PROBLEM 5-12 DESIGN A LINKAGE TO CARRY THE BODY SHOWN IN THE FIGURE THROUGH THE TWO POSITIONS P_1 AND P_2 AT THE ANGLES SHOWN IN THE FIGURE. USING ANALYTICAL SYNTHESIS WITHOUT REGARD FOR THE FIXED PIVOTS SHOWN. (HINT: TRY THE FREE CHOICES VALUES $z=2$, $\phi=150°$, $\beta_2=30°$, $s=3$, $\psi=-50°$, $\gamma_2=40°$.

GIVEN:

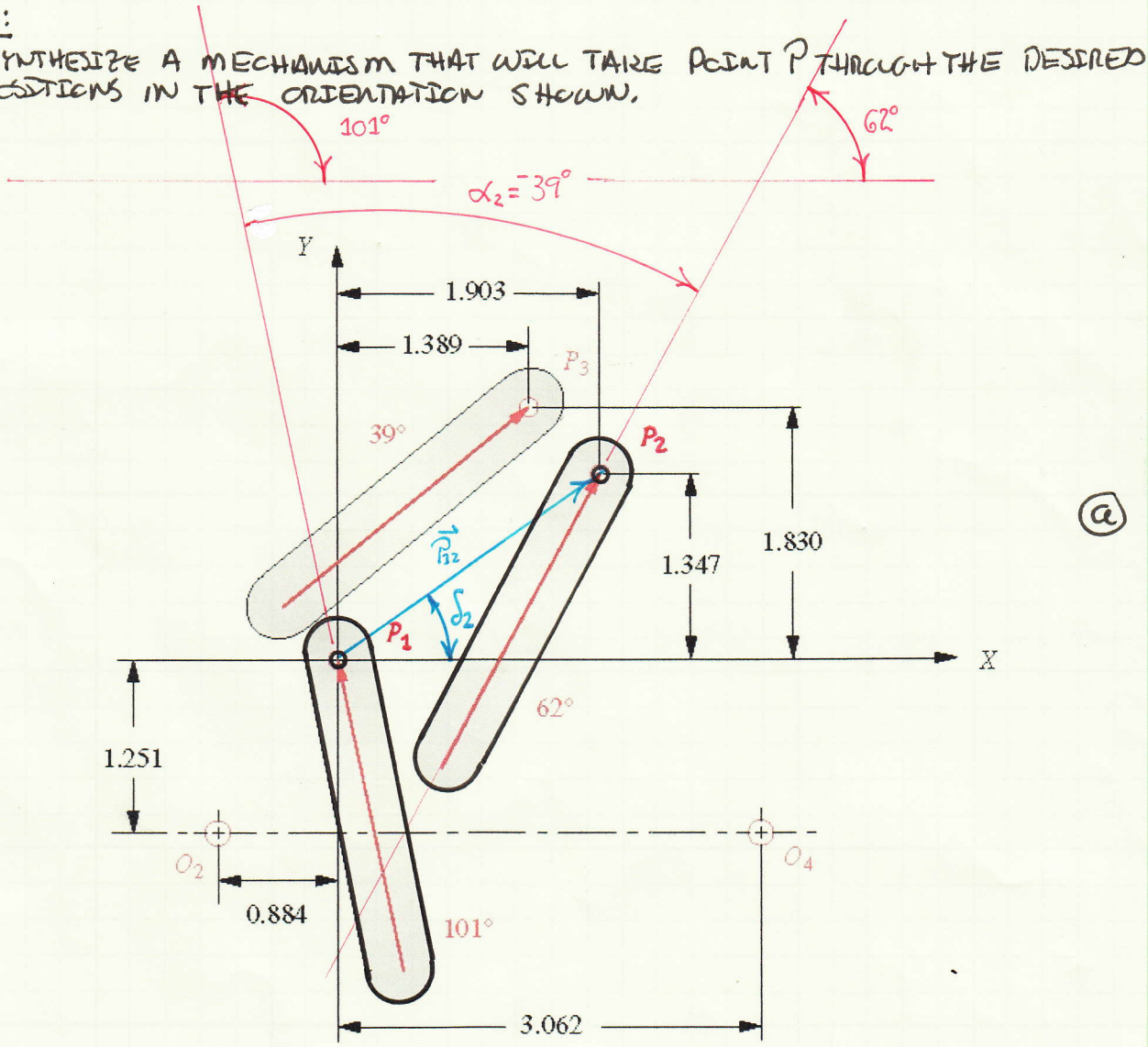
1. THE TWO POSITIONS OF A COUPLER LINK, SEE BELOW
2. P_1 @ (0in, 0in) ORIENTATED AT 101° FROM +X AXIS
3. P_2 @ (1.903in, 1.347in) ORIENTATED AT 62° FROM +X AXIS

