Question 1

length of link 2 (from O_2 to A), $a := 63mm$

length of link 3 (from A to B) $b := 130mm$

offset $c := -52mm$

link 2 position

$\Theta_2 := 141°$

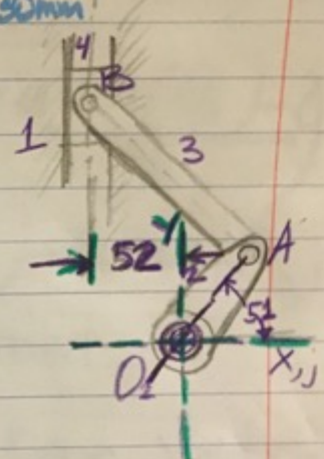
link 2 angular velocity

$\omega_2 := -25 \frac{rad}{sec}$

link 2 acceleration:

$\alpha := 0 \cdot \frac{rad}{sec^2}$

Coordinate rotation angle: $\alpha := -90°$



Question 1

Using the equations for the crossed circuit, let me find θ_3 & d:

$$\theta_3 := asin\left(\frac{a \cdot \sin(\theta_2) - c}{b}\right), \quad \theta_3 = 44.828 \cdot deg$$

$$d := a \cdot \cos(\theta_2) - b \cdot \cos(\theta_3),$$

$$d = -141.16 mm$$

The angular velocity of the 3rd link is then:

$$\omega_3 := \frac{a}{b} \frac{\cos(\theta_2)}{\cos(\theta_3)} \cdot \omega_2$$

$$\omega_3 = 13.276 \cdot \frac{rad}{sec}$$

According to the Euler identity, I can then expand for $\mathbf{A}_B$:

$$\mathbf{A}_A := a \cdot \alpha_2 \left(-\sin(\theta_2) + j \cdot \cos(\theta_2)\right) - \\ - a \cdot \omega_2^2 \left(\cos(\theta_2) + j \sin(\theta_2)\right)$$

$$\mathbf{A}_A = (30600.122 - 24779.49i) \cdot \frac{mm}{sec^2} \text{ at}$$

$$\theta_{AA} := arg(\mathbf{A}_A) + \alpha$$

Length of link 1 (O_2 to O_4), $d := 185$ in

Hence, the acceleration of pin A is:

$A_A = 39375 \frac{mm}{sec^2}$ at $\theta_{AA} = -129 \cdot deg$

Then, $\alpha_3 := \frac{a \cdot \alpha_2 \cdot \cos(\theta_2) - a \cdot \omega_2^2 \cdot \sin(\theta_2) + b \cdot \omega_3^2 \cdot \sin(\theta_3)}{b \cdot \cos(\theta_3)}$

$\alpha_3 = -93.574 \frac{rad}{sec^2}$

Hence, the acceleration of pin B is

$A_B := -a \cdot \alpha_2 \cdot \sin(\theta_2) - a \cdot \omega_2^2 \cdot \cos(\theta_2) +$
$+ b \cdot \alpha_3 \cdot \sin(\theta_3) + b \cdot \omega_3^2 \cdot \cos(\theta_3)$

$A_B = 38274 \frac{mm}{sec^2}$ and since it's a positive number, vector A_B is directed downward.

Question2

$$R_2 := R_1 + R_3$$

$$a \cdot e^{j \cdot \theta_2} := d + b \cdot e^{j \cdot \theta_3}$$

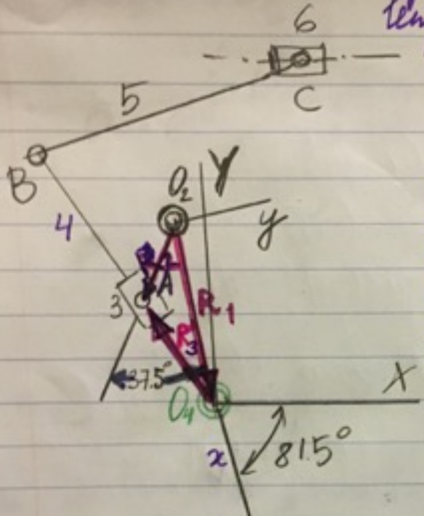
$$a \cdot (\cos(\theta_2) + j \cdot \sin(\theta_2)) := d + b(\cos(\theta_3) + j \cdot \sin(\theta_3))$$

I will separate this expression into real & imaginary components

$$\theta_3 := \operatorname{atan2}(a \cdot \cos(\theta_2) - d, a \cdot \sin(\theta_2))$$

$$\theta_3 = -158.2\ deg$$

Question 2



length of link 1 (O_2 to O_4), $d := 1.85$ in
length of Link 2 (O_2 to A), $a := .8$ in
length of Link 4 ($O_4 \to B$), $a' := 2.97$ in
length of L_5 (B to C), $b' := 2.61$ in

