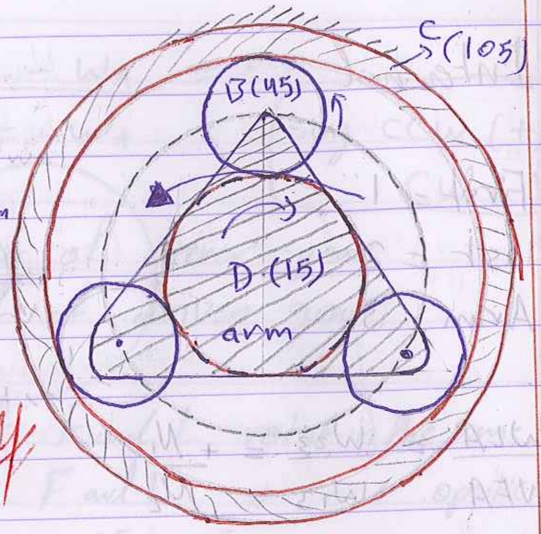


$$\frac{W_{LA}}{W_{FA}} = \frac{W_{23}}{W_{13}} = +\frac{N_1}{N_2}$$

but $$\frac{W_{23}}{W_{13}} = \frac{W_2 - W_3}{W_1 - W_3}$$

$$\frac{N_1}{N_2} = \frac{W_2 - W_3}{0 - W_3} \Rightarrow \boxed{W_2 = W_3\left(1 - \frac{N_1}{N_2}\right)}$$





Find W_{out} if $W_{in} = 1000$ rpm

أو العكس

$F = D \quad , \quad L = C$

$$\frac{W_{LA}}{W_{FA}} = \frac{W_C - W_A}{W_D - W_A} = \frac{-N_D}{N_C}$$

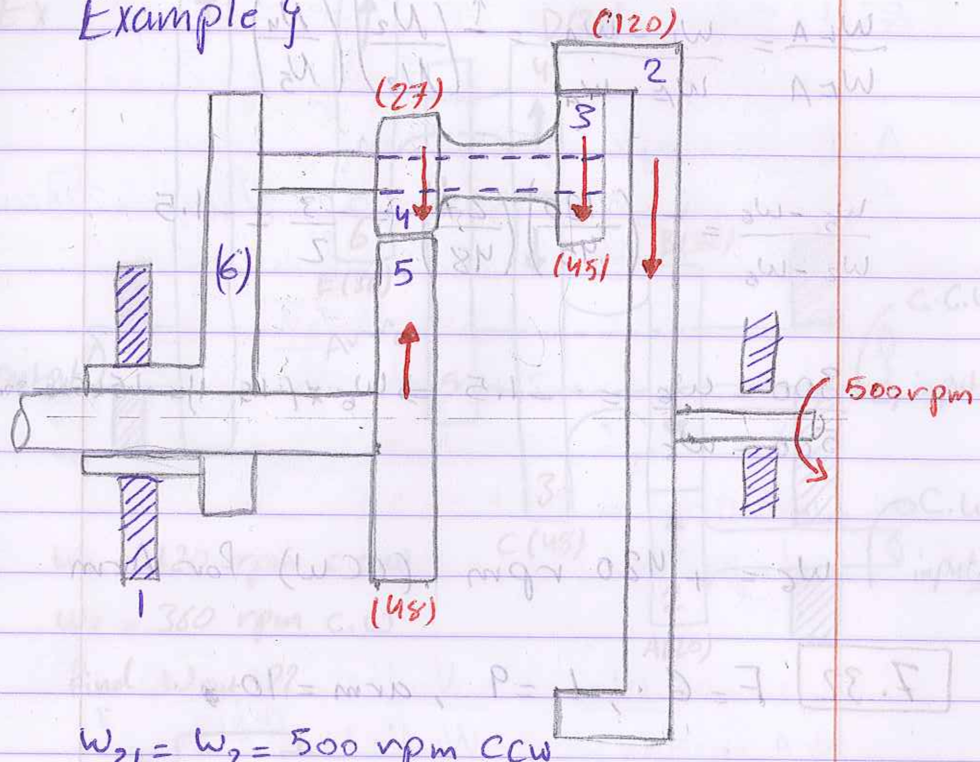
$$\frac{0 - W_A}{W_D - W_A} = \frac{-15}{105} \Rightarrow W_A\left(1 + \frac{15}{105}\right) = W_D\left(\frac{15}{105}\right)$$

$$W_A = W_D \frac{\frac{N_D}{N_C}}{\left(1 + \frac{N_D}{N_C}\right)} = 0.125\, W_D = +125 \text{ rpm}$$

in the same direction W_D

$\therefore$ W_{in} and W_{out} in the same direction

Example



$W_{21} = W_2 = 500$ rpm CCW

$W_{51} = W_5 = 300$ rpm CW

Find $W_6 = ??$

$F = 2$

$L = 5$

Arm $= 6$

W_F عكس W_L لانو

$$\frac{\omega_{LA}}{\omega_{FA}} = \frac{\omega_L - \omega_A}{\omega_F - \omega_A} = -\left(\frac{N_2}{N_3}\right)\left(\frac{N_4}{N_5}\right)$$

$$\frac{\omega_5 - \omega_6}{\omega_2 - \omega_6} = -\left(\frac{120}{45}\right)\left(\frac{27}{48}\right) = -\frac{3}{2} = -1.5$$

$$\frac{300 - \omega_6}{500 - \omega_6} = -1.5 \Rightarrow \omega_6 * (-1.5 - 1) = -1.5 * 500 - 300$$

$\omega_6 = +420$ rpm (CCW) for Arm

$\boxed{7.32}$ $F = 6$, $L = 9$, arm $= 10$

$$\frac{\omega_9 - \omega_{10}}{\omega_6 - \omega_{10}} = +\frac{N_6 N_8}{N_7 N_9} \Rightarrow \omega_B$$

but ω_6 and ω_{10} is unknown

[illegible] 2, 3, 4, 5 compound gear

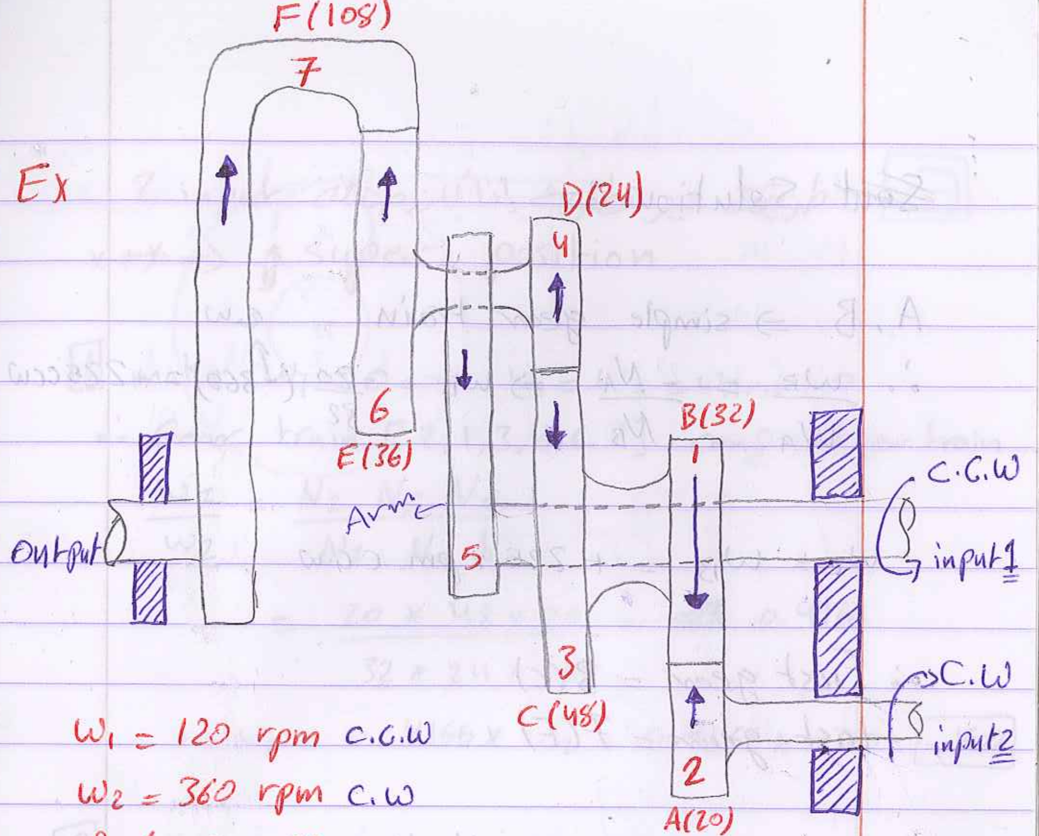
relative to arm

$\therefore \frac{\omega_5}{\omega_2} = +\frac{N_2 N_4}{N_3 N_5} \Rightarrow \omega_5 = \omega_{10}$ ✓

1500

$\therefore \omega_6 = rv$

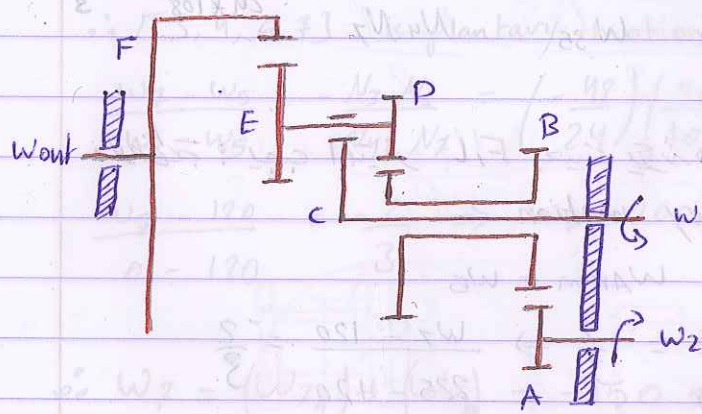
Ex



$\omega_1 = 120$ rpm c.c.w

$\omega_2 = 360$ rpm c.w

find W_{out} ??



