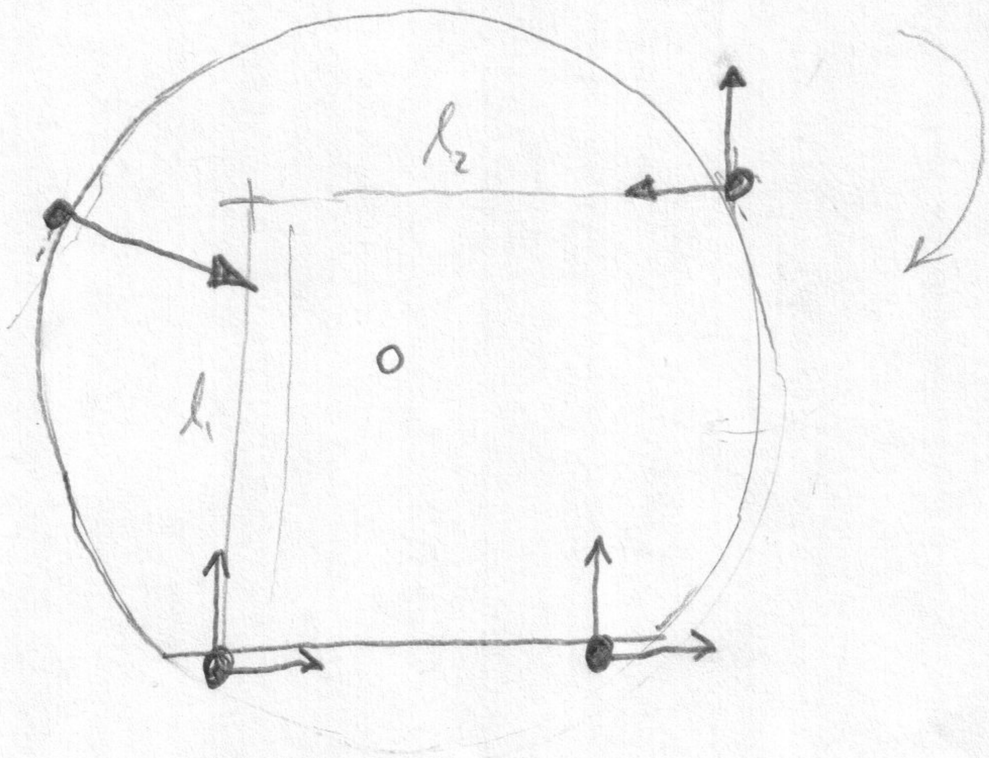
$F = 3(n-1) - 2l - h$

$=$

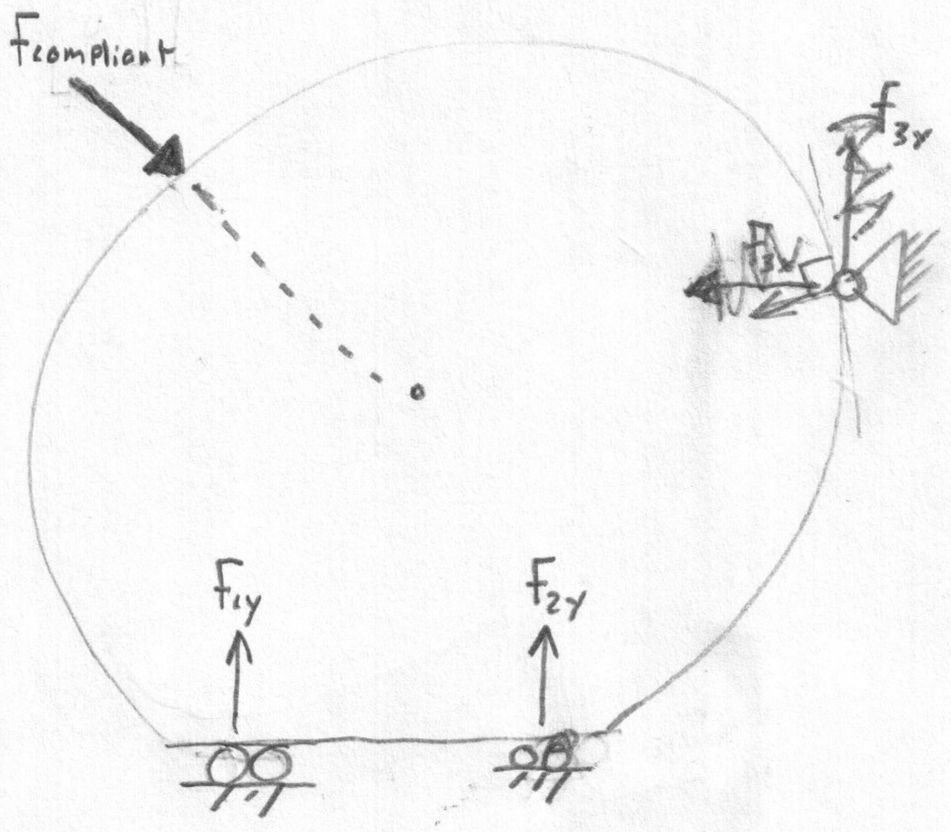


$$\Sigma f_x = \cancel{P_{1x}} + \cancel{P_{2x}} + P_{3x} - P_{Lx}$$

$$P_{3x} = P_{Lx}$$

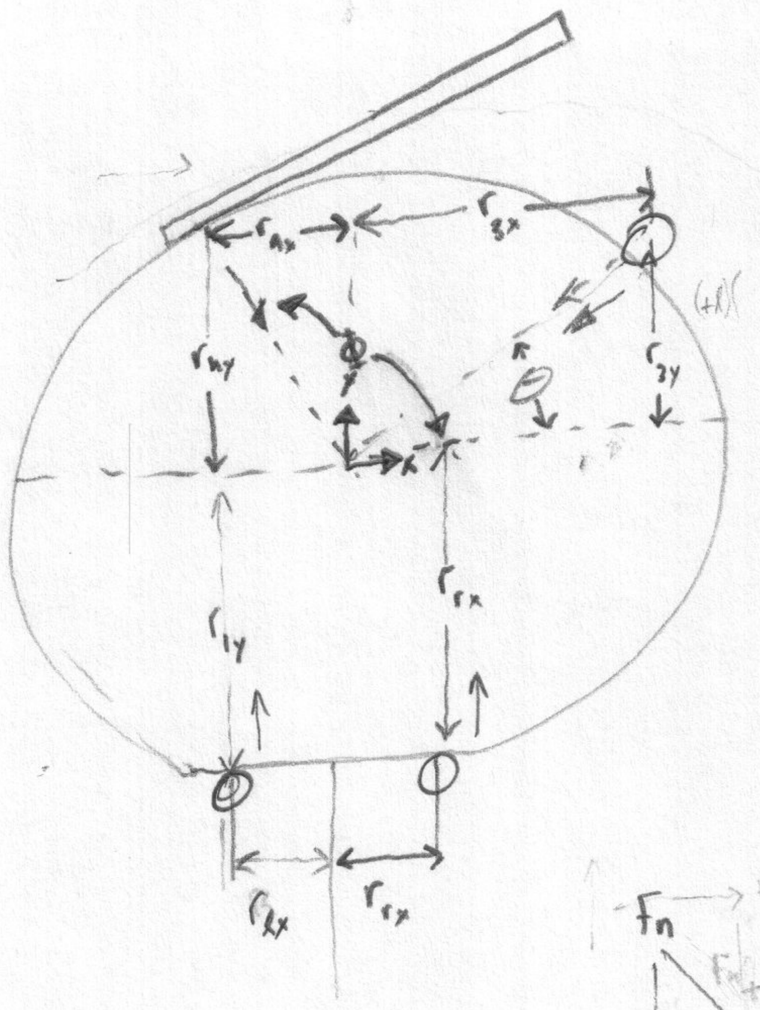
$$\Sigma F_y = P_{1y} + P_{2y} + P_{3y} - P_{Ly}$$