Crank angle
$\theta_2 := -37.5°$ in the local xy system

Coordinate rot. angle $\beta := -81.5°$, Slider-crank offset $c' := 3.25$ in

Input crank motion
$\omega_2 := 40 \frac{rad}{min}$

$\alpha_2 := -1500 \frac{rad}{min^2}$

Question 2

$$R_2 := R_1 + R_3$$

$$a \cdot e^{j \cdot \theta_2} := d + b \cdot e^{j \cdot \theta_3}$$

$$a \cdot (\cos(\theta_2) + j \cdot \sin(\theta_2)) := d + b(\cos(\theta_3) + j \cdot \sin(\theta_3))$$

I will separate this expression into real & imaginary components

$$\theta_3 := \operatorname{atan2}(a \cdot \cos(\theta_2) - d, a \cdot \sin(\theta_2))$$

$$\theta_3 = -158.2 \text{ deg}$$

$$b := \frac{a \cdot \sin(\theta_2)}{\sin(\theta_3)} \qquad b = 1.31\ in$$

$$j \cdot w_2 \cdot e^{j \cdot \theta_2} := b \cdot j \cdot w_3 \cdot e^{j \theta_3} + bdot \cdot e^{j \cdot \theta_3}$$

$$w_3 := \frac{a \cdot w_2}{b} \cdot \cos(\theta_2 - \theta_3) \qquad w_3 = -.208 \frac{rad}{sec}$$

$$bdot := \frac{a \cdot w_2 \cdot \cos(\theta_2) - b \cdot w_3 \cdot \cos(\theta_3)}{\sin(\theta_3)}, \quad bdot = -.459 \frac{in}{sec}$$

$$j \cdot \alpha_2 \cdot e^{j\theta_2} + a \cdot j^2 \cdot w_2^2 \cdot e^{j\theta_2} := bdot \cdot j \cdot w_3 \cdot e^{j\theta_3} + b j \alpha_3 e^{j\theta_3} \ldots$$

$$+ b j^2 w_3^2 \cdot e^{j \cdot \theta_3} + b \cdot ddot \cdot e^{j\theta_3} + bdot j w_3 e^{j\theta_3}$$

$$\alpha_3 := \frac{1}{b} \cdot \left(a \cdot \alpha_2 \cdot \cos(\theta_2 - \theta_3) + a \cdot w_2^2 \cdot \sin(\theta_3 - \theta_2) - 2 \cdot bdot \cdot w_3\right)$$

$$\alpha_3 = -0.249 \frac{rad}{sec^2}$$

$$\mathbf{A_A} := a \cdot \alpha_2 \cdot (-\sin(\theta_2) + j \cdot \cos(\theta_2)) - a \cdot w_2^2 \cdot (\cos(\theta_2) + j \cdot \sin(\theta_2))$$

$$A_A := |\mathbf{A_A}| \qquad A_A = 0.487 \frac{in}{sec^2} \qquad \theta_{AA} := \arg(\mathbf{A_A})$$

$$\theta_{AA} = -174.348 deg$$

In the global XY coordinate system, the acceleration of points A and B on link 3; (given that θ_3 is transformed to the global XY coord. system: $\theta_3 := \theta_3 + \beta + 360 \cdot deg$

$$\theta_3 = 120.337\ deg$$

$$\mathbf{A_3} := b \cdot \alpha \cdot (-\sin(\theta_3) + j \cdot \cos(\theta_3)) - b \cdot w_3^2 \cdot (\cos(\theta_3) + j \cdot \sin(\theta_3))$$

$A_{A3} := |\mathbf{A}_{A3}|$ $A_{A3} = .331 \frac{in}{sec^2}$

$\theta_{AA3} := arg(\mathbf{A}_{A3})$, $\theta_{AA3} = 20.518 \cdot deg$

$\mathbf{A}_B := a' \cdot \alpha_3 \cdot (\sin(\theta_3) + j \cdot \cos(\theta_3)) - a' \cdot \omega_3^2 \cdot (\cos(\theta_3) + j \cdot \sin(\theta_3))$

$A_B := |\mathbf{A}_B|$ $A_B = .752 \frac{in}{sec^2}$

$\theta_{AB} := arg(\mathbf{A}_B)$

$\theta_{AB} = 20.518 \cdot deg$

$\theta_5 := a \cdot \sin\left(-\frac{a' \cdot \sin(\theta_3) - c'}{b'}\right) + \pi$

$\theta_5 = 195.254 deg$

$\omega_5 := \frac{a'}{b'} \cdot \frac{\cos(\theta_3)}{\cos(\theta_5)} \cdot \omega_3$, $\omega_5 = -.124 \frac{rad}{sec}$

$\alpha_5 := \frac{-a' \cdot \alpha_3 \cdot \cos(\theta_3) - a' \omega_3^2 \cdot \sin(\theta_3) + b' \cdot \omega_5^2 \cdot \sin(\theta_5)}{b' \cos(\theta_5)}$

$\alpha = -.1 \frac{rad}{sec^2}$

Hence, the acceleration of pin C,

$A_C := -a' \cdot \alpha_3 \cdot \sin(\theta_3) - a' \cdot \omega_3^2 \cdot \cos(\theta_3) + b' \cdot \alpha_5 \cdot \sin(\theta_5) + b' \cdot \omega_5^2 \cdot \cos(\theta_5)$