~~Sout~~ Solution :-

A, B $\Rightarrow$ simple gear train

$$\therefore \frac{\omega_B}{\omega_A} = \frac{-N_A}{N_B} \Rightarrow \omega_B = \frac{-20}{32}(\overset{C.W}{-360}) = +225\ CCW$$

$$\omega_C = \omega_B = +225 \text{ rpm } C.C.W$$

$\therefore$ First gear = 3(C)

last gear = 7(F)

$$\frac{\omega_{LA}}{\omega_{FA}} = \frac{\omega_{75}}{\omega_{35}} = \frac{-N_3 N_6}{N_4 N_7} = -\frac{48 * 36}{24 * 108} = \frac{-2}{3}$$

ملاحظة: يجب اختيار F,L بحيث يكون جميع ما بينها Planetary motion

$$\omega_1 = \omega_{Arm} = \omega_5$$

$$\frac{\omega_7 - \omega_5}{\omega_3 - \omega_5} = \frac{-2}{3} \Rightarrow \frac{\omega_7 - 120}{225 - 120} = \frac{-2}{3}$$

$$\omega_7 = 50 \text{ rpm } C.C.W$$

طريقة غير مطلوبة إذا لازمنا 2 input

*** $\Rightarrow$ super position

$\boxed{1}$ make $\omega_1 = 0 \Rightarrow \omega_1 = \omega_5 = \omega_{Arm} = 0$

$\therefore$ Gear train [2, 1, 3, 4, 6, 7] compound gear train

$$\frac{\omega_7}{\omega_2} = \frac{N_2 N_3 N_6}{N_7 N_4 N_1} = \frac{20 * 48 * 36}{32 * 24 * 108} = 0.4166$$

$$\therefore \omega_7 = 0.4166 * \omega_2 = 0.4166 * -360 = \boxed{-150}$$

$\boxed{2}$ make $\omega_2 = 0 \Rightarrow \omega_1 = \omega_2 = \omega_3 = 0$

$\therefore$ [3, 4, 6, 7] is plantary motion

$$\frac{\omega_7 - \omega_5}{\omega_2 - \omega_5} = \frac{-N_3 N_6}{N_4 N_7} = \left(-\frac{48}{24}\right)\left(\frac{36}{108}\right) = \frac{-2}{3}$$

$$\frac{\omega_7 - 120}{0 - 120} = \frac{-2}{3} \Rightarrow \omega_7 = 200 \text{ rpm } CCW$$

$$\therefore \omega_7 = (\omega_{7a}) + (\omega_{7b}) = -150 + 200 = +50 \text{ rpm } C.C.W$$

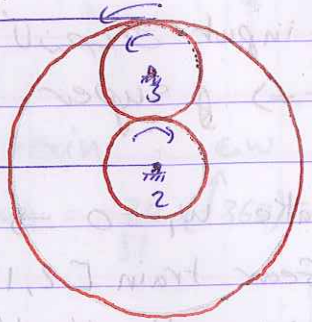
مش مطلوب

$\boxed{Ex}$ $N_2 = 20$

$N_3 = 15$

$\omega_2 = 100\ c.w$

Find ω_4??



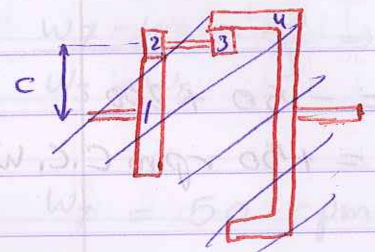
$$c = \frac{d_2}{2} + d_3 = \frac{d_4}{2} \quad \text{but same diameter pitch}$$

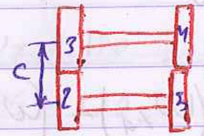
$$\therefore \frac{N_2}{2P} + \frac{N_3}{P} = \frac{N_4}{2P}$$

$$\omega_4 = -\omega_2\left(\frac{N_2}{N_4}\right)$$

$\boxed{Ex}$
$$c = \frac{d_2 + d_3}{2} = \frac{d_4 + d_5}{2}$$

$$\frac{N_2 + N_3}{2P_1} = \frac{N_4 + N_5}{2P_2}$$

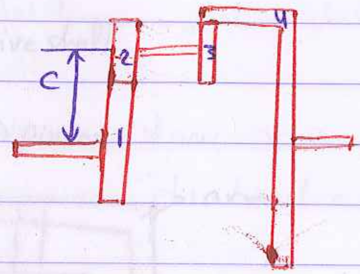




مش مطلوب

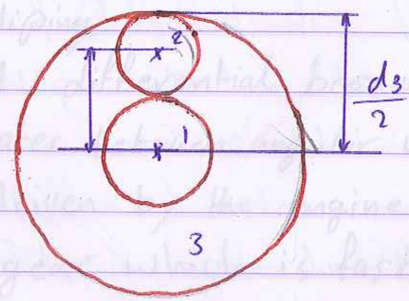
$\boxed{Ex}$
$$\frac{d_1 + d_2}{2} = \frac{d_4}{2} - \frac{d_3}{2}$$

$$\frac{N_1 + N_2}{2P_1} = \frac{N_4 - N_3}{2P_3}$$



$\boxed{Ex}$
$$c = \frac{d_1 + d_3}{2} = \frac{N_1 + N_2}{2P}$$

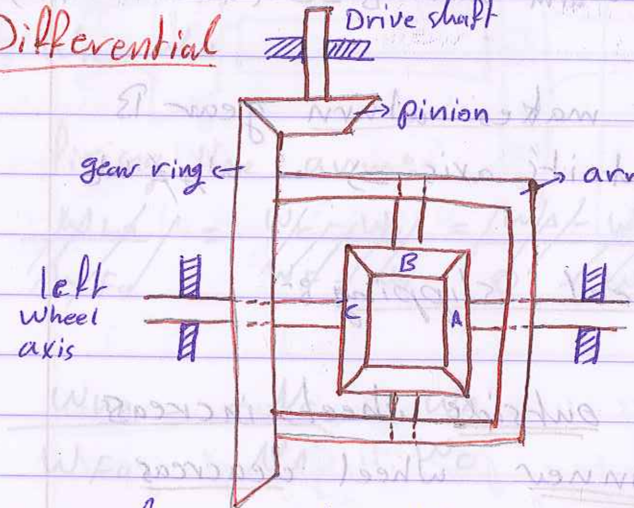
$$\frac{d_3}{2} = \frac{d_1}{2} + d_2 \Rightarrow \frac{N_3}{2P} = \frac{N_1}{2P} + \frac{N_2}{P}$$



[*] Application of plantary Motion

1- air craft Propeller (speed reducer)
2- automobile differential
3- automotive gear transmition

⇒ Differential



* used in automobile rear drive
* permit the car to turn corner without wheel sliping
* It called differential because it differntiates between angular velocity of gear A,C (right, left)
* pinion driven by the engine. Pinion drives the ring gear which is fastend to the arm

Differential Function :-

- In straight line motion of car A, C, B, ring rotat as a unit ~~whith~~ with the arm. (no relative motion between A, C)

$\therefore W_A = W_c = W_{arm}$ and $W_B = 0$ (about it axis)

- when car makes a turn gear B rotat about it's axis $\Rightarrow \therefore W_A \neq W_c$

- for no wheel slipping :-

The speed outside wheel increass and the inner wheel deacreas by the same amount

$\Rightarrow$ If left wheel held fixed (dry parement) and the right wheel free to rotat (on mud or snow)