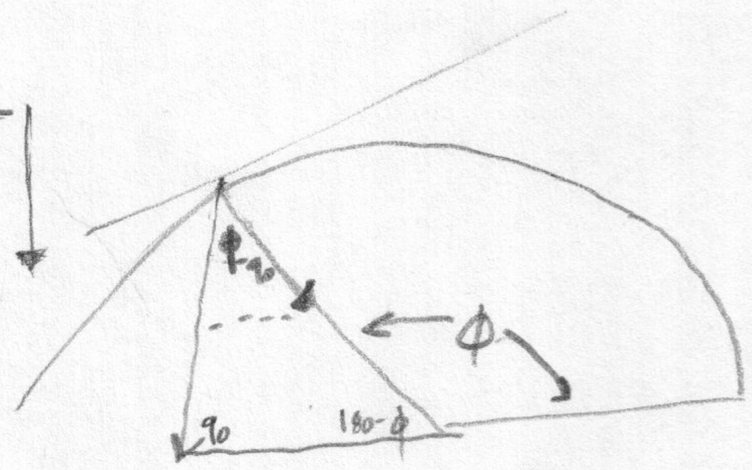
$$\Sigma M_{P_1} = (\ell_{P_1})(P_{2y}) + \ell_1 P_{3x} + \ell_2 P_{3y} + M_{in3}$$

