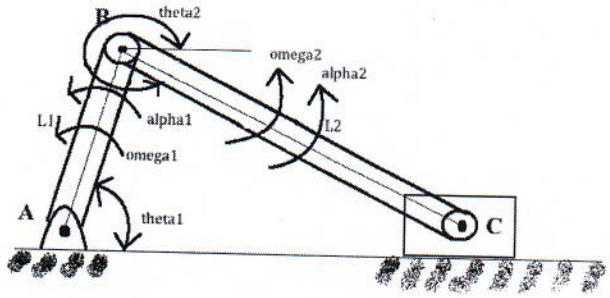
PROBLEM STATEMENT

FOR THE GIVEN MECHANISM, DERIVE EQUATIONS FOR $\overrightarrow{V_B}, \overrightarrow{V_C}, \omega_2, \alpha_2, \overrightarrow{a_B}$, AND $\overrightarrow{a_C}$ IN TERMS OF $l_1, l_2, \theta_1, \theta_2, \omega_1$, AND α_1. THEN, DEVELOP A SPREADSHEET TO CALCULATE VALUES FOR THE TIME, $t, \theta_2, V_{Bx}, V_{By}, V_B, V_C, \omega_2, a_{Bx}, a_{By}, a_B, a_C, \alpha_2, a_{CG1x}, a_{CG1y}, a_{CG2x}, a_{CG2y,}$ THE REACTION FORCES PRODUCED BY THE PINS A_x, A_y, B_x, B_y, C_x, AND C_y, THE NORMAL FORCE, N, THE FRICTION BETWEEN THE BLOCK AND SURFACE, f, AND THE TORQUE EXERTED BY A MOTOR AT A, T. FOR THE SPREADSHEET, USE THE FOLLOWING PARAMETERS: $l_1 = 5cm, l_2 = 15cm, \omega_1 = 4t\ \frac{rad}{s}, \overrightarrow{V_A} = 0, \overrightarrow{a_A} = 0, \mu_K = 0.1$ AND θ_1 GOING FROM 0^0 TO 360^0 IN 3^0 INCREMENTS. ALSO, USE THE SPREADSHEET TO PLOT LINE GRAPHS CHARTING θ_1 VS θ_2, V_B VS θ_1, V_C VS θ_1, a_{Bx} AND a_{By} VS θ_1, AND a_C VS θ_1.

GIVEN



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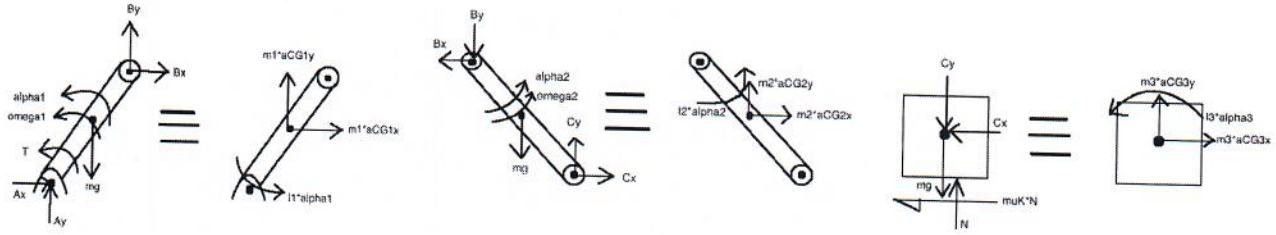

$l_1 = 5cm$ $l_2 = 15cm$ $\omega_1 = 4t\ \frac{rad}{s}$ $\overrightarrow{V_A} = 0$ $\overrightarrow{a_A} = 0$

$\theta_1 = 0^0, 3^0, 6^0 \ldots 360^0$ $\mu_K = 0.1$ $\alpha_1 = 4\frac{rad}{s*s}$

$m_1 = 10kg$ $m_2 = 50kg$ $m_3 = 3kg$

FIND

DERIVATIONS FOR $\overrightarrow{V_B}, \overrightarrow{V_C}, \omega_2, \alpha_2, \overrightarrow{a_B}$, AND $\overrightarrow{a_C}$.
A SPREADSHEET CALCULATING VALUES:
$t, \theta_2, V_{Bx}, V_{By}, V_B, V_C, \omega_2, a_{Bx}, a_{By}, a_B, a_C, \alpha_2, a_{CG1x}, a_{CG1y}, a_{CG2x}, a_{CG2y,}$ THE REACTION FORCES A_x, A_y, B_x, B_y, C_x, AND C_y PRODUCED BY THE PINS, THE NORMAL FORCE, N, FRICTION, f, AND THE TORQUE EXERTED BY A MOTOR AT A, T.
LINE GRAPHS CHARTING θ_1 VS θ_2, V_B VS θ_1, V_C VS θ_1, a_{Bx} AND a_{By} VS θ_1, AND a_C VS θ_1.