$\therefore W_c = 0 \Rightarrow W_A = \left(1 + \frac{N_c}{N_A}\right) W_{arm}$

$\Rightarrow$ it is adis advantag of differential

$\Rightarrow$ wheel c fixed :

$$\frac{W_{La}}{W_{Fa}} = \frac{W_L - W_a}{W_F - W_a} = \frac{W_A - W_a}{0 - W_a}$$

but $W_F = W_c = 0$

$W_L = W_A$

fixing the arm :-

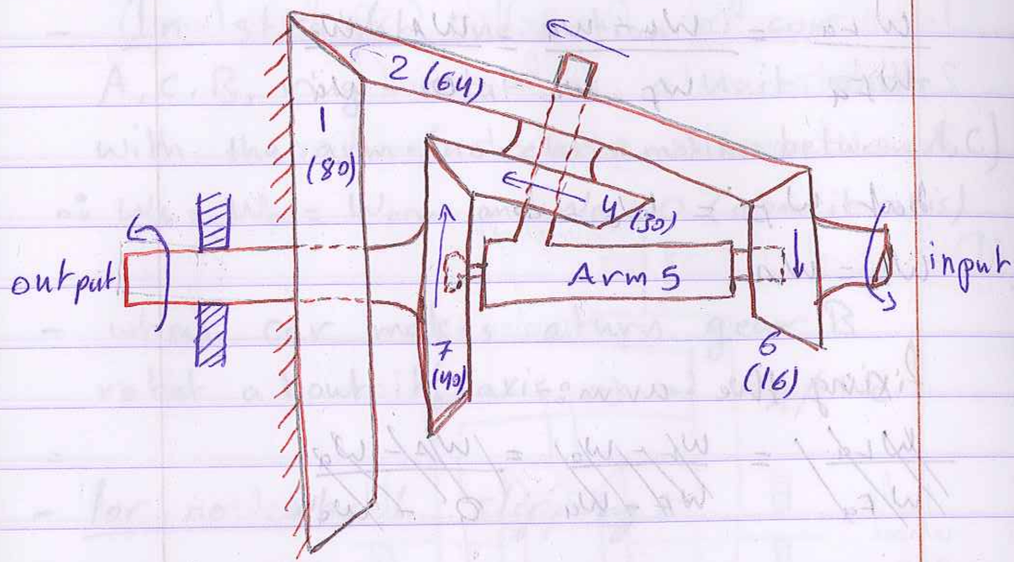
$$\cancel{\frac{W_{La}}{W_{Fa}}} = \cancel{\frac{W_L - W_a}{W_F - W_a}} = \cancel{\frac{W_A - W_a}{0 - W_a}}$$

$$\frac{W_{La}}{W_{Fa}} = \frac{-N_c}{N_A} = \frac{W_A}{W_c}$$

$$\therefore \frac{-N_c}{N_A} = \frac{W_A - W_a}{0 - W_a} \Rightarrow W_A = W_{arm}\left(1 + \frac{N_c}{N_A}\right)$$

for $N_A = N_c \Rightarrow W_A = 2\,W_{arm}$

Ex Epicyclic Bevel gear train



Bevel gears used to make more compact plantary system permitting high speed reduction with few gear

gear 1 = fixed

gear 2, 4 is turns freely on arm 5

find $\frac{W_{out}}{W_{in}}$??

$$\frac{W_{out}}{W_{in}} = \frac{W_7}{W_6}$$

$F = 6$, $L = 7$, $Arm = 5$

$$\therefore \frac{W_7 - W_5}{W_6 - W_5} = -\frac{N_6 N_4}{N_2 N_7} = \left(\frac{-16}{64}\right) * \left(\frac{30}{40}\right) = \frac{-3}{16}$$

$$\Rightarrow \frac{W_7 - W_5}{W_6 - W_5} = \frac{-3}{16}$$

Since W_5 is unknown $\Rightarrow$ we can't solve this eq or we can find W_5 with respect to W_6 by taking [6, 2, 4, 1] and arm plantary motion

$\therefore F = 6$, $L = 1$, $Arm = 5$

$$\frac{W_1 - W_5}{W_6 - W_5} = \frac{-1}{5} \Rightarrow \frac{-1}{5} W_6 + \frac{1}{5} W_5 = -W_5$$

$\frac{16}{80}$

$$\therefore \frac{0 - W_5}{W_6 - W_5} = \frac{-1}{5} \Rightarrow \frac{-1}{5} W_6 + \frac{1}{5} W_5 = -W_5$$

$$\therefore \frac{1}{5} W_6 = \frac{6}{5} W_5 = \boxed{W_6 = 6 W_5}$$

$$\therefore \boxed{W_5 = \frac{W_6}{6}}$$ substituting in first Eq

$$\frac{\omega_7 - \frac{\omega_6}{6}}{\omega_6 - \frac{\omega_6}{6}} = -\frac{3}{16} \Rightarrow \omega_7 - \frac{\omega_6}{6} = \frac{-5}{32}\omega_6$$

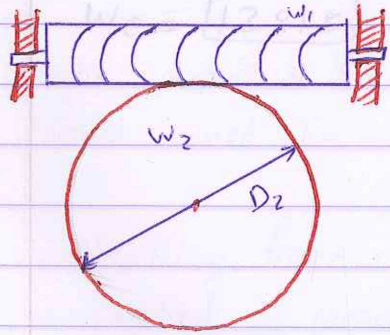
$$\therefore \frac{\omega_7}{\omega_6} = \frac{1}{96}$$

$\boxed{*}$ Power Screw : [Translation Screw]

* lead :- the distance the screw advance axialy by one true rotation (complete rotation)

* for single thread : $L = P$
  for Double thread : $L = 2P$
  for Triple thread : $L = 3P$

* RH : CW
* LH : CCW



$$\frac{\omega_2}{\omega_1} = \frac{L}{\pi D_2}$$

7.25 ✓
7.14
7.34

$W_A = 300\ rpm = W_7$

$W_B = 600\ rpm = W_2$

$W_A = C.W$

$W_B = C.W$

$W_C = ??\ ,\ W_5 = ??$

$$\frac{W_9}{W_7} = \frac{N_7}{N_9}$$

$$W_9 = \frac{30}{24}(300)$$

$$= 375\ C.W$$

$$W_9 = W_6 = 375\ C.W$$

L = B (2)
F = C (5)

$$\frac{W_{L}\ Arm}{W_{F}\ Arm} = \frac{\pi\ N_{Driver}}{\pi\ N_{Driven}}$$

$$\frac{W_L - W_{Arm}}{W_F - W_{Arm}} = \frac{N_5 * N_3}{N_4 * N_2} \Rightarrow$$

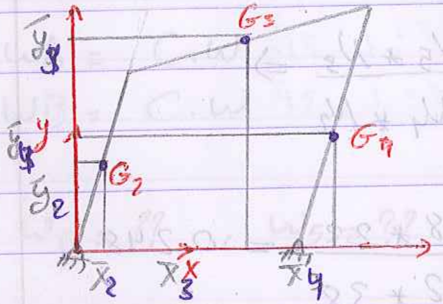
$$\frac{600 - 375}{W_c - 375} = \frac{18 * 22}{42 * 38} = 0.248$$

magnitued direction

$$W_C = \boxed{1281.5}\ \boxed{C.W}$$

"Balancing of"
Meachanism

1. Balancing of rotating masses (rotating shaft)
2. Balancing of mechanism

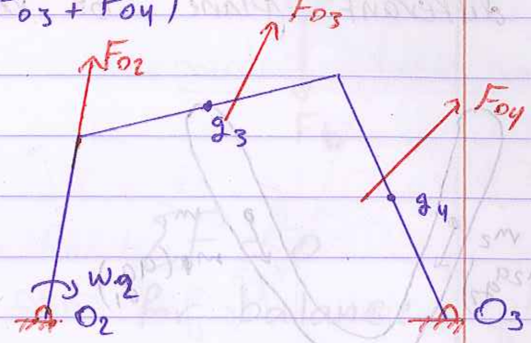


$$\bar{X} = \frac{\sum m_i x_i}{\sum m_i}$$

$$\bar{y} = \frac{\sum m_i y_i}{\sum m_i}$$

Shaking Force: Σ of Inertia Force

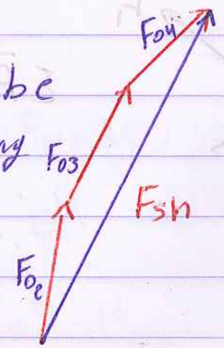
$$F_{sh} = \Sigma (F_{02} + F_{03} + F_{04})$$



→ Shaking force causes vibration if transfer to frame.