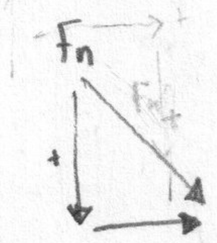


3 eqns

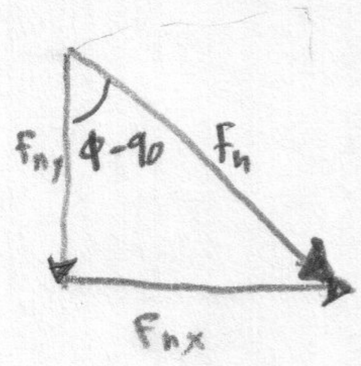
4 unknowns







$180 - 90 - 180 + \phi$



$\downarrow F_{ny} = -F_n \cos(\phi - 90) = -F_n \sin(\phi)$

$\rightarrow F_{nx} = -F_n \cos(\phi)$

$\leftarrow F_{3x} = -F_3 \cos\theta$

$\downarrow F_{3y} = -F_3 \sin\theta$

$F_{1y} = F_L$

$F_{ry} = F_r$

$$\sum F_y = f_{ny} + f_{1y} + f_{ry} + f_{3y} = 0$$

$$-F_3 \sin\theta + F_L + F_R = -F_n \sin\phi$$

$$\sum f_x = f_{nx} + f_{3x} = 0$$

$$-F_3 \cos\theta = f_n \cos\phi$$

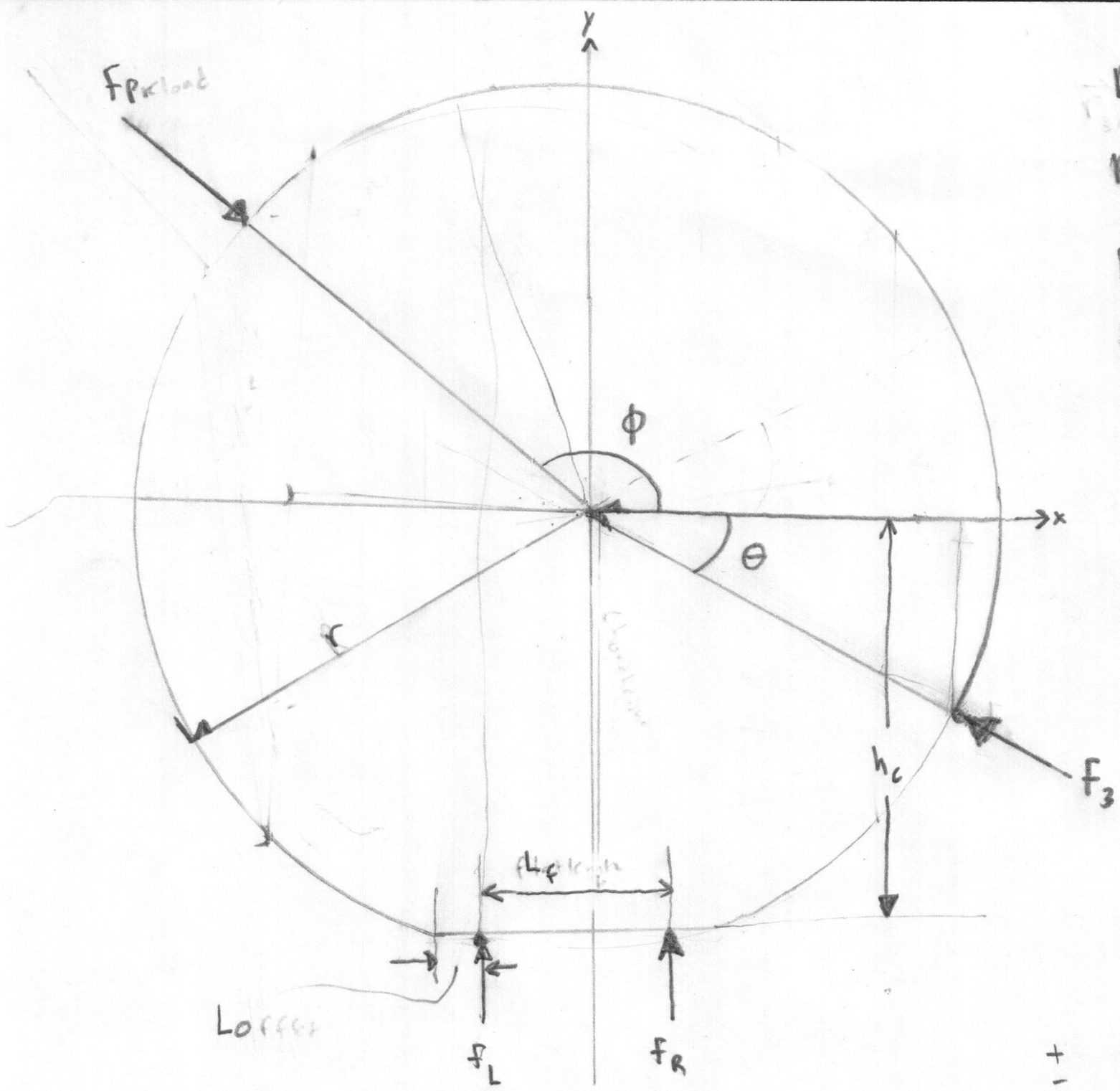
$$-f_3 \cos(\theta) - f_n \cos\phi = 0$$

$$\sum M_{P3} = (R_{rx} - R_{lx}) F_{ly} + (r_{3x} - r_{lx}) F_{3y} + (F_{ny})(r_{nx} - r_{lx})$$

$$+ (r_{3y} - r_{ly}) f_{3x} + (r_{ny} - r_{ly}) F_{nx} = 0$$

$$= -(R_{rx} - R_{lx}) F_{ly} + -(r_{3y} - r_{ly}) \sin\theta F_3 + -(r_{3x} - r_{lx}) \cos\theta F_3 + -(r_{nx} - r_{lx})(\sin\phi F_n) + (r_{ny} - r_{ly}) \cos\phi F_n$$