$A_C = .73 \frac{in}{sec^2}$ ← since .73 is a positive result, the vector $\mathbf{A_C}$ will be directed right →

Question 3

#7.52

length of $L1$ (O_2O_4), $d := 1.22 in$ $\angle O_2O_4$ makes with X-axis, $\theta_1 := 56.5°$

length of $L2$ (O_2A) $a := 1.35 in$, $\angle O_2A$ makes with X-axis, $\theta_2 := 14°$

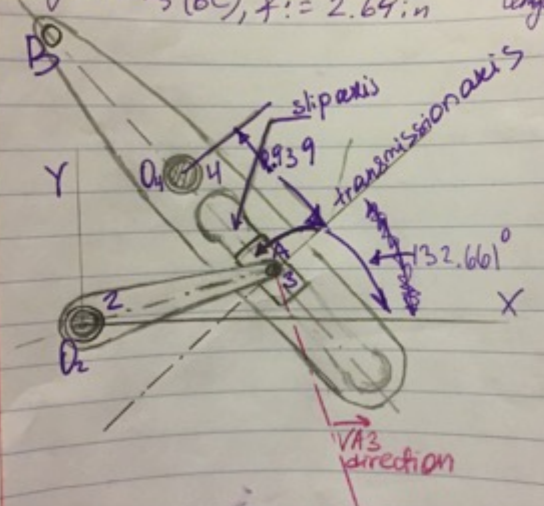
length $L4$ (O_4B), $e := 1.36 in$

length of L_5 (BC), $f := 2.69 in$

length of L_6 (CO_6)
$g := 1.8 in$
angle CO_6 makes with X-axis
$\theta_6 := 88°$

Link 2 motion:
$\omega_2 := 20 rad\,sec^{-1}$ CW

$\alpha_2 := 0\,rad \cdot sec^{-2}$

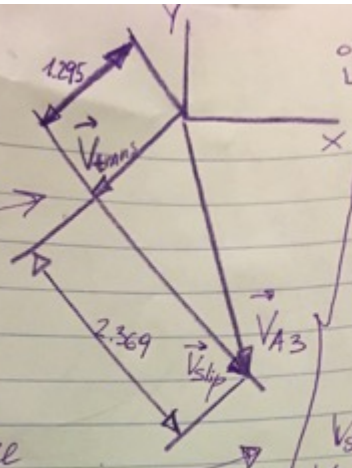


$V_{A3} := a \cdot \omega_2$ $\theta_{VA3} := \theta_2 - 90°$

$V_{A3} = 27 \frac{in}{sec}$ $\theta_{VA3} = -76°$

By approaching $\mathbf{V_{A3}} = \mathbf{V_{trans}} + \mathbf{V_{slip}}$ graphically

$0 \quad 10\,\frac{in}{sec}$
Scale



From the velocity triangle, we can therefore find

Velocity scale factor:

$k_v := \frac{10 \cdot in \cdot sec^{-1}}{in}$

$V_{slip} := 2.369 \cdot in \cdot k_v$

$V_{slip} = 23.69\,\frac{in}{sec}$

$V_{trans} := 1.295\,in\,k_v$

$V_{trans} = 12.95\,\frac{in}{sec}$

The point A true velocity @ link 4 is $V_{A4} := V_{trans}$ $V_{A4} = 12.95\,in/sec$

From the picture above, the $c := 0.939\,in$, $\Theta_4 := 132.661°$

$\omega_4 := \frac{V_{A4}}{c}$ $\omega_4 = 13.791\,\frac{rad}{sec}$ CW

Then, $V_B := e \cdot \omega_4$, $V_B = 18.756\,in/sec$

$\Theta_{VA4} := \Theta_4 - 90°$, $\Theta_{VA4} = 42.661°$

Using the equation

$\mathbf{V_C} = \mathbf{V_B} + \mathbf{V_{CB}}$ the graphic approach exhibited

... angular velocity of L5 is:

$\omega_5 := \frac{V_{CB}}{f}$, $\omega_5 = 5.647 \frac{rad}{sec}$ CCW

The angular velocity of L6:

$\omega_6 := \frac{V_C}{g}$, $\omega_6 = 11.6 \frac{rad}{sec}$ CCW

From the following equation,

$$\left(A^t_{A2} + A^n_{A2}\right) = A^t_{A4} + A^n_{A4} + A^{cor}_{A} + A^{slip}_{A}$$, where

$A_{A2n} := a\cdot\omega_2^2$ $\quad A_{A2n} = 54\ in\cdot sec^{-2}$

$\Theta_{AA} := \Theta_2 + 180°$ $\quad \Theta_{AA} = 194°$

$A_{A2t} := a\cdot\alpha_2$ $\quad A_{A2t} = 0\ in\cdot sec^{-2}$

$A_{A4n} := c\cdot\omega_4^2$ $\quad A_{A4n} = 178.6\ in\cdot sec^{-2}$

$\Theta_{AA4n} := \Theta_4$ $\quad \Theta_{AA4n} = 132.661°$

$A_{Acor} := \left|2\cdot V_{slip}\cdot\omega_4\right|$ $\quad A_{Acor} = 653.43\ in\cdot sec^{-2}$