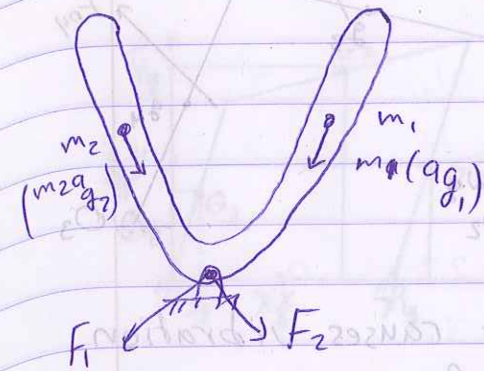
→ to avoid vibration → shaking force must be balance.

→ shaking force canbe eleminated by producing a force in opposite direction ((that cancle it effect))

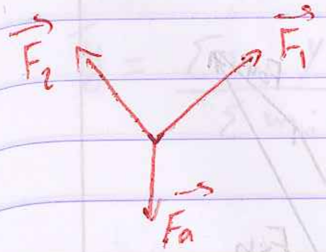


a) all masses are on the same plan of rotation

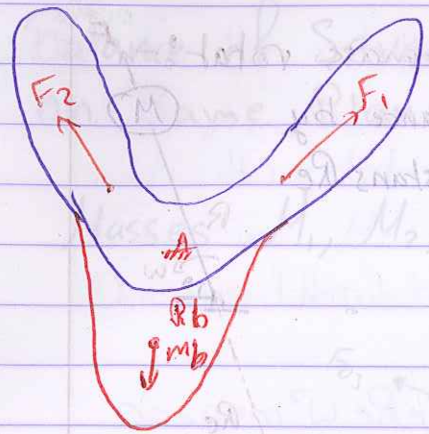
b) differant plane of rotation

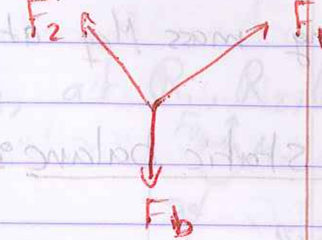


Diffrant plan of rotation



$\Sigma \vec{F} = 0$





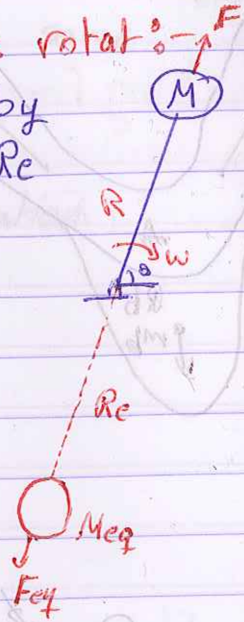
$\Sigma F = 0$
for balance

$$-m_1 R_1 \cancel{\omega_2^2} - m_2 R_2 \cancel{\omega_2^2} - m_b R_b \cancel{\omega_2^2} = 0$$

$$m_b \vec{R}_b = -\sum \overrightarrow{m_i R_i}$$

Balance of single mass rotat :-

This mass can be balance by adding mass M_{eq} at distans R_e



For static balanc :-

$\Sigma M_o = 0$

$M g R \cos\theta = M_e g R_e \cos\theta$

$\boxed{M R = M_{eq} R_{eq}}$

for dynamic balance :

$w =$ constant

$F = F_{eq}$

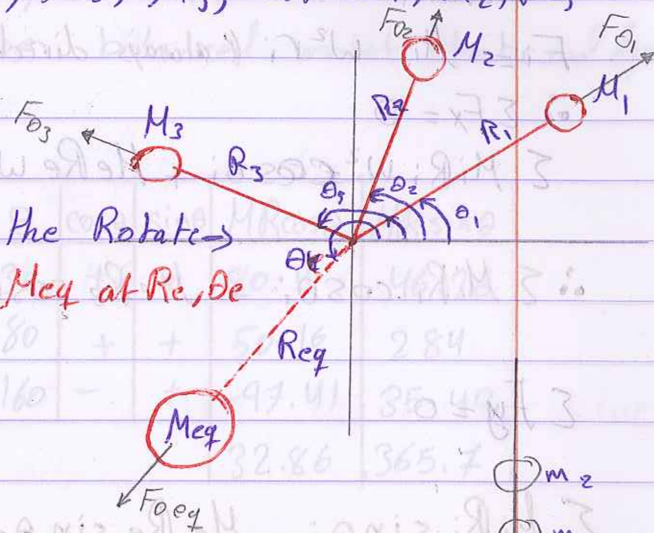
but $F = M w^2 R$ (Inertia Forc)

$\therefore M w^2 R = M_{eq} w^2 R_{eq}$

$\therefore \boxed{M R = M_e R_{eq}}$

Balance of Several masses laying on Same Plane :-

Masses M_1, M_2, M_3, at R_1, R_2, R_3



To balance the Rotate → a single mass M_{eq} at R_e, θ_e

Static balance :-

$\Sigma M_o = 0$

Σ

$\Sigma M_i R_i \cancel{g} \cos\theta_i + M_e R_e \cancel{g} \cos\theta_e = 0$

$\Sigma M_i R_i \cos\theta_i + M_e R_e \cos\theta_e = 0$

Dynamic balance:

Inertia force if rotat with constant ω

$F_i = M_i \omega^2 r_i$ (always directed outward)

$\therefore \sum F_x = 0$

$\sum M_i R_i \omega^2 \cos\theta_i + M_e R_e \omega^2 \cos\theta_e = 0$

$\therefore \sum M_i R_i \cos\theta_i + M_e R_e \cos\theta_e = 0$

$\sum F_y = 0$

$\sum M_i R_i \sin\theta_i + M_e R_e \sin\theta_e = 0$

For static and dynamic balance:

$$\boxed{\begin{aligned} &\sum M_i R_i \cos\theta_i + M_e R_e \cos\theta_e = 0 \\ &\sum M_i R_i \sin\theta_i + M_e R_e \sin\theta_i = 0 \end{aligned}}$$

↳ for several masses on the same plane

Ex] for the rotat with mass M_1 (0.907), M_2 (2.27), M_3 (1.36) at R_1 (102), R_2 (127), R_3 (16.2) and angular position θ_1 (30), θ_2 (80), θ_3 (160), Find M_e at $R_e = 88.9$ mm and θ_e to be balanced rotat static and dynam

No	M(kg)	R(mm)	θ	cosθ	sinθ	MRcosθ	MRsinθ
1	0.907	102	30	+	+	80.11	46.26
2	2.27	127	80	+	+	50.16	284
3	1.36	16.2	160	−	+	-97.41	35.49
						32.86	365.7

$\sum M_i R_i \cos\theta_i + M_e R_e \cos\theta_e = 0$

$32.86 + M_e R_e \cos\theta_e = 0$

① $M_e R_e \cos\theta_e = -32.86 \Rightarrow (\cos\theta_e = -ve)$

$\sum M_i R_i \sin\theta_i + M_e R_e \sin\theta_e = 0$

$365.7 + M_e R_e \sin\theta_e = 0$

② $M_e R_e \sin\theta_e = -365.7 \Rightarrow (\sin\theta_e = -ve)$

From ① and ② [illegible]

$$\tan\theta_e = -\frac{365.7}{-32.86} = 84.86^\circ$$

but because the $\sin\theta_e$ and $\cos\theta_e$ is negative

∴ θ_e is in 3rd quadratic

∴ $\theta_e = 84.86 + 180 = 264.86$

$$M_e = \frac{-365.7}{R_e \times \sin\theta_e} = 4.13 \text{ Kg (positive value)}$$

Graphical Solution الطريقة الثانية

Inertia Force ⇒

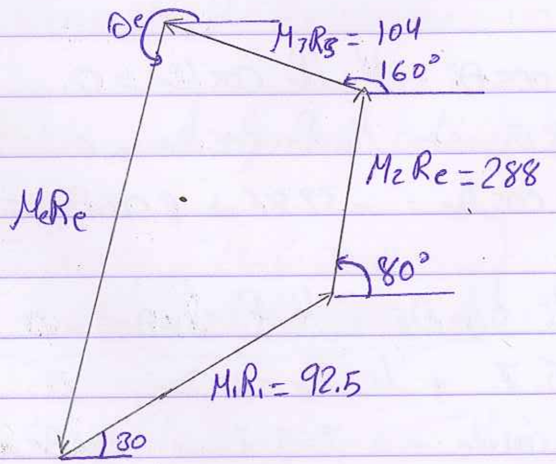
$F_i = M_i R_i W^2$ but ω = constant

F_i is always directed out ward in the direction of θ_i

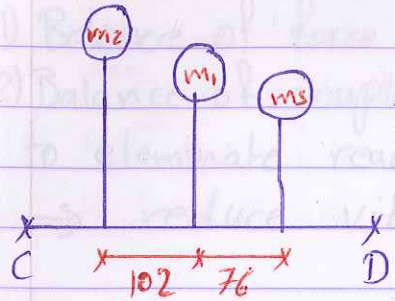
$$\sum F_i + F_e = 0$$

$$\sum M_i R_i \cancel{w^2} + M_e R_e \cancel{w^2} = 0$$

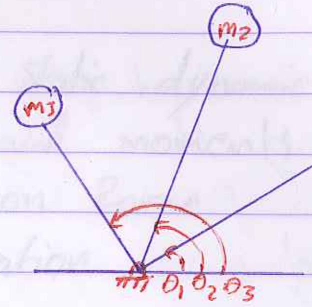
$$\sum \vec{M_i R_i} + \vec{M_e R_e} = 0$$