$$\begin{matrix} F_x \\ F_y \\ M_L \end{matrix} \begin{bmatrix} -\cos\theta & 0 & 0 \\ -\sin\theta & 1 & 1 \\ -\cos\theta(r_{3y} - r_{ly}) & & \\ +\sin\theta(r_{3x} - r_{lx}) & 0 & -(r_{rx} - r_{lx}) \end{bmatrix} \begin{bmatrix} F_3 \\ F_L \\ F_R \end{bmatrix} = \begin{bmatrix} \cos\phi \\ \sin\phi \\ -(r_{nx} - r_{lx})\sin\phi + (r_{ny} - r_{ly})\cos\phi \end{bmatrix} f_n$$



$$R_{3x} = r\cos\theta$$

$$R_{3y} = r\sin\theta$$

$$R_{Lx} = L_o - \frac{L_f}{2}$$

$$R_{Ly} = -h_c$$

$$R_{Rx} = \frac{L_f}{2} - L_o$$

$$R_{Ry} = -h_c$$

$$R_{Px} = r\cos\phi$$

$$R_{Py} = r\sin\phi$$

(M) + (ccw)

(M) − (cw)

$$\Sigma F_x = -F_p\cos(\phi) - F_3\cos(\theta) = 0$$

$$\Sigma F_y = -F_p\sin(\phi) - F_3\sin(\theta) + F_L + F_R = 0$$

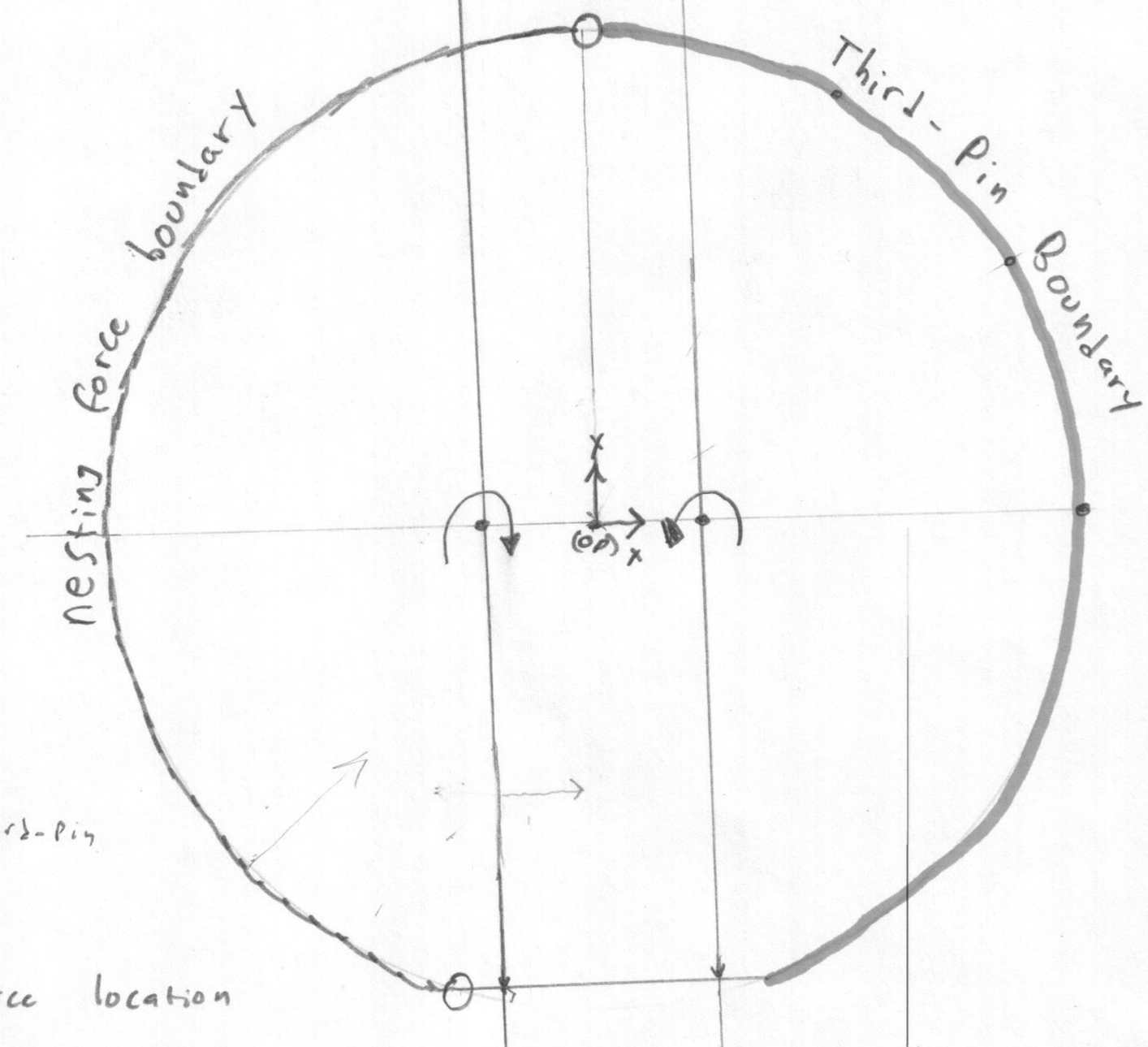
$$\Sigma m_L = -F_R\left(L_f - 2L_o\right) + F_3\left(\cos(\theta)\left(R_{3y} - R_{Ly}\right)\right) + F_3\sin(\theta)\left(R_{3x} - R_{Lx}\right)$$