ASSUMPTIONS:

1. PLANAR MOTION OF THE LINKS
2. ALL ELEMENTS ARE RIGID

FIND:

1. SYNTHESIZE A MECHANISM THAT WILL TAKE POINT P THROUGH THE DESIRED POSITIONS IN THE ORIENTATION SHOWN.



(a)

SOLUTION:

TWO POSITION SYNTHESIS HAS TWO APPROACHES. THE INFORMATION GIVEN IN THIS PROBLEM STATEMENT SUPPORTS WHAT HAS BEEN GIVEN AS APPROACH B IN WHICH ρ_{21}, δ_2, AND α_2 ARE GIVEN. THESE PARAMETERS ARE ILLUSTRATED IN (a). THE VALUES ARE CALCULATED AS FOLLOWS.

$$\rho_{21} = \sqrt{(1.903_{in}-0_{in})^2 + (1.347_{in}-0_{in})^2} = \underline{2.331_{in}} \quad (1)$$

$$\delta_2 = \tan^{-1}\frac{1.347_{in}}{1.903_{in}} = \underline{35.29^\circ} \quad (2)$$

$$\alpha_2 = 67^\circ - 101^\circ = \underline{-39^\circ} \quad (3)$$

THE BOOK SUGGESTS THE FOLLOWING FREE CHOICES

$z = 2_{in}$ (4) $\qquad s = 3_{in}$ (7)

$\phi = 150^\circ$ (5) $\qquad \psi = -50^\circ$ (8)

$\beta_2 = 30^\circ$ (6) $\qquad \gamma_2 = 40^\circ$ (9)

z & ϕ DEFINE ONE SIDE OF THE COUPLER LINK AND s & ψ DEFINE THE OTHER. β_2 AND γ_2 DEFINE THE TRAVEL OF LINKS 2 & 3.

THE SOLUTION TO THIS SYNTHESIS USING THE ANALYTICAL METHOD IS FOUND ON THE NEXT PAGES. THAT PAGES THAT FOLLOW THE ANALYTICAL SOLUTION CONTAIN THE SOLUTION TO ATTACHING A DRIVE DYAD TO THIS MECHANISM.

SUMMARY:

FOR THE ANALYTICAL SOLUTION IT IS IMPORTANT TO CORRECTLY IDENTIFY THE PARAMETERS THAT ARE GIVEN. ALTHOUGH NOT NEEDED IN THIS PROBLEM, A GRAPHICAL SOLUTION WILL HELP THE DESIGNER ASSIGN VALUES TO THE FREE CHOICES THAT ARE REQUIRED TO SOLVE THE PROBLEM ANALYTICALLY.

APPROACH B **FIRST DYAD**

GIVEN:		CHOSEN:		FIND:					x-coord	y-coord
P12	2.331	z	2	w	1.948			O2	1.281	0.896
δ2	35.29	ϕ	150	θ	-76.614			A1	1.732	-1.000
α2	-39	β2	30	W1x	0.451			A2	2.619	-0.521
				W1y	-1.896			P1	0.000	0.000
					x-coord	y-coord		P2	1.903	1.347
				W1	0.451	-1.896				
				W2	1.338	-1.416				
				Z1	-1.732	1.000				
				Z2	-0.717	1.867				

					inverse	
-0.133974596	-0.5	W1x	=	0.887337	-0.5	1.866025
0.5	-0.133974596	W1y		0.479493	-1.86603	-0.5