Balance of masses in different Plane:-

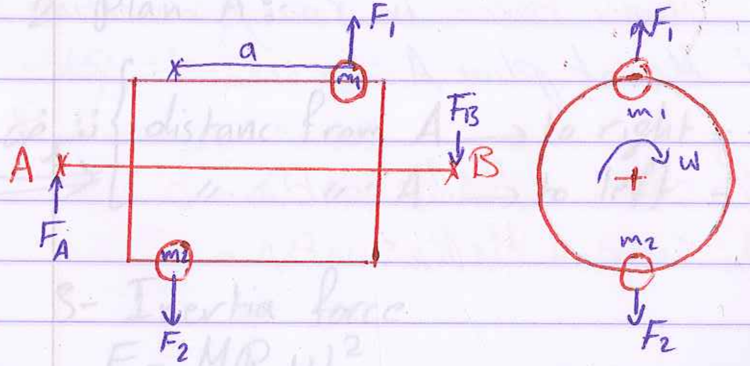


من الامام



من الجنب

Rotor composed of tow equivalent masses on different planes.



rotar is in static balanc

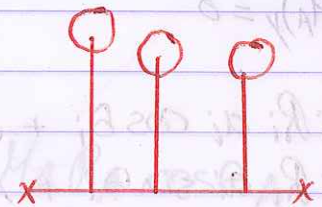
Inertia Force $F_1 = F_2 = MRW^2$

Couple $T = F\,a$, will case reaction A, B

Balancing of rotor :-

1) Balance of force , Static , dynamic
2) Balance of couple and moments
to eleminate reaction force
$\Rightarrow$ reduce vibration

طريقة الحل



1- choose any transverse plan A, B
2- plan A :-

نفرض { distanc from A $\rightarrow$ to right = +ve
" " A $\rightarrow$ to left = -ve

3- Inertia force
$F = M R \omega^2$

to balanc Inertia force

to balance Inertia force :-

Moment about plan A is balanc by adding Mass M_B at plane $\underline{\underline{B}}$

$\Sigma(M_A)_x = 0$
$\Sigma(M_A)_y = 0$

$\Sigma M_i R_i a_i \cos\theta_i + M_B R_B a_B \cos\theta_B = 0$
$\Sigma M_i R_i a_i \sin\theta_i + M_B R_B a_B \sin\theta_B = 0$

4- To blance Force in x and y direction add M_A at plan A

$\Sigma M_i R_i \cos\theta_i + M_A R_A \cos\theta_A = 0$
$\Sigma M_i R_i \sin\theta_i + M_A R_A \sin\theta_A = 0$

For balanc several masses in diffrent plane

moment balance :-

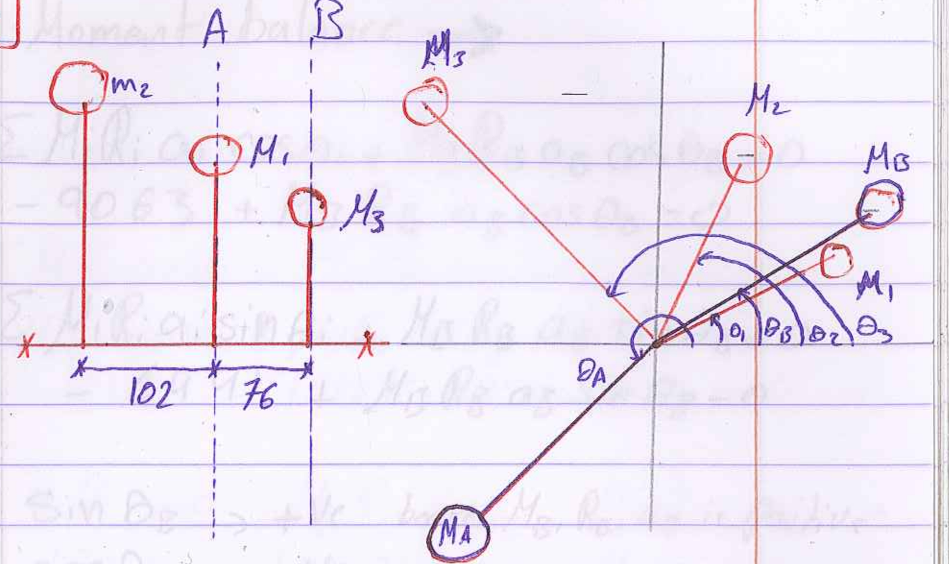
mass on B
$$\begin{cases} \Sigma M_i R_i a_i \cos\theta_i + M_B R_B a_B \cos\theta_B = 0 \\ \Sigma M_i R_i a_i \sin\theta_i + M_B R_B a_B \sin\theta_B = 0 \end{cases}$$

Force balance :-

mass on A
$$\begin{cases} \Sigma M_i R_i \cos\theta_i + M_A R_A \cos\theta_A = 0 \\ \Sigma M_i R_i \sin\theta_i + M_A R_A \sin\theta_A = 0 \end{cases}$$

نضع معها تأثير الكتلة
الجديدة التي وضعت في B

Ex]



Find M_A, M_B at $R_A = R_B = 76$ mm to balanc M_1, M_2, M_3 ??

الطريقة الاولى

NO	M_i	R_i	θ	a	$MR\cos\theta$	$MR\sin\theta$	$MRa\cos$	$MRa\sin$
1	0.454	50.8	30	0	20	11.5	0	0
2	1.36	76	60	-102	51.7	89.5	-5271	-9130
8	0.907	63.5	150	76	-49.9	28.8	-3792	2189
				Σ	21.8	129.8	-9063	-6941

1) Moment balance $\Rightarrow$

$$\sum M_i R_i a_i \cos\theta_i + M_B R_B a_B \cos\theta_B = 0$$

$$-9063 + M_B R_B a_B \cos\theta_B = 0$$

$$\sum M_i R_i a_i \sin\theta_i + M_B R_B a_B \sin\theta_B = 0$$

$$-6941 + M_B R_B a_B \sin\theta_B = 0$$

$\sin\theta_B \rightarrow +ve$ because M_B, R_B, a_B is positive

$\cos\theta_B \rightarrow +ve$ " " " " " "

θ in first quadrant

$$\tan\theta_B = \frac{6941}{9063} \Rightarrow \boxed{\theta_B = 37.4^\circ}$$

$$\Rightarrow M_B = \frac{6941}{R_B a_B \sin\theta_B} = \frac{6941}{76 * 76 * \sin 37.4} = 1.98$$

$M_B = 1.98$ kg

2) force balance $\Rightarrow$

مهم جداً

مهم أنه نجمع القوة إلنا تجب عند الحالة إضافة $\underline{\underline{M_B}}$

$$\Sigma M_i R_i \cos\theta_i + M_A R_A \cos\theta_A = 0$$

$$\Sigma M_i R_i \cos\theta_i + M_B R_B \cos\theta_B + M_A R_A \cos\theta_A = 0$$

$$21.8 + 1.98 * 76 * 0.794) + M_A R_A \cos\theta_A = 0$$

$$\Sigma M_i R_i \sin\theta_i + M_B R_B \sin\theta_B + M_A R_A \sin\theta_A = 0$$

$$129.8 + 1.98 * 76 * 0.007) + M_A R_A \sin\theta_A = 0$$

$$\left.\begin{array}{l} \cos\theta_A \rightarrow -ve \\ \sin\theta_A \rightarrow -ve \end{array}\right\} \text{third qudrant}$$

$$\tan\theta_A = \frac{-221.1}{-141.3} \Rightarrow \theta = 57.4$$

$$\therefore \theta_A = 180 + 57.4 = 237.3$$

$$M_A = \frac{-129.8 - (1.98 * 76 * 0.007)}{R_A \sin\theta_A}$$

الطريقة الثانية Graphical solution

Inertia Force :-

$F_i = M_i \, \omega^2 R_i$

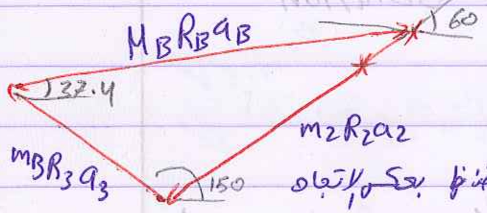
$\Rightarrow F_i \propto M_i R_i$ radialy out word