$$+ F_p\cos(\phi)\left(R_{Py} - R_{Ly}\right) + F_p\sin\theta\left(R_{Px} - R_{Lx}\right) = 0$$

$$= F_R\left(L_f - 2L_o\right) + F_3\left(\left(\cos\theta\left(R_{3y} - R_{Ly}\right) - \sin\theta\left(R_{3x} - R_{Lx}\right)\right)\right.$$

$$\left. + F_p\left(\cos(\pi - \phi)\left(R_{Py} - R_{Ly}\right) - \sin(\pi - \phi)\left(R_{3x} - R_{Lx}\right)\right)\right) = 0$$

$$\begin{bmatrix} -\cos\theta & 0 & 0 \\ \sin(-\theta) & 1 & 1 \\ \left(\cos\theta\left(R_{3y} - R_{Ly}\right)\right) - \sin\theta\left(R_{3x} - R_{Lx}\right) & 0 & L_f - 2L_o \end{bmatrix} \begin{bmatrix} F_3 \\ F_L \\ F_R \end{bmatrix} = F_p \begin{bmatrix} -\cos(\pi - \phi) \\ \sin(\pi - \phi) \\ \cos(\pi - \phi)\left(R_{Py} - R_{Ly}\right) - \sin(\pi - \phi)\left(R_{3x} - R_{Lx}\right) \end{bmatrix}$$



1) Define arbitrary third-pin location

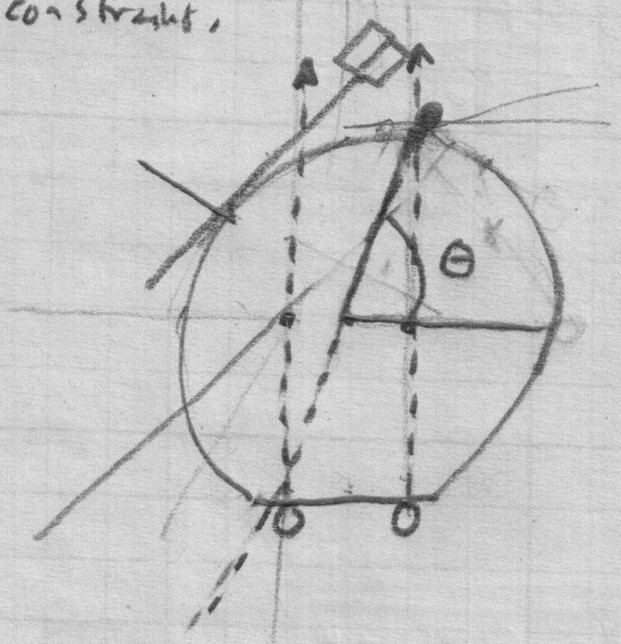
2) For each nesting force location check that each pin is in compression