$$\begin{bmatrix}\cos(\beta_2)-1 & -\sin(\beta_2)\\ \sin(\beta_2) & \cos(\beta_2)-1\end{bmatrix}\begin{Bmatrix}W_{1x}\\ W_{1y}\end{Bmatrix}=\begin{Bmatrix}p_{21}\cdot\cos(\delta_2)-z\cdot[\cos(\phi+\alpha_2)-\cos(\phi)]\\ p_{21}\cdot\sin(\delta_2)-z\cdot[\sin(\phi+\alpha_2)-\sin(\phi)]\end{Bmatrix}$$

$$\begin{bmatrix}\cos(\beta_2)-1 & -\sin(\beta_2)\\ \sin(\beta_2) & \cos(\beta_2)-1\end{bmatrix}\begin{Bmatrix}W_{1x}\\ W_{1y}\end{Bmatrix}=\begin{Bmatrix}p_{21}\cdot\cos(\delta_2)-z\cdot[\cos\phi\cdot\cos\alpha_2-\sin\phi\cdot\sin\alpha_2-\cos(\phi)]\\ p_{21}\cdot\sin(\delta_2)-z\cdot[\sin\phi\cdot\cos\alpha_2+\cos\phi\cdot\sin\alpha_2-\sin(\phi)]\end{Bmatrix}$$

APPROACH B **SECOND DYAD**

GIVEN:		CHOSEN:		FIND:					x-coord	y-coord
P12	2.331	s	3	u	6.283			O4	-2.853	8.513
δ2	35.29	ψ	-50	σ	-81.542			B1	-1.928	2.298
α2	-39	γ2	40	U1x	0.924			B2	1.850	4.346
				U1y	-6.215			P1	0.000	0.000
					x-coord	y-coord		P2	1.903	1.347
				U1	0.9242	-6.2149				
				U2	4.7028	-4.1669				
				S1	1.9284	-2.2981				
				S2	0.0524	-2.9995				

					inverse	
-0.23396	-0.64279	U1x	=	3.778657	-0.5	1.373739
0.642788	-0.23396	U1y		2.048064	-1.37374	-0.5

$$\begin{bmatrix}\cos(\gamma_2)-1 & -\sin(\gamma_2)\\ \sin(\gamma_2) & \cos(\gamma_2)-1\end{bmatrix}\begin{Bmatrix}U_{1x}\\ U_{1y}\end{Bmatrix}=\begin{Bmatrix}p_{21}\cdot\cos(\delta_2)-s\cdot[\cos(\psi+\alpha_2)-\cos(\psi)]\\ p_{21}\cdot\sin(\delta_2)-s\cdot[\sin(\psi+\alpha_2)-\sin(\psi)]\end{Bmatrix}$$

$$\begin{bmatrix}\cos(\gamma_2)-1 & -\sin(\gamma_2)\\ \sin(\gamma_2) & \cos(\gamma_2)-1\end{bmatrix}\begin{Bmatrix}U_{1x}\\ U_{1y}\end{Bmatrix}=\begin{Bmatrix}p_{21}\cdot\cos(\delta_2)-s\cdot[\cos\psi\cdot\cos\alpha_2-\sin\psi\cdot\sin\alpha_2-\cos\psi]\\ p_{21}\cdot\sin(\delta_2)-s\cdot[\sin\psi\cdot\cos\alpha_2+\cos\psi\cdot\sin\alpha_2-\sin\psi]\end{Bmatrix}$$

SYNTHESIZED LINKAGE KINEMATICS

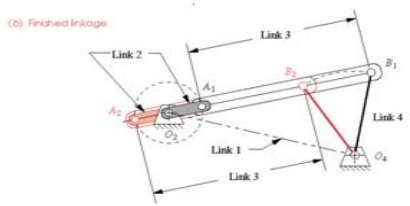
Angular Velocity	DL ω4–1 => ω2–1	10.000 1/s
	DL ω4–2 => ω2–2	10.000 1/s^2
	ω3-1	5.090 1/s
	ω3-2	0.386 1/s
	ω4-1	-15.281 1/s
	ω4-2	2.783 1/s
Angular Acceleration	DL α4–1 => α2–1	0.000
	DL α4–2 => α2–2	0.000
	α3-1	-437.439 1/s^2
	α3-2	-46.243 1/s^2
	α4-1	274.868 1/s^2
	α4-2	30.657 1/s^2