$\Theta_{AAcor} := \Theta_4 + 90°$ $\quad \Theta_{AAcor} = 222.661°$

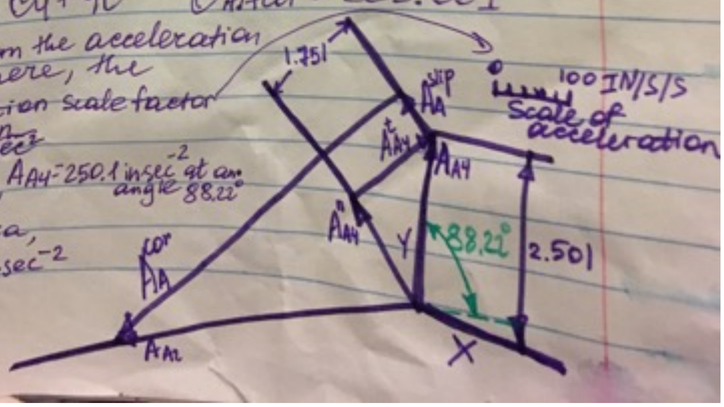
As seen from the acceleration polygon, here, the acceleration scale factor

$k_a := 100\cdot\frac{in}{sec^2}$

$A_{A4} := 2.501\cdot k_a$, $A_{A4} = 250.1\ in\,sec^{-2}$ at an angle $88.22°$

$A_{A4t} := 1.751\cdot k_a$,

$A_{A4t} = 175.1\ in\cdot sec^{-2}$



Hence, the link 4 angular acceleration is:

$\alpha_4 := \frac{A_{A4t}}{c}$ $\alpha_4 = 186.5 \frac{rad}{sec^2}$ CCW

In the pin-joined fourbars case, the equation is:

$$(A_P^t + A_P^n) = (A_A^t + A_A^n) + (A_{PA}^t + A_{PA}^n)$$

where for point C, this equation is then

$$(A_C^t + A_C^n) = (A_B^t + A_B^n) + (A_{CB}^t + A_{CB}^n)$$, where

$A_{cn} := g \cdot \omega_6^2$ $A_{C_n} = 242.2\ in \cdot sec^{-2}$

$\theta_{ACn} := \theta_6 + 180°$ $\theta_{AC_n} = 268°$

$A_{Bn} := e\omega_4^2$ $A_{Bn} = 258.7\ in\,sec^{-2}$

$\theta_{ABn} := \theta_4 + 180°$ $\theta_{ABn} = 312.661°$

$A_{Bt} := e \cdot \alpha_4$ $A_{Bt} = 253.6\ in \cdot sec^{-2}$

$\theta_{ABt} := \theta_4 + 90°$

$\theta_{ABt} = 222.661°$

$A_{CBn} := f \cdot \omega_5$

$A_{CBn} = 85.78\ in \cdot sec^{-2}$

$\theta_5 := 27.5°$

$\theta_{ACBn} := \theta_5$, $\theta_{ACBn} = 27.5°$

In the picture below, which represents the solution to the point C equation, we can see the polygon which gives us the acceleration

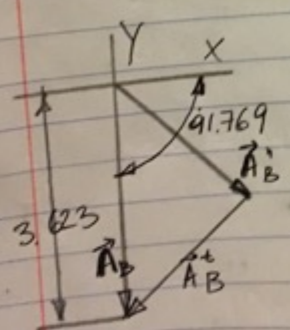
Scale factor $k_a := 100 \frac{in}{sec^2}$

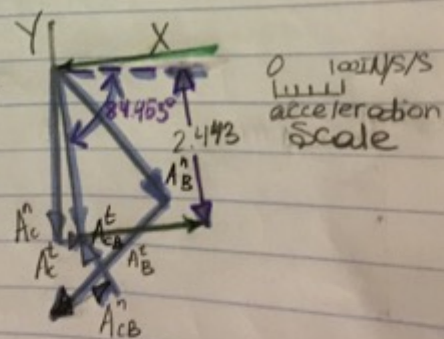
$A_B := 3.623 \cdot k_a$ at an angle $-91.8°$