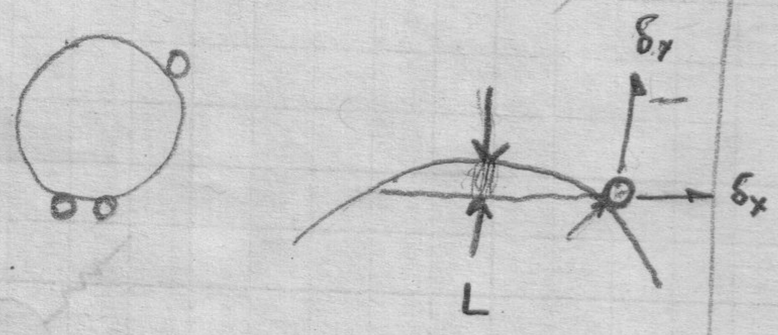
(direction of nesting force always orthogonal to the point of tangency on circle)

3) Verify w/ Blanding's method ★ of moments about rotation centers → Find location where moments are most similar

★ Blanding mentions finding "nesting force window" for constraints that are not parallel. For parallel constraints we must assume a translation instead of a rotation about instantaneous center of two parallel pins. Here, the line of action of nesting force must have LOA component in +X direction

Results indicate that we want θ close to 90 and ϕ such that magnitude of forces are equal. We now have numerical solution for phi as a function of theta. We must decide how close θ can be to $90°$ w/o over constraint.





Undercontstrnt/slip $\longrightarrow \delta_y < L$
Binding $\longrightarrow \sigma << \sigma_y$

Perhaps θ^* sets the limit b/c line of action is really a 'ray'