Kinematics						Normal (r)		Perpendicular (θ)	
		x comp	y comp	mag	angle	i	j	i	j
Displacements	G = r1	-4.134	7.618	8.667	118.5	-0.4769	0.8789	-0.8789	-0.4769
	U1 = r4-1	0.924	-6.215	6.283	-81.5	0.1471	-0.9891	0.9891	0.1471
	U2 = r4-2	4.703	-4.167	6.283	-41.5	0.7485	-0.6632	0.6632	0.7485
	W1 = r2-1	0.451	-1.896	1.948	-76.6	0.2315	-0.9728	0.9728	0.2315
	W2 = r2-2	1.338	-1.416	1.948	-46.6	0.6869	-0.7267	0.7267	0.6869
	V1 = r3-1	-3.660	3.298	4.927	138.0	-0.7429	0.6694	-0.6694	-0.7429
	V2 = r3-2	-0.769	4.867	4.927	99.0	-0.1561	0.9877	-0.9877	-0.1561
	Z1	-1.732	1.000	2.000	150.0	-0.8660	0.5000	-0.5000	-0.8660
	Z2	-0.717	1.867	2.000	111.0	-0.3584	0.9336	-0.9336	-0.3584
	S1	1.928	-2.298	3.000	-50.0	0.6428	-0.7660	0.7660	0.6428
	S2	0.052	-3.000	3.000	-89.0	0.0175	-0.9998	0.9998	0.0175
Velocity	vA-1	18.955	-177.365	178.375	-83.9	0.1063	-0.9943	0.9943	0.1063
	vA-2	14.160	-320.197	320.510	-87.5	0.0442	-0.9990	0.9990	0.0442
	vB-1	-94.971	-14.122	96.015	-171.5	-0.9891	-0.1471	0.1471	-0.9891
	vB-2	11.596	13.088	17.486	48.5	0.6632	0.7485	-0.7485	0.6632
	vP-1	13.865	-4.306	14.518	-17.3	0.9550	-0.2966	0.2966	0.9550
	vP-2	13.440	13.108	18.774	44.3	0.7159	0.6982	-0.6982	0.7159
Acceleration	aA-1	-45.108	189.554	194.847	103.4	-0.2315	0.9728	-0.9728	-0.2315
	aA-2	-133.841	141.605	194.847	133.4	-0.6869	0.7267	-0.7267	-0.6869
	aB-1	1492.476	1705.296	2266.169	48.8	0.6586	0.7525	-0.7525	0.6586
	aB-2	91.322	176.446	198.678	62.6	0.4596	0.8881	-0.8881	0.4596
	aB-P	437.214	921.307	1019.786	64.6	0.4287	0.9034	-0.9034	0.4287
	aB-P	-47.392	174.471	180.793	105.2	-0.2621	0.9650	-0.9650	-0.2621

NON-QUICK-RETURN (From Two-Position Approach B Results)

	X-pos	Y-pos	mag	angle	i	j
2P-O2 => O4	**1.28**	**0.90**	**1.56**	**35.0**	**0.8196**	**0.5730**
2P-A1	**1.73**	**-1.00**	**2.00**	**-30.0**	**0.8660**	**-0.5000**
2P-A2	**2.62**	**-0.52**	**2.67**	**-11.2**	**0.9808**	**-0.1949**