Moment of Inertia force :-

$m_i = M_i R_i a_i$

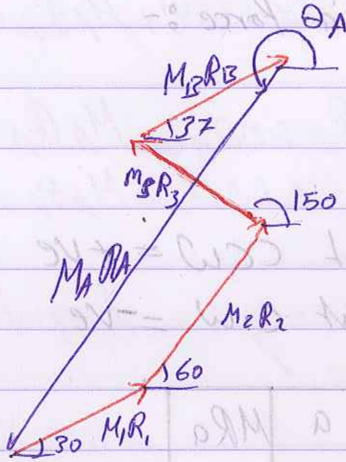
assume $\Rightarrow \begin{cases} \text{moment CCW} = +ve \\ \text{moment CW} = -ve \end{cases}$

No	M	R	MR	a	MRa
1	0.454	50.8	23.1	0	0
2	1.36	76	103.4	-102	-10500
3	0.907	63.5	57.6	57.6	43800



Moment balance

أضفنا بعكس الاتجاه
لانه النتيجة سالبة
Look ↑



Forc Balance

يجب انه نضع M_BR_B
ايضاً مع باقي الحل
[illegible]

Crank shaft balanc from book

Fly WHEEL

Flywheel :- rotating mass used to store energy on flywheel

$\Rightarrow E = \frac{1}{2} I W^2$

$W \uparrow \rightarrow E \uparrow \rightarrow$ Energy stored on flywheel
$W \downarrow \rightarrow E \downarrow \rightarrow$ Energy lost from flywheel

Application of flywheel :-

1- Punch press Machines (الكبس)
if the engin is used without flywheel, alarg motor must be used.
Flywheel is used to store energy after manufacturing process rise the velocity from $W_{min} \rightarrow W_{max}$ then Small motor is needed

$W_1 = W_{max}$
$W_2 = W_{min}$

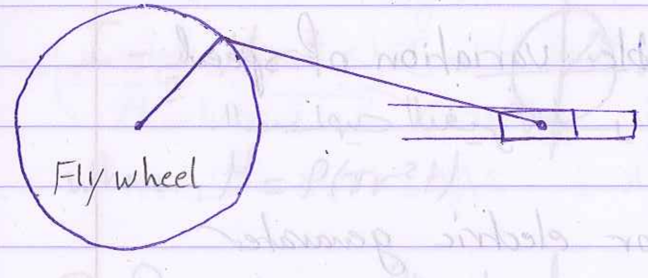
$W_{avg} = \frac{W_1 + W_2}{2}$

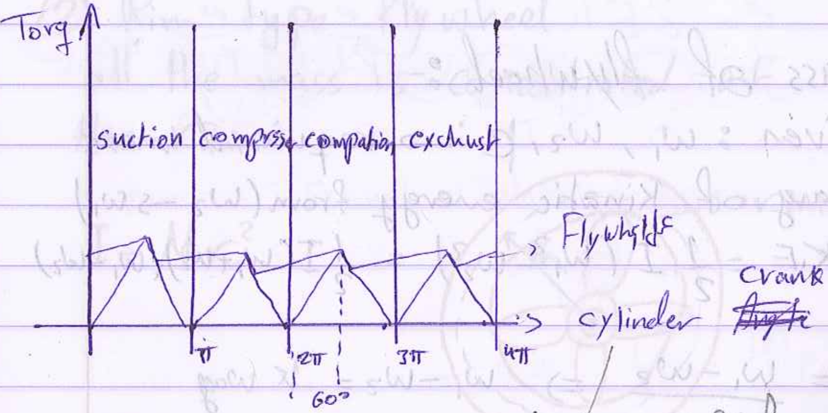
2- Engins

Strock engin (Disead, Petrol)

Steam engin

Single cylinder (Piston)





maximum torque is at ≈ 60° frome dead center

TDC

BDC

cofficient of fluctuation :-

$$K = \frac{W_{max} - W_{min}}{W_{avg}}$$

K : Permissible variation of speed

السماحية للتغير في السرعة

$k = 0.001$ for electric genarater

Mass of flywheel :-

given : w_1, w_2, k → requierd mass

chang of Kinatic energy from (w_2 → w_1)

$$\Delta K.E = \frac{1}{2} I (w_1^2 - w_2^2) = \frac{1}{2} I (w_1 + w_2)(w_1 - w_2)$$

$$k = \frac{w_1 - w_2}{W_{avg}} \Rightarrow w_1 - w_2 = k\, w_{avg}$$

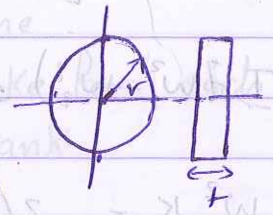
$$\boxed{\Delta E = \Delta K.E = k I w_{avg}^2}$$

where : ΔE : energy requir to rise vilocity from W_2 to W_1

Type of follower

① Disk type fly wheel

$$I = \frac{1}{2} M r^2$$

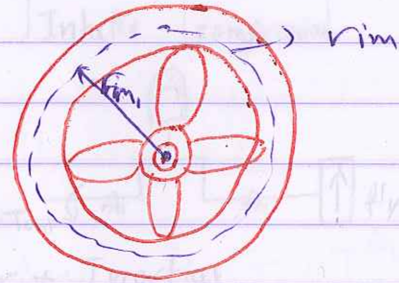


where $M = \rho(\pi r^2 t)$

② Rim type fly wheel

all the mass is concentrated at the rim

$$I = M r_m^2$$



كل ما كان بعد الكتلة عن المركز ↑

I ↑ ←

$e \equiv$ maximum fluctuation of energy
(Energy supplied by the fly wheel
Flywheel الطاقة التي يجب ان يعطيها

$$= \frac{1}{2} I \omega_1^2 - \frac{1}{2} I \omega_2^2$$

$$= \frac{1}{2} I (\omega_1^2 - \omega_2^2) = I \frac{(\omega_1 + \omega_2)}{2} \left(\frac{\omega_1 - \omega_2}{\omega}\right) \omega$$

$$I \omega^2 K = 2\left(\frac{1}{2} I \omega^2\right) K = 2EK$$

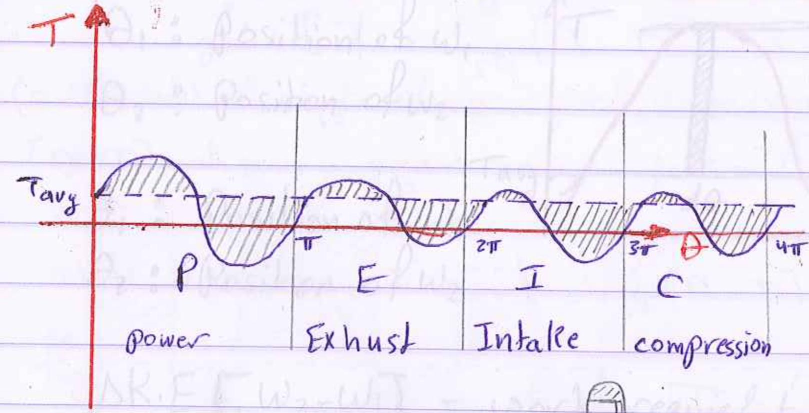
$$e = 2EK \Rightarrow K = \frac{e}{2E} = \frac{e}{I\omega^2}$$

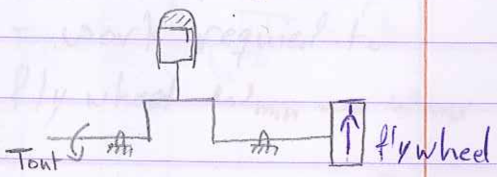
Single cylinder engine :-

Fly wheel of internal combustion engin :-

4 - stroke engine

one power stroke for each two revolution of crank





$T_{out} = T_{gas\ presser} + \text{Inertias}$

$$T_{avg} = \frac{\Sigma \text{ area under } T\text{-}\theta \text{ curve}}{\text{Total Angle}} = \boxed{\frac{\Sigma A_i}{4\pi}}$$

Power $= T \times \omega$

T_L = Load Torque

$T_L = T_{avg}$

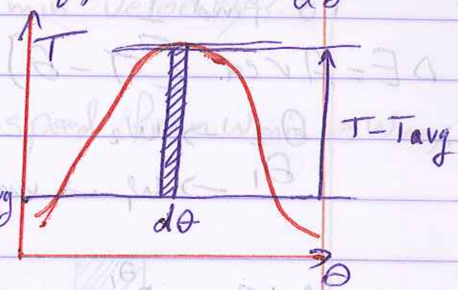
$T > T_{avg} \Rightarrow$ Energy stored on flywheel