$A_B = 362.3 \frac{in}{sec^2}$

$A_C := 2.443 \cdot k_a$

$A_C = 244.3 \frac{in}{sec^2}$ at an angle $-84.5°$





(1) Question 4

#7.71

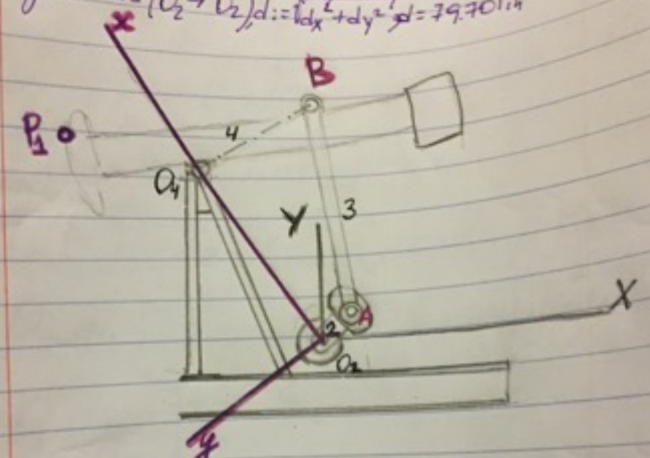
length of link 2 ($O_2 \to A$) $a := 14\,in$

length of link 3 ($A \to B$) $b := 80\,in$

length of link 4 ($O_2 \to B$) $c := 51.26 \cdot in$

length of L1, X-offset $d_x := 47.5\,in$, L1, Y-offset $d_y := (116 - 12)\,in$ $:= 64\,in$

length of L1 ($O_2 \to O_2$) $d := \sqrt{d_x^2 + d_y^2}$, $d = 79.701\,in$



coupler point (x-offset): $p_x := 114.68\,in$

y-offset: $p_y := 33.19\,in$

crank angle: $\theta_2 := 0 \cdot deg, 1 \cdot deg \ldots 360 \cdot deg$

the global XY to local xy system transf.

coordinate rotation angle $\cdot\ \alpha = 126.582 \cdot deg$

Input crank angular velocity: $\omega_2 := 10 \cdot rad \cdot sec^{-1}$ (CCW)

$\alpha_2 := 0 \cdot rad \cdot sec^{-2}$

The constants:

$K_1 := d/a$	$K_2 := d/c$	$K_3 := \dfrac{a^2 - b^2 + c^2 + d^2}{2a \cdot c}$
$K_1 = 5.6929$	$K_2 = 1.5548$	$K_3 = 1.934$

$$A(\theta_2) = \cos(\theta_2) - K_1 - K_2 \cdot \cos(\theta_2) + K_3$$

$$B(\theta_2) := -2\sin(\theta_2)$$

$$C(\theta_2) := K_1 - (K_2 + 1)\cos(\theta_2) + K_3$$

$$\theta_4(\theta_2) := 2 \cdot \left(\operatorname{atan2}\left(2 \cdot A(\theta_2), -B(\theta_2) + \sqrt{B(\theta_2)^2 - 4A(\theta_2)C(\theta_2)}\right)\right)$$

$K_4 := d/b$	$K_5 := \dfrac{c^2 - d^2 - a^2 - b^2}{2 \cdot a \cdot b}$
$K_4 = .9963$	$K_5 = -4.6074$

$$D(\theta_2) := \cos(\theta_2) - K_1 + K_4 \cos(\theta_2) + K_5$$

$$E(\theta_2) := -2\sin(\theta_2)$$

$$F(\theta_2) := K_1 + (K_4 - 1)\cos(\theta_2) + K_5$$

$$\theta_3(\theta_2) = 2\left(\operatorname{atan2}\left(2 \cdot D(\theta_2), -E(\theta_2) + \sqrt{E(\theta_2)^2 - 4 \cdot D(\theta_2) \cdot F(\theta_2)}\right)\right)$$

The angular velocity of L_3:

$$\omega_3(\theta_2) := \frac{a \cdot \omega_2}{b} \cdot \frac{\sin(\theta_4(\theta_2) - \theta_2)}{\sin(\theta_3(\theta_2) - \theta_4(\theta_2))}$$

the angular velocity of L_4:

$$\omega_4(\theta_2) := \frac{a \cdot \omega_2}{c} \cdot \frac{\sin(\theta_2 - \theta_3(\theta_2))}{\sin(\theta_4(\theta_2) - \theta_3(\theta_2))}$$

Thus, the angular acceleration of L_4;

$$A'(\theta_2) := c \cdot \sin(\theta_4(\theta_2))$$

$$B'(\theta_2) := b \cdot \sin(\theta_3(\theta_2))$$

$$D'(\theta_2) := c\cos(\theta_4(\theta_2))$$

$$E'(\theta_2) := b \cdot \cos(\theta_3(\theta_2))$$

$$C'(\theta_2) := a \cdot \alpha_2 \sin(\theta_2) + a \cdot \omega_2^2 \cdot \cos(\theta_2) + b\omega_3(\theta_2)^2 \cdot \cos(\theta_3(\theta_2)) - c \cdot \omega_4(\theta_2)^2 \cdot \cos(\theta_4(\theta_2))$$

$$F'(\theta_2) := a \cdot \alpha \cos(\theta_2) - a \cdot \omega_2^2 \cdot \sin(\theta_2) - b\omega_3(\theta_2)^2 \sin(\theta_3(\theta_2)) + c \cdot \omega_4(\theta_2)^2 \cdot \sin(\theta_4(\theta_2))$$

$$\alpha_4(\theta_2) := \frac{C'(\theta_2) \cdot E'(\theta_2) - B'(\theta_2) \cdot F'(\theta_2)}{A'(\theta_2) \cdot E'(\theta_2) - B'(\theta_2) \cdot D'(\theta_2)}$$

