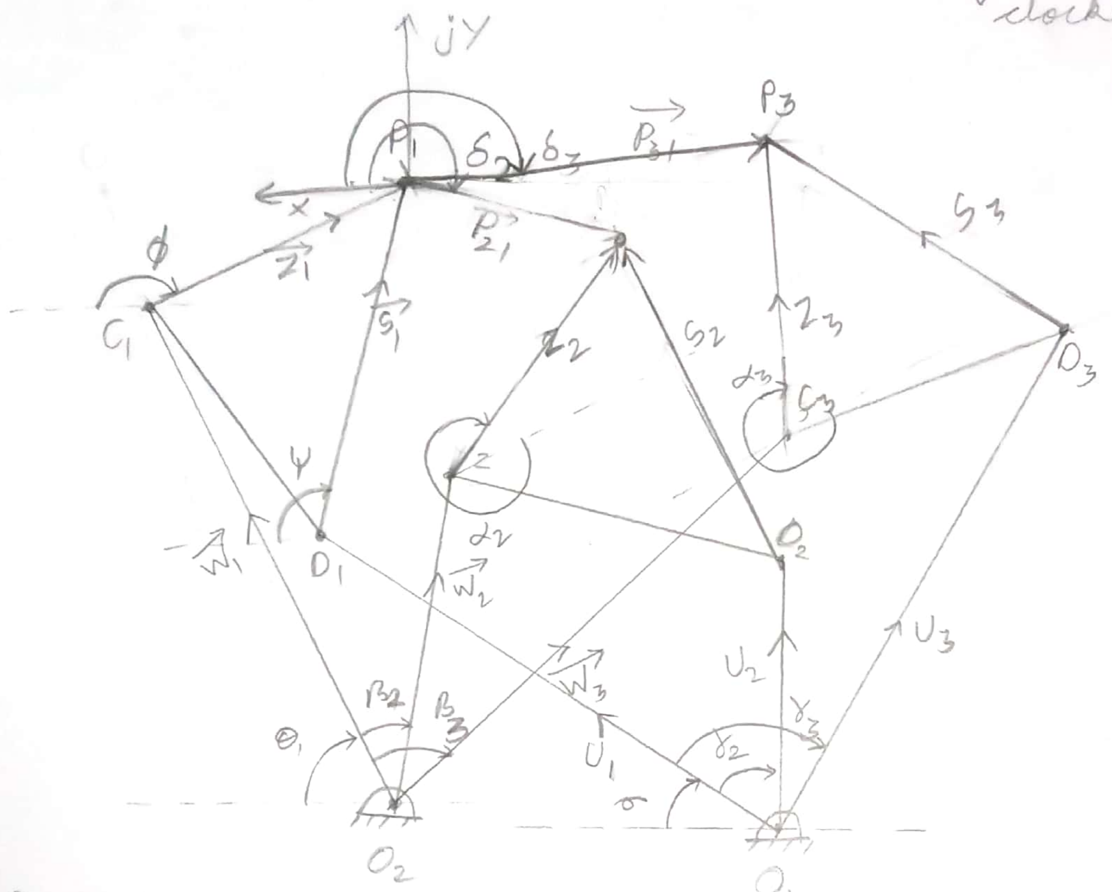
# Assignment-4

1)

lowering angle clockwise




By loop closure equations for left dyad we get

$$\left.\begin{aligned} we^{i\theta}(e^{i\beta_2}-1)+ze^{i\phi}(e^{i\alpha_2}-1) &= p_{21}e^{i\delta_2} \\ we^{i\theta}(e^{i\beta_3}-1)+ze^{i\phi}(e^{i\alpha_3}-1) &= p_{31}e^{i\delta_3} \end{aligned}\right\} -①$$

$$\left(\because \vec{W_2}+\vec{Z_2}-\vec{P_{21}}-\vec{Z_1}-\vec{W_1}=0 \ \& \quad \vec{W_3}+\vec{Z_3}-\vec{P_{31}}-\vec{Z_1}-\vec{W_1}=0\right)$$