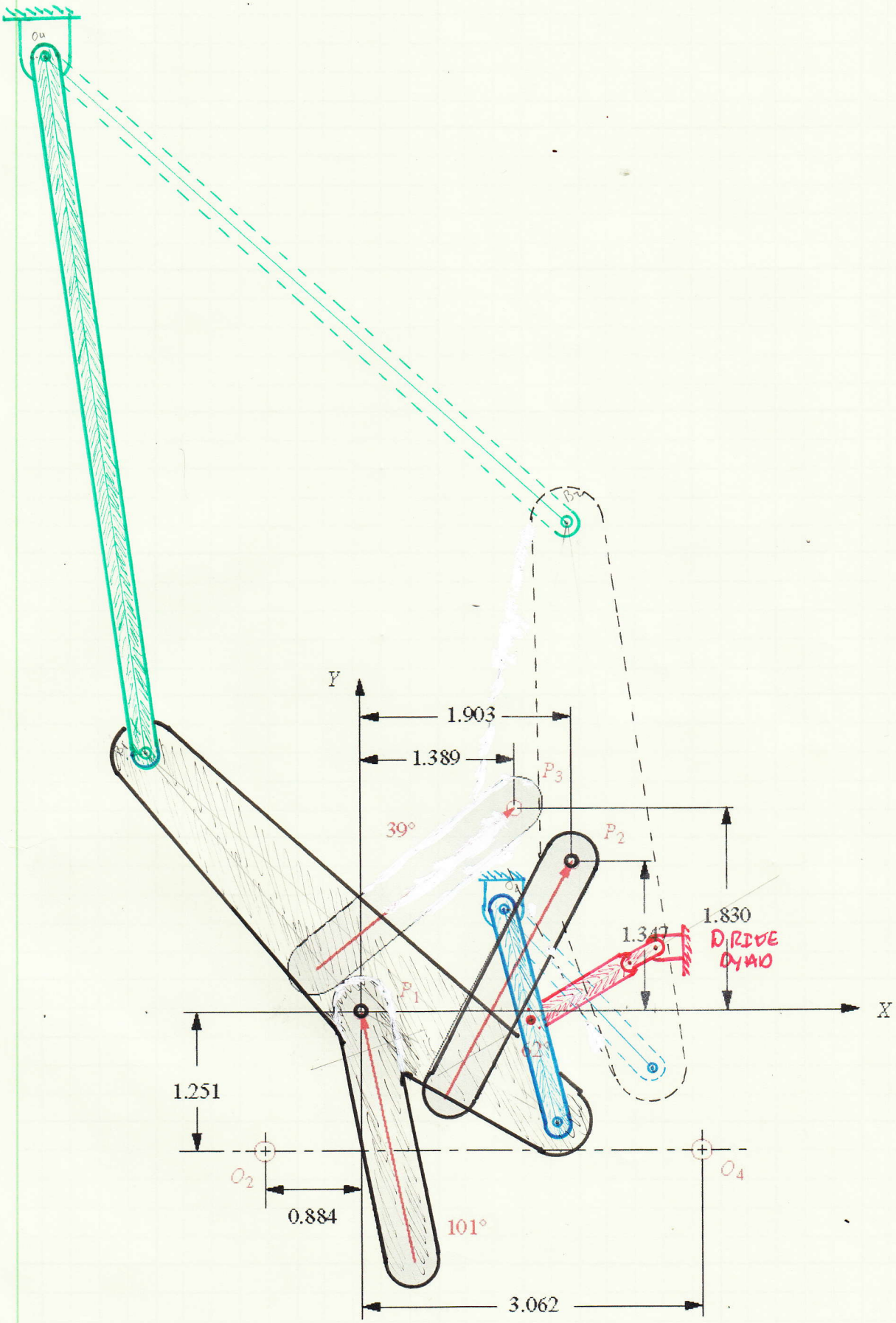
Factors		
P	0.5	**% dist up Link 4**
K	2.5	**Length of Link 3+Link 2 wrt B1B2**
Link 1	**1.38**	
Link 2	**0.25**	
Link 3	**1.01**	
Link 4	**0.97**	**Grashof**



$\dot{\theta}_2$ =	1.0470 1/s
$\ddot{\theta}_2$ =	0.0000 1/s^2
ω3-1	-0.2618 1/s
ω3-2	0.2618 1/s
ω4-1	0.0000 1/s
ω4-2	0.0000 1/s
α3-1	0.0918 1/s^2
α3-2	0.0551 1/s^2
α4-1	0.3672 1/s^2
α4-2	-0.2203 1/s^2