The acceleration of the point P_1 on L4 is:

$u := \sqrt{(p_x - d)^2 + p_y^2}$,

$u = 48.219\,in$

$\delta_4 := 141.067 \cdot deg$

$\mathbf{A}_{P1}(\theta_2) := u \cdot \alpha_4(\theta_2) \cdot (-\sin(\theta_4(\theta_2) + \delta_4) + j \cdot \cos(\theta_4(\theta_2) + \delta_4)) \ldots + -u \omega_4(\theta_2)^2 \cdot (\cos(\theta_4(\theta_2) + \delta_4) + j \cdot \sin(\theta_4(\theta_2) + \delta_4))$

$A_{P1} := |\mathbf{A}_{P1}(\theta_2)|$

$\theta_{AP1}(\theta_2) := \arg(\mathbf{A}_{P1}(\theta_2)) + \vec{\alpha}$

$\theta_{AP1}(\theta_2) := if(\theta_{AP1}(\theta_2) > 100°, \theta_{AP1}(\theta_2) - 2\pi, \theta_{AP1}(\theta_2))$

From the crank angle plot,

$A_{P1}(-81.582°) = 792.706 \frac{in}{sec^2}$

$\theta_{AP1}(-81.582°) = 60.447°$

Question 5

#7.73

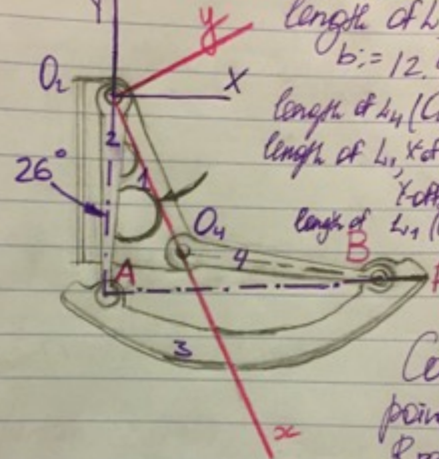
~~Length of~~

length of L_2 ($O_2 \to A$):

$a := 9.174 \cdot in$

length of L_3 (A to B):

$b := 12.971 \cdot in$



length of L_4 (O_4 to B): $c := 9.573 \cdot in$

length of L_1, X-offset: $d_x := 2.79 \cdot in$

Y-offset: $d_y := -6.948 \cdot in$

length of L_1 (O_2 to O_4):

$d := \sqrt{d_x^2 + d_y^2}$

$d = 7.487 in$

Coupler point data:

$R_{pa} := 15 \cdot in$

$\delta_3 := 0 \cdot deg$

Crank∠: $\theta_2 := -26 \cdot deg$

$-25.9 \ldots -15°$

$\theta_{20} := -26°$

Coordinate rotation∠: $\alpha := -68.121°$, in the Global XY-coord. system to local xy coord System transformation

Angular velocity input crank: $\omega_{20} := 0 \cdot rad \cdot sec^{-1}$

$\alpha_2 := 10 \cdot rad \cdot sec^{-1}$

The constants: $K_1 := \frac{d}{a}$, $K_1 = .8161$

$K_2 := d/c$, $K_2 = .7821$

$K_3 := \frac{a^2 - b^2 + c^2 + d^2}{2 \cdot a \cdot c}$, $K_3 = .3622$

$A(\theta_2) := \cos(\theta_2) - K_1 - K_2 \cos(\theta_2) + K_3$

$B(\theta_2) := -2\sin(\theta_2)$

$C(\theta_2) := K_1 - (K_2 + 1) \cdot \cos(\theta_2) + K_3$

For the crossed circuit,

$\theta_4(\theta_2) := 2\left(atan2\left(2 \cdot A(\theta_2), -B(\theta_2) + \sqrt{B(\theta_2)^2 - 4A(\theta_2) \cdot C(\theta_2)}\right)\right)$