From diagram

$p_{21} = 3\,cm$

$p_{31} = 5\,cm$

$\delta_2 = 195°$

$\delta_3 = 174°$

$\alpha_2 = 332°$

$\alpha_3 = 295°$

choose:

$\beta_2 = 30°$

$\beta_3 = 45°$

$\rightarrow$ Let $W = we^{i\theta}$ $\quad S_2 = e^{i\beta_2} - 1 \quad T_2 = e^{i\alpha_2} - 1 \quad U_2 = p_{21} e^{i\delta_2}$
$\quad\quad Z = ze^{i\phi} \quad S_3 = e^{i\beta_3} - 1 \quad T_3 = e^{i\alpha_3} - 1 \quad U_3 = p_{31} e^{i\delta_3}$ — ②

By ① & ②

$$\Longrightarrow \left.\begin{aligned} WS_2 + ZT_2 &= U_2 \\ WS_3 + ZT_3 &= U_3 \end{aligned}\right\} — ④$$

By elimination we get

$$\Longrightarrow W = \frac{U_2T_3 - U_3T_2}{S_2T_3 - S_3T_2}$$

solving in MATLAB we get

$$W = -0.0203 + i\, 0.0214$$

$$\Longrightarrow w\cos\theta = -0.0203$$

$$w\sin\theta = 0.0214 \Longrightarrow w = \frac{0.0214}{\sin\theta} \quad — ③$$

$$\Longrightarrow \frac{0.0214}{\sin\theta}\cos\theta = -0.0203$$

$$\Longrightarrow \cot\theta = -0.95$$

$$\Longrightarrow \theta = -46.5^\circ$$

$\Longrightarrow$ $\theta = 46.5^\circ$ clockwise as in diagram

from ③

$$w = \frac{0.0214}{\sin 46.5^\circ} = 0.03\,m = 3\,cm$$

$$w = 3\,cm$$

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Using (4) we also get

$$\overline{Z} = \frac{U_2 S_3 - U_3 S_2}{T_2 S_3 - T_3 S_2}$$

Using MATLAB,

$\overline{Z} = -0.0447i$ $\qquad \overline{Z} = ze^{i\phi}$

$z\cos\phi = 0$

$[\phi = 90^\circ]$ clockwise → Refer Dia

$z = 0.0447\ m$

$[z = 4.47\ cm]$

Similarly by loop closure equations for right Dyad we get

$$ue^{i\sigma}\underbrace{(e^{i\gamma_2}-1)}_{S_2} + se^{i\psi}\underbrace{(e^{i\alpha_2}-1)}_{T_2} = \underbrace{p_{21}e^{i\delta_2}}_{U_2}$$

$$\underbrace{ue^{i\sigma}}_{U}\underbrace{(e^{i\gamma_3}-1)}_{S_3} + \underbrace{se^{i\psi}}_{S}\underbrace{(e^{i\alpha_3}-1)}_{T_3} = \underbrace{p_{31}e^{i\delta_3}}_{U_3}$$

Choose

$\gamma_2 = 70^\circ$

$\gamma_3 = 100^\circ$

$$\Rightarrow \quad US_2 + ST_2 = U_2$$

$$US_3 + ST_3 = U_3$$

$$U = \frac{U_2T_3 - U_3T_2}{S_2T_3 - S_3T_2}$$

Using MATLAB ; $U = -0.004 + 0.0103i$

$$\Rightarrow \quad U \cos\sigma = -0.004$$

$$U \sin\sigma = 0.0103$$

$$\Rightarrow \quad \tan\sigma = \frac{0.0103}{-0.004}$$

$$\Rightarrow \quad \left[\begin{array}{l} \sigma = 68.78^\circ \text{ clockwise} \\ U = 1.11\,cm \end{array}\right] \rightarrow \text{Refer dia}$$

Similarly

$$S = \frac{U_2 S_3 - U_3 S_2}{T_2 S_3 - T_3 S_2}$$

$$= 0.0055 - 0.0453\,i$$

$$S \cos\psi = 0.0055$$

$$S \sin\psi = -0.0453$$

$$\left[\begin{array}{l} \psi = 83^\circ \text{ clockwise} \\ S = 4.564\,cm \end{array}\right] \rightarrow \text{Refer dia}$$