$T < T_{avg} \Rightarrow$ Energy lost by flywheel

$$T - T_{avg} = I\alpha = I\frac{d\omega}{dt} = I\omega\frac{d\omega}{d\theta}$$

θ_1 : Position of ω_1

θ_2 : Position of ω_2



θ_1 : Position of ω_1

θ_2 : Position of ω_2

$\Delta K.E[\omega_2 - \omega_1]$ = work requied to rise velocity of flywheel $\omega_{min} \rightarrow \omega_{max}$

$$\Delta K.E[\omega_2 - \omega_1] = \text{Area Under } [T-\theta]_{\theta_2}^{\theta_1}$$

$$K I \omega_{avg}^2 = \text{Area}[\theta_2 - \theta_1]$$

To find θ_2 and θ_1 :-

$w_1 = W_{max} \Rightarrow$ Energy max $[E_{max}]$

$\Rightarrow$ Area under $[T-\theta]_{max}$ $([A_{max}])$

* Area represent Energy stored on flywheel

To find I

$$\Delta E = Area\,[T-\theta]_{\theta_2}^{\theta_1} = K I w_{avg}^2$$

$\theta_2 \rightarrow w_2 \rightarrow$ min energy $\rightarrow$ min Area $[T-\theta]$

$\theta_1 \rightarrow w_1 \rightarrow$ max energy $\rightarrow$ max Area $[T-\theta]$

$$A\,[T-\theta]_{\theta_2}^{\theta_1} = K I w_{avg}^2$$

$$P = T_{avg} \cdot w_{avg}$$

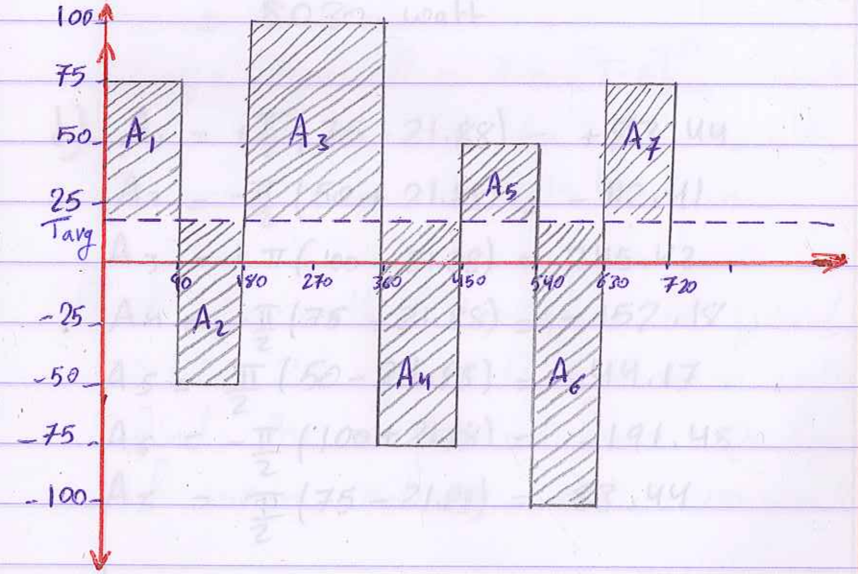
9.44

$\boxed{Ex}$ output torque of single cylinder engine. find

a) average output torque and avarege power if $w_{avg} = 3500$ rpm??

b) location of max and min velocity??

c) work done to change speed from $w_{min} \rightarrow w_{max}$?



Positive area represent work done to increase flywheel speed

negative area represent work done to decrease fly wheel speed

a) $T_{avg} = \dfrac{A_{net}}{\theta}$

$+ve \ A = \frac{\pi}{2}(75) + \pi(100) + \frac{\pi}{2}(50) + \frac{\pi}{2}(75) = 628.3 \, N.m$

$-ve \ A = \frac{\pi}{2}(50) + \frac{\pi}{2}(75) + \frac{\pi}{2}(100) = 353.4 \, N.m$

$A_{net} = 628.3 - 353.4 = 274.9 \, N.m$

$T_{avg} = \dfrac{A_{net}}{4\pi} = \dfrac{274.9}{4\pi} = \boxed{21.88 \, N.m}$

$P_{avg} = T_{avg} \cdot \omega_{avg} = 21.88 * \left(3500 * \frac{2\pi}{60}\right)$

$= 8030 \ watt$

b) $A_1 = +\frac{\pi}{2}(75 - 21.88) = +83.44$

$A_2 = -\frac{\pi}{2}(50 + 21.88) = -112.41$

$A_3 = +\pi(100 - 21.88) = 245.42$

$A_4 = -\frac{\pi}{2}(75 + 21.88) = -152.18$

$A_5 = \frac{\pi}{2}(50 - 21.88) = 44.17$

$A_6 = -\frac{\pi}{2}(100 + 21.88) = -191.45$

$A_7 = \frac{\pi}{2}(75 - 21.88) = 83.44$

A_1	83.44
$A_1 + A_2$	-29.47
$A_1 + A_2 + A_3$	$\omega_{max, \theta=360} \Leftarrow$ 215.95
$A_1 + A_2 + A_3 + A_4$	63.77
$A_1 + A_2 + A_3 + A_4 + A_5$	107.94
$A_1 + A_2 + A_3 + A_4 + A_5 + A_6$	$\omega_{min, \theta=630}$ -83.51
$A_1 + A_2 + A_3 + A_4 + A_5 + A_6 + A_7$	0

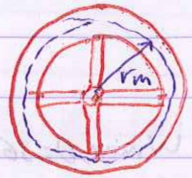
c) Energy requierd to rise speed from $\omega_{min} \longrightarrow \omega_{max}$

$$\text{Energy required} = \text{Area}\,[T-\theta]_{\theta_2}^{\theta_1} = \text{work}\,[\theta_2 - \theta_1]$$
$$= A_7 + A_1 - A_2 + A_3$$
$$= 299.4 \text{ N.m}$$

d) if permitted variation in speed $\Delta\omega = 35$ rpm // fluctuation in velocity = 35 rpm find the weight of rim type fly wheel of mean radius $r_m = 200$ mm ??

$C = \max E - \min E$

$C =$



$$K = \frac{\omega_1 - \omega_c}{\omega_{avg}} = \frac{\Delta\omega}{\omega_{avg}} = \frac{35}{3500} = 0.01$$

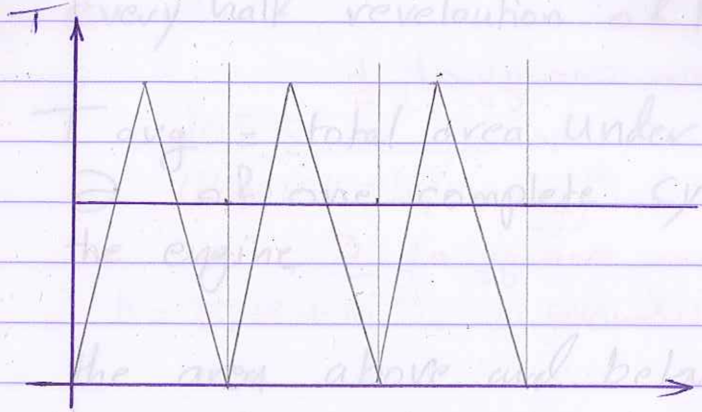
$$\Delta E = K I \omega_{avg}^2 = Area\,[T-\theta]_{\theta_2}^{\theta_1}$$

$$0.01 * I * (367)^2 = 299.4$$

$$I = 0.22\ kg.m^2$$

$$I = M r_m^2 \Rightarrow M = 5.56\ kg$$

Problem 13-21

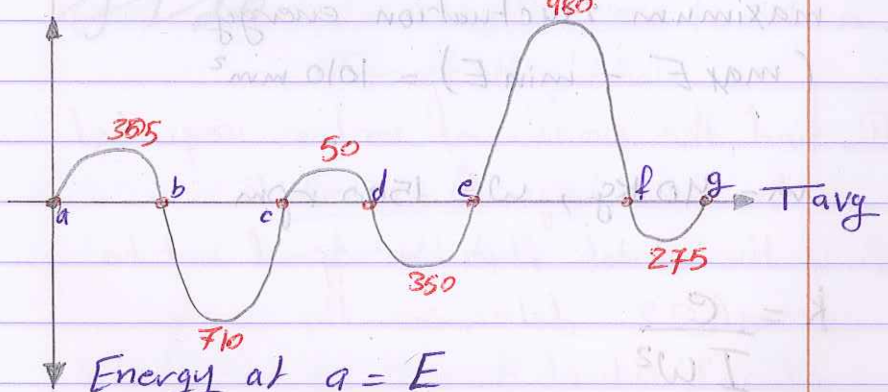


the turning-moment diagram for apetrol engine is drawn to a vertical Scale of 1mm to 6 N.m and a horizontal Scale of 1mm to 1°. The turning moment repeats it self after every half revolution of engine. The Area a bove and below the mean torque line are: 305, 710, 50, 350, 980 and 275 mm^2 the rotating part amount to a mass of 40 kg at a radious of gyration of 140 mm Calculate the cofficient of fluctuation of speed if the speed of engin is 1500 rpm