The constants: $K_4 := d/b$ $K_4 = .5772$

$K_5 := \frac{c^2 - d^2 - a^2 - b^2}{2ab}$, $K_5 = -.9111$

$D(\theta_2) := \cos(\theta_2) - K_1 + K_4 \cdot \cos(\theta_2) + K_5$

$E(\theta_2) := -2\sin(\theta_2)$

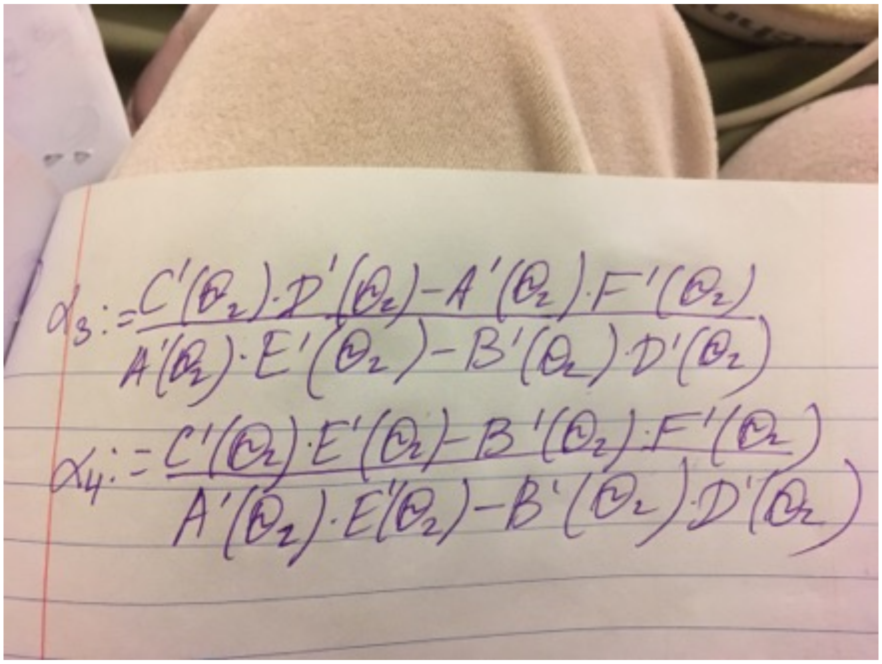
$F(\theta_2) := K_1 + (K_4 - 1) \cdot \cos(\theta_2) + K_5$

$\theta_3(\theta_2) := 2\left(atan2\left(2 \cdot D(\theta_2), -E(\theta_2) + \sqrt{E(\theta_2)^2 - 4D(\theta_2)F(\theta_2)}\right)\right)$

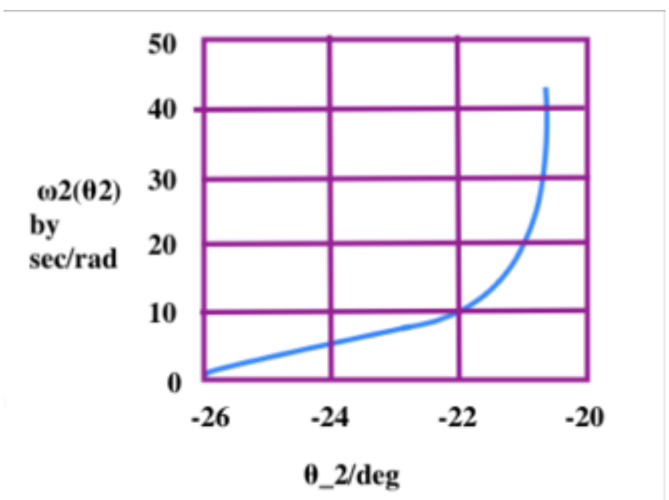
the angular velocity of $\angle 3$:

$\omega_2(\theta_2) := \sqrt{2(\theta_2 - \theta_{20})\alpha_2}$

$\omega_3(\theta_2) := \frac{a \cdot \omega_2}{b} \cdot \frac{\sin(\theta_4(\theta_2) - \theta_2)}{\sin(\theta_3(\theta_2) - \theta_4(\theta_2))}$

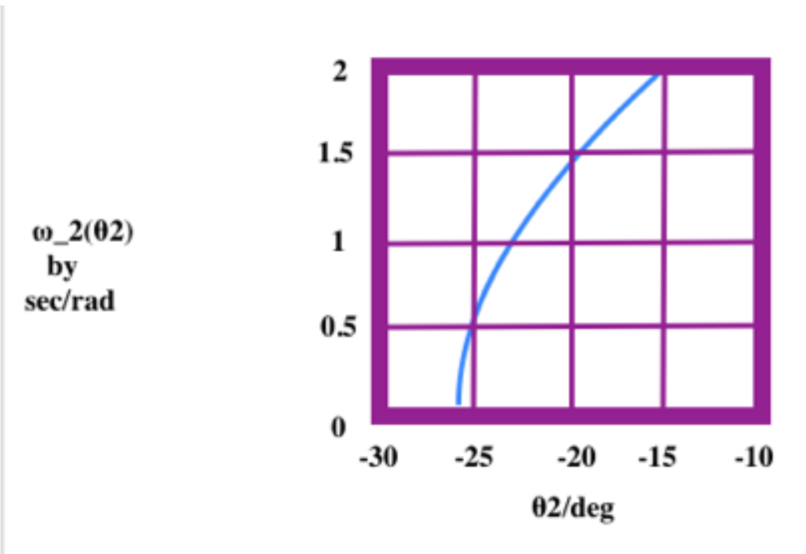


On the plot below, I have used R Programming language to visualize theta_2/deg on x-axis vs. CORRECTION!!! I meant omega_4, not omega_2 on the y-axis where I have accidentally mistyped: omega_2(theta_2) multiplied by seconds/rad



On the plot below, I have theta_2/deg on x-axis vs. omega_2(theta_2) multiplied by seconds/rad on y-axis