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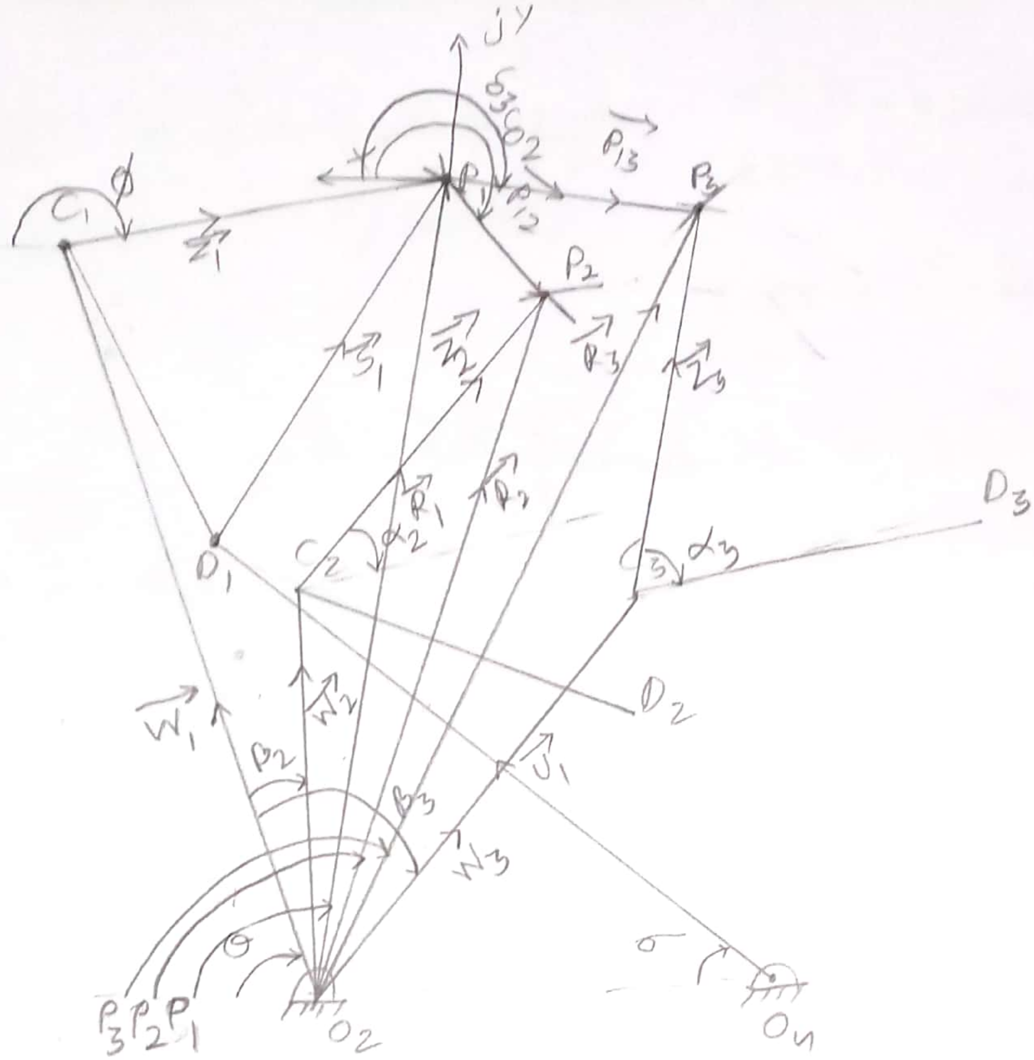
2)