The turning moment repeat it self every half reveloution of the engin T

T_{avg} = total area under TMD / θ of one complete cycle of the engine

the area above and below the mean torque line are as follow



Energy at $a = E$

" " $b = E + 305$

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

" " $d = E - 405 + 50 = E - 355$

" " $e = E - 355 + 350 = E - 705$

" " $f = E + 275$

$a = g = E$

maximum energy at $\underline{b}$ and ω_{max}

minmum energy ab $\underline{e}$ and ω_{min}

~~maximum absolute energy~~

maximum fluctuation energy

$(\max E - \min E) = 1010\ mm^2$

$m = 40\ Kg,\ \omega = 1500\ rpm$

$$K = \frac{e}{I\omega^2}$$

$$e = 1010\ mm^2 * \left(\frac{6.\ N.m}{1\ mm}\right) * \left(\frac{1^\circ}{1\ mm} * \frac{\pi}{180}\right) = 105.8\ N.m$$

$$\frac{rev}{min} * \frac{rad}{rev} * \frac{min}{60s}$$

$$K = \frac{e}{I\omega^2}$$

$$= \frac{105.8}{(40) * (0.140)^2 * \left(\frac{1500 * 2\pi}{60}\right)^2}$$

$K = 5.45 * 10^{-3} = 0.545\ \%$

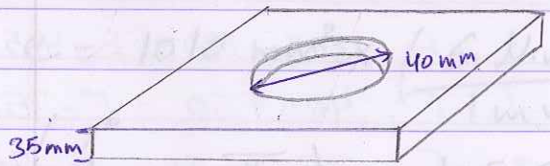
$\cancel{\int T\, d\theta}$

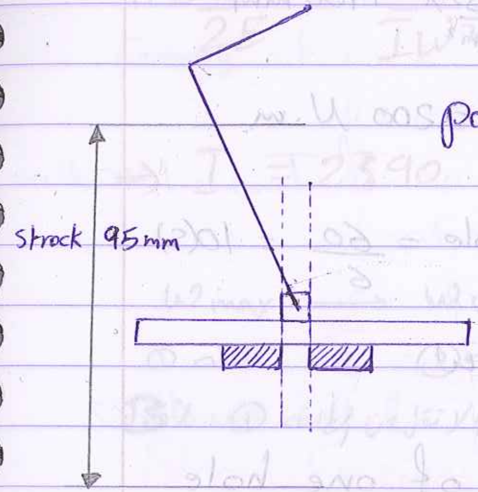
cofficant of fluctioution Energy $= \dfrac{e}{\text{total work in one cycle}}$

Example 13.12??

Punch machin carryies out six holes per ~~menit~~ minute each hole of 40 mm in 35 mm thick plate that requier 8 N.m of energy/mm² of sheared area the punch has a strock of 95 mm

① find the power of motor requierd if the mean speed = 20 m/s
② if the total flucution speed not to exceed 3% determine the mass of fly wheel





$$\text{power} = \frac{\text{Energy}}{\text{Time}}$$

$$\text{power} = \frac{\text{total Energ for 6 hole}}{\text{Time of cutting 6 hole}}$$

$$= \frac{\text{Energy for 1 cut hole}}{\text{total time one hole}}$$

total Energy to cut one hole

$= \text{area sheard of the hole} * \dfrac{\text{Energy requierd}}{mm^2}$

$\text{Sheard area} = \pi d * \text{thickness} = \pi(40\,mm) * 35$

$= 4400\ mm^2$

$$\text{Energy requierd} = \frac{8\,N.m}{mm^2} * 4400\,mm^2$$

$$= 35200\ N.m$$

the time in one hole $= \frac{60}{6} = 10(s)$

$$\frac{35200}{10} = 3520\ KW$$

acual cutting time of one hole

$$= \frac{35}{2*95} * 10(s) = 1.89\ (s)$$

motor gives $1.84 * 3520 = 6480\ N.m$

hole want 35200 N.m to cut it

$$35200 - 6480 = 28720$$

$$e = 28720\ N.m = 2\ KE$$

flywheel الطاقة التي يجب انه يعطيها

$$K = \frac{e}{2E} = \frac{e}{I\omega^2} = \frac{28720}{I(20)^2}$$

$$\Rightarrow I = 2390\ kg$$

$\omega_{max} \longrightarrow \omega_{min}$

① طاقة ② طاقة

1.5% لازم الطاقة ② لا تقل عن الطاقة ① 1.5%

Steam engine

Remark

ex for 4 stok engine if $T_{max} = 1000\ N.m$ at $60°$ from dead center

find ① T_{avg} ??

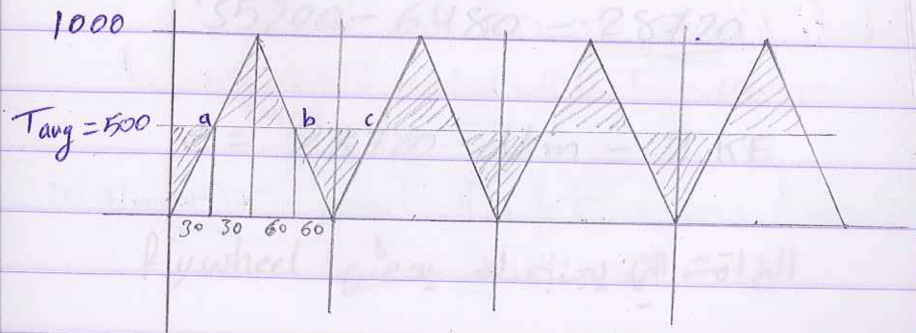
② Total energy of the mach??

③ e??

Total Energy = area the curve

$$= 4 * \frac{1}{2} * \pi (1000) = 2000\pi\ N.m$$

$$T_{avg} = \frac{\text{total Area}}{\text{total Angle}} = \frac{2000\pi}{4\pi} = 500\ N.m$$



assum

Energy at a = E

$b = E + \frac{1}{2} * \frac{\pi}{2} (500) = 125\pi$

$c = E$

$d = E + 125\pi$

$c = E$

$\boxed{e = 125\ \pi}$

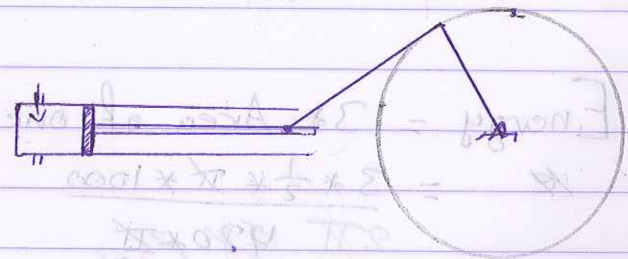
Steam Engines

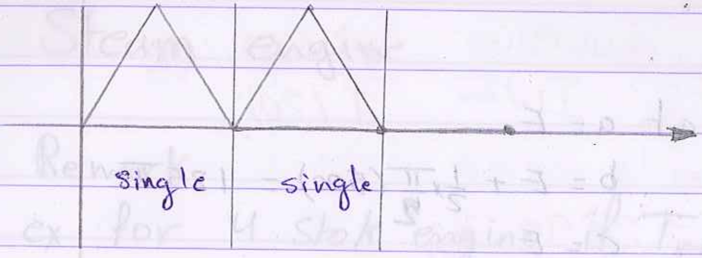
① Single acting cylinder

② Double acting cylinder

→ cycle 2π

①

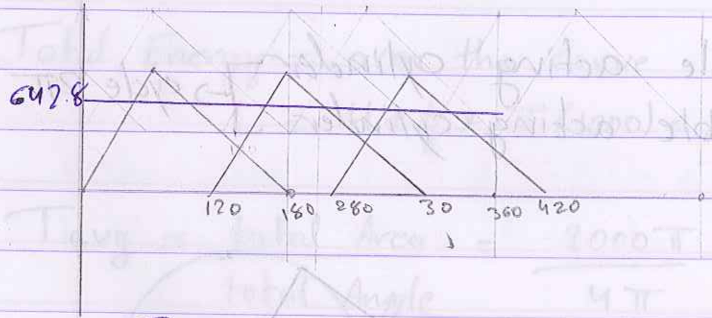




2 piston

$180 = \frac{360}{2} \pi \Leftarrow$ 2 piston افضل توزيع

$120 = \frac{360}{3} \Leftarrow$ 3 piston افضل توزيع



Energy = 3 * Area of one triangle

$\cancel{\alpha} = \frac{3 * \frac{1}{2} * \cancel{\pi} * 1000}{2\pi \quad 480 * \frac{\cancel{\pi}}{180}}$

$\cancel{\alpha} = 642.8$

675