On the plot below, I have theta_2/deg on x-axis vs.alpha_2 multiplied by seconds^2/rad on y-axis

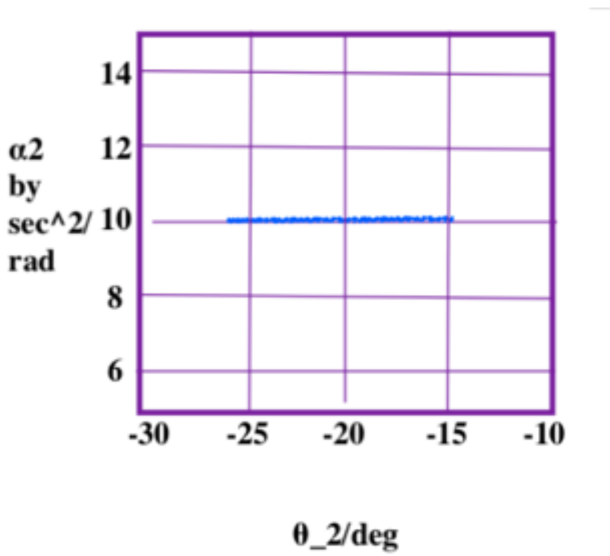


With Euler identity, I will expand the expression for A_A:

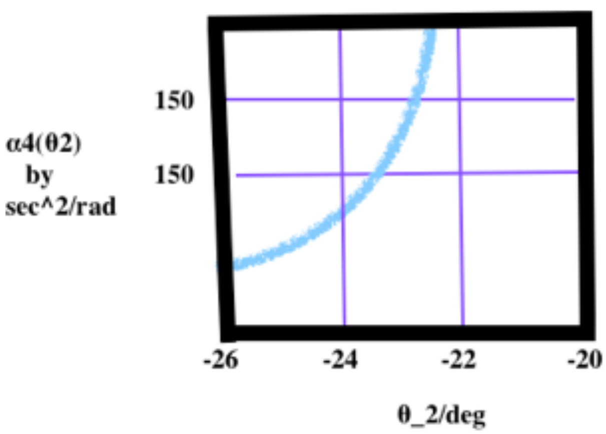
$$A_A(\theta_2) := a\cdot\alpha_2(-\sin(\theta_2)+j\cos(\theta_2)) - a\cdot\omega_2(\theta_2)^2\cdot(\cos(\theta_2)+j\sin(\theta_2))$$

the angular acceleration for L_3:

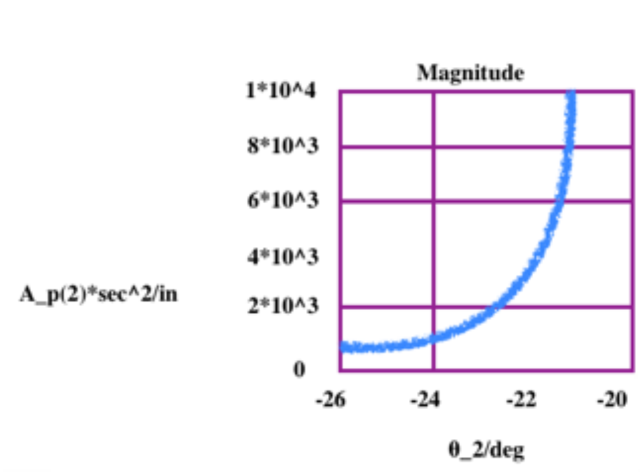
$$A'(\theta_2) := c\cdot\sin(\theta_4(\theta_2))$$
$$B'(\theta_2) := b\cdot\sin(\theta_3(\theta_2))$$
$$D'(\theta_2) := c\cdot\cos(\theta_4(\theta_2))$$
$$E'(\theta_2) := b\cdot\cos(\theta_3(\theta_2))$$
$$C'(\theta_2) := a\cdot\alpha_2\cdot\sin(\theta_2) + a\cdot\omega_2(\theta_2)^2\cdot\cos(\theta_2) + b\cdot\omega_3(\theta_2)^2\cdot\cos(\theta_3(\theta_2))) - c\omega_4(\theta_2)^2\cos(\theta_4(\theta_2))$$
$$F'(\theta_2) := a\cdot\alpha_2\cdot\cos(\theta_2) - a\omega_2(\theta_2)^2\sin(\theta_2) - b\omega_3(\theta_2)^2\sin(\theta_3(\theta_2)) + c\omega_4(\theta_2)^2\sin(\theta_4(\theta_2))$$



On the plot below, I have theta_2/deg on x-axis vs.alpha_4 multiplied by seconds^2/rad on y-axis



The following plot illustrates the magnitude for the associated point P motion, on y-axis, Acceleration of point P with the units of measurement sec^2/rad; on-x-axis – theta_2/deg



The following plot illustrates the direction for the associated point P motion, on y-axis, angle of Acceleration of point P, which is theta_Ap(theta_2) with the units of measurement sec^2/rad; on-x-axis – theta_2/deg