Using loop closure equation

$$\vec{W_1} + \vec{Z_1} = \vec{R_1}$$
$$e^{i\beta_2}\vec{W_1} + e^{i\alpha_2}\vec{Z_1} = \vec{R_2}$$
$$e^{i\beta_3}\vec{W_1} + e^{i\alpha_3}\vec{Z_1} = \vec{R_3}$$

$$\Rightarrow \quad we^{i\theta} + ze^{i\phi} = Re^{iP_1}$$
$$e^{i\beta_2}we^{i\theta} + e^{i\alpha_2}ze^{i\phi} = Re^{iP_2}$$
$$e^{i\beta_3}we^{i\theta} + e^{i\alpha_3}ze^{i\phi} = Re^{iP_3}$$

To find:
$w, \theta, \beta_1, \beta_2, z, \phi$
6 variables

3 complex equations $\Rightarrow$ 6 equations

Given:

$R = 5$ cm
$P_1 = 93^\circ$
$P_2 = 95^\circ$
$P_3 = 97^\circ$
$\alpha_2 = 35^\circ$
$\alpha_3 = 70^\circ$

measured from the dimensions given in the text book figure summary of calculations:

let $A = e^{i\alpha_2}\vec{R_3} - e^{i\alpha_3}\vec{R_2}$

$B = e^{i\alpha_3}\vec{R_1} - \vec{R_3}$

$C = \vec{R_2} - e^{i\alpha_2}\vec{R_1}$

&

$a = \bar{A}B$, $b = A\bar{A} + B\bar{B} - C\bar{C}$ & $c = A\bar{B}$.

then

$$e^{i\beta_2} = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = t_{1,2}$$

&

$$e^{i\beta_3} = \frac{-A + Bt_{1,2}}{C}$$

$\Downarrow$

we get $\beta_2$ & $\beta_3$ from above

then use

$\vec{W_1} + \vec{Z_1} = \vec{R_1}$ &

$e^{i\beta_2}\vec{W_1} + e^{i\alpha_2}\vec{Z_1} = \vec{R_2}$ Ans 2

$e^{i\beta_3}\vec{W_1} + e^{i\alpha_3}\vec{Z_1} = \vec{R_3}$

to get $w, \theta, z$ & $\phi$

$\Rightarrow$ For MATLAB implementation, run A3.m with input array as [5 93 95 97 35 70]

we get

$$\left[\begin{array}{l} \beta_2 = 2^\circ \text{ clockwise} \\ \beta_3 = 163.4564^\circ \text{ clockwise} \end{array}\right]$$