$$\theta^* = \cos^{-1}(R_{rx}/R)$$

$$\theta^* \approx 77°$$

$$\phi(\theta^*) \approx 150°$$

Restoring moment = 477 N-mm

For $\theta = 0$ moment = 62 N-mm $\phi = 146$

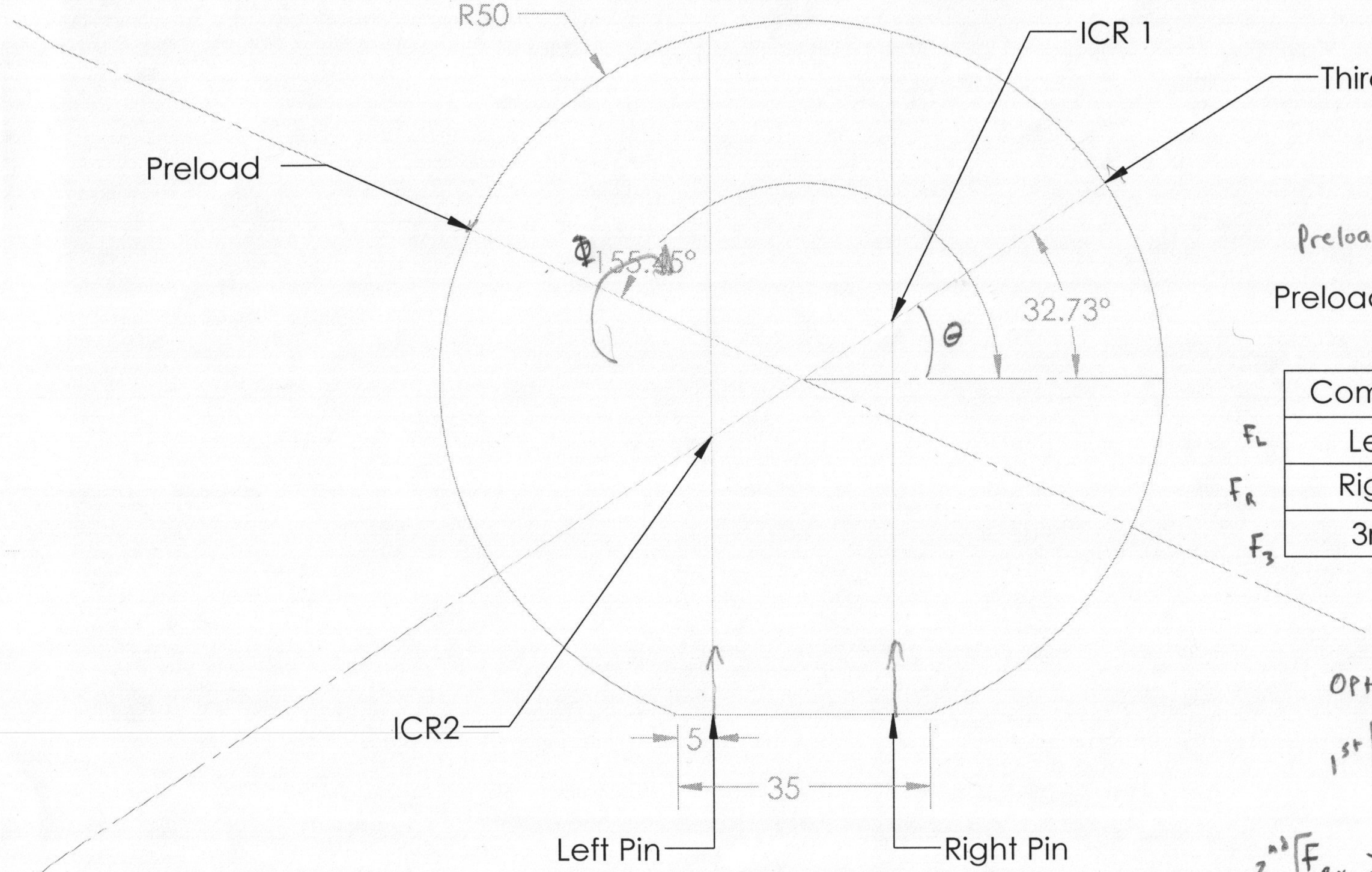
$\theta = \frac{\theta^*}{2}$ moment = 137 N-mm $\phi = 14$

How do we ensure that Undercontstrnt in x-axis will not occur?

Propose $\theta^* - \varepsilon_{Ping}$ or $\theta^* - SF$

1 from Blanding... Does it apply to parallel constraints?

TOPS™



Preload Magnitude: 10N

Preload moment about ICRs = .125nm

	Component	Fx N	Fy N
F_L	Left Pin	0	5
F_R	Right Pin	0	5
F_3	3rd Pin	-9.10	-6.28

Optimization Parameters

1st $\left[90° < \Phi < 180°\right]$

$\left[-45° < \theta < 90°\right]$

2nd $\left[F_{Ry} > 1 \text{ and } F_{Ly} > 1 \text{ and } F_{3x} < 1\right]$

3rd [Maximize Preload moment about ICR]

	NAME	SIGNATURE	DATE
DRAWN	Andrew Duenner	ACD	2/19/15
CHK'D			
APPV'D			
MFG			
Q.A			

MATERIAL: N/A

WEIGHT:

TITLE:

Wafer Alignment

DWG NO. 1/1

SCALE:1:1

SHEET 1 OF 1