					Normal (r)		Perpendicular (θ)	
	x comp	**y comp**	**mag**	**angle**	**i**	**j**	**i**	**j**
rO4	**1.28**	**0.90**	**1.56**	**35.0**	**0.8196**	**0.5730**	**-0.5730**	**0.8196**
rP2O2-A1	0.45	-1.90	1.95	-76.6	0.2315	-0.9728	0.9728	0.2315
rP2O2-A2	1.34	-1.42	1.95	-46.6	0.6869	-0.7267	0.7267	0.6869
rB1	**1.51**	**-0.05**	**1.51**	**-2.0**	**0.9994**	**-0.0346**	**0.0346**	**0.9994**
rO4B1	0.23	-0.95	0.97	-76.6	0.2315	-0.9728	0.9728	0.2315
rB2	**1.95**	**0.19**	**1.96**	**5.5**	**0.9954**	**0.0957**	**-0.0957**	**0.9954**
rO4B2	0.67	-0.71	0.97	-46.6	0.6869	-0.7267	0.7267	0.6869
rB1B2	0.44	0.24	0.50	28.4	0.8798	0.4754	-0.4754	0.8798
rO2	**2.62**	**0.55**	**2.67**	**11.8**	**0.9788**	**0.2047**	**-0.2047**	**0.9788**
rB102	1.11	0.60	1.26	28.4	0.8798	0.4754	-0.4754	0.8798
rA1	**2.39**	**0.43**	**2.43**	**10.1**	**0.9844**	**0.1757**	**-0.1757**	**0.9844**
rO2A1	-0.22	-0.12	0.25	-151.6	-0.8798	-0.4754	0.4754	-0.8798
rA2	**2.84**	**0.67**	**2.91**	**13.2**	**0.9735**	**0.2288**	**-0.2288**	**0.9735**
rO2A2	0.22	0.12	0.25	28.4	0.8798	0.4754	-0.4754	0.8798
rB1A1	0.89	0.48	1.01	28.4	0.8798	0.4754	-0.4754	0.8798
rB2A2	0.89	0.48	1.01	28.4	0.8798	0.4754	-0.4754	0.8798
rO4O2	1.33	-0.35	1.38	-14.6	0.9676	-0.2526	0.2526	0.9676

Kinematics					Normal (r)		Perpendicular (θ)	
	x comp	**y comp**	**mag**	**angle**	**i**	**j**	**i**	**j**
r1	-1.33	0.35	1.38	165.4	-0.9676	0.2526	-0.2526	-0.9676
r4-1	0.23	-0.95	0.97	-76.6	0.2315	-0.9728	0.9728	0.2315
r4-2	0.67	-0.71	0.97	-46.6	0.6869	-0.7267	0.7267	0.6869
r2-1	-0.22	-0.12	0.25	-151.6	-0.8798	-0.4754	0.4754	-0.8798
r2-2	0.22	0.12	0.25	28.4	0.8798	0.4754	-0.4754	0.8798
r3-1	-0.89	-0.48	1.01	-151.6	-0.8798	-0.4754	0.4754	-0.8798
r3-2	-0.89	-0.48	1.01	-151.6	-0.8798	-0.4754	0.4754	-0.8798
vA-1	0.13	-0.23	0.26	-61.6	0.4754	-0.8798	0.8798	0.4754
vA-2	-0.13	0.23	0.26	118.4	-0.4754	0.8798	-0.8798	-0.4754
vB-1	0.00	0.00	0.00	undefined	undefind	undefind	undefind	undefind
vB-2	0.00	0.00	0.00	undefined	undefind	undefind	undefind	undefind
aA-1	0.24	0.13	0.28	28.4	0.8798	0.4754	-0.4754	0.8798
aA-2	-0.24	-0.13	0.28	-151.6	-0.8798	-0.4754	0.4754	-0.8798
aB-1	0.35	0.08	0.36	13.4	0.9728	0.2315	-0.2315	0.9728
aB-2	-0.16	-0.15	0.21	-136.6	-0.7267	-0.6869	0.6869	-0.7267


Y
X
1.903
1.389
1.830
1.347
DRIVE DYAD
1.251
0.884
3.062
39°
101°
P_1
P_2
P_3
O_2
O_4