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Using

$$W_1 + Z_1 = R_1$$

$$e^{i\beta_2} W_1 + e^{i\alpha_2} Z_1 = R_2$$

we will get $w, \theta, z$ & $\phi$

$$e^{i\beta_2}(R_1 - Z_1) + e^{i\alpha_2} Z_1 = R_2$$

$$R_1 e^{i\beta_2} - Z_1 e^{i\beta_2} + Z_1 e^{i\alpha_2} = R_2$$

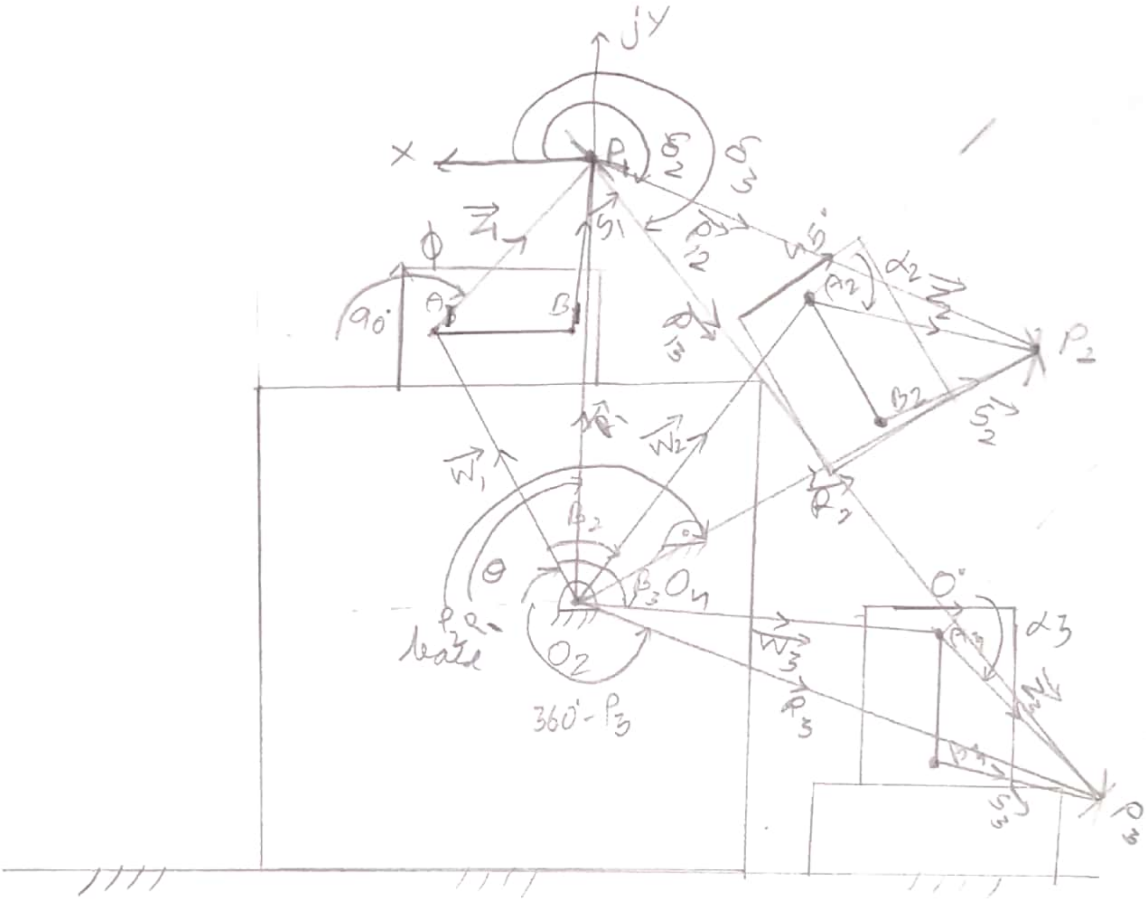
$$Z_1 = \frac{R_2 - R_1 e^{i\beta_2}}{e^{i\alpha_2} - e^{i\beta_2}} = z e^{i\phi}$$

$$W_1 = R_1 - Z_1 = w e^{i\theta}$$

For solution run MATLAB A4.m with input array as [5 93 95 97 35 70] we get

| ① | ② |
|---|---|
| $Z = 5.618$ cm | $z = 5.0345$ cm |
| $\phi = 76.5°$ | $\phi = 31.1196$ |
| $w = 2.8020$ cm | $w = 8.2186$ cm |
| $\theta = -179.5953°$ | $\theta = 128.1498°$ |
| $\beta_2 = -35°$ | $\beta_2 = -2°$ |
| $\beta_3 = 163.6002°$ | $\beta_3 = -163.4564°$ |

3)




In the above problem, we are constrained by the condition that the fixed pivot points should lie inside the base, as a result let us choose $O_2$ & $O_4$ as marked in the above diagram.

Hence once fixing $O_2$ & $O_4$ we will get input values from the dimensions mentioned in the textbook diagram.

As a result given input values are:

$R = 1.86$ cm

$\rho_1 = 62°$

$\rho_2 = 150°$

$\rho_3 = 200°$

$\alpha_2 = 58°$

$\alpha_3 = 94°$

Run Ah.m with input array as [1.8 62 150 200 58 94]

we get the result:

| ① | ② |
|---|---|
| $Z = 2.5451$ cm | $Z = 1.3499$ cm |
| $\phi = 77°$ | $\phi = 117.5633°$ |
| $\omega = 1.3285$ cm | $\omega = 3.1273$ cm |
| $\theta = -45.9366°$ | $\theta = 67.9442$ |
| $\beta_2 = -88°$ | $\beta_2 = -58°$ |
| $\beta_3 = -156.8469°$ | $\beta_3 = -134.0954°$ |

Alternative

Using Graphical Analysis we can create a Crank-Rocker Mechanism too as in 3rd Problem of Assignment 3