THEORY

THE KINEMATICS AND KINETICS OF MOTION FOR A MECHANISM

EQUATIONS

$$\overrightarrow{V_B} = \overrightarrow{V_A} + \overrightarrow{V_{B/A}} = \overrightarrow{V_A} + \overrightarrow{\omega_1} X \overrightarrow{r_1}$$
$$V_{Bx} = V_B\,\vec{\imath} \qquad V_{By} = V_B\,\vec{\jmath}$$
$$\overrightarrow{V_B} = \sqrt{{V_{Bx}}^2 + {V_{By}}^2}$$
$$\overrightarrow{r_1} = l_1 \cos\theta_1\,\vec{\imath} + l_1 \sin\theta_1\,\vec{\jmath}$$

$$\overrightarrow{V_C} = \overrightarrow{V_B} + \overrightarrow{V_{C/B}} = \overrightarrow{V_B} + \overrightarrow{\omega_2} X \overrightarrow{r_2}$$
$$V_{Cx} = V_C\,\vec{\imath} \qquad V_{Cy} = V_C\,\vec{\jmath} = 0$$

$$\overrightarrow{r_2} = l_2 \cos\theta_2\,\vec{\imath} + l_2 \sin\theta_2\,\vec{\jmath}$$

$$\overrightarrow{a_B} = \overrightarrow{a_A} + \overrightarrow{a_{B/A}} = \overrightarrow{a_A} + \overrightarrow{\alpha_1} X \overrightarrow{r_1} - \omega_1^2 \overrightarrow{r_1}$$
$$a_{Bx} = a_B\,\vec{\imath} \qquad a_{By} = a_B\,\vec{\jmath}$$
$$\overrightarrow{a_B} = \sqrt{{a_{Bx}}^2 + {a_{By}}^2}$$

$$\overrightarrow{a_C} = \overrightarrow{a_B} + \overrightarrow{a_{C/B}} = \overrightarrow{a_B} + \overrightarrow{\alpha_2} X \overrightarrow{r_2} - \omega_2^2 \overrightarrow{r_2}$$

$$a_{CG1x} = \frac{a_{Ax}+a_{Bx}}{2}$$

$$a_{CG2x} = \frac{a_{Bx}+a_{Cx}}{2}$$

$$a_{CG1y} = \frac{a_{Ay}+a_{By}}{2}$$

$$a_{CG2y} = \frac{a_{By}+a_{Cy}}{2}$$

$$a_{CG3x} = a_C\,\vec{\imath}$$
$$a_{CG3y} = a_C\,\vec{\jmath} = 0$$

$$\sum F_{x1} = B_x - A_x = m_1 a_{CG1x}$$
$$\sum F_{y1} = B_y + A_y = m_1 a_{CG1y} + m_1 g$$
$$\sum M_{CG1} = I_{CG1}\alpha_1 = (-A_y + B_y)\left(\frac{l_1}{2}\cos\theta_1\right) - (A_x + B_x)\left(\frac{l_1}{2}\sin\theta_1\right) + T$$
$$\sum F_{x2} = -B_x + C_x = m_2 a_{CG2x}$$
$$\sum F_{y2} = -B_y + C_y = m_2 a_{CG2y} + m_2 g$$
$$\sum M_{CG2} = I_{CG2}\alpha_2 = (C_y + B_y)\left(\frac{l_2}{2}\cos\theta_2\right) + (C_x + B_x)\left(\frac{l_2}{2}\sin\theta_2\right)$$

$$\sum F_{x3} = -C_x - \mu_K N = m_3 a_{CG3x}$$
$$\sum F_{y3} = -C_y + N = m_3 a_{CG3y} + m_3 g = 0$$
$$f = \mu_K N$$

ASSUMPTIONS

THE SYSTEM IS COMPOSED OF PERFECTLY RIGID BODIES.
ALL SYSTEM MEMBERS ARE UNIFORM.
POSITIVE MOMENTS AND RADIAL KINEMATIC VALUES ARE MEASURED CCW FROM THE POSITIVE X-AXIS.
THERE IS NO Y-COMPONENT TO THE MOTION AT C.
THE BLOCK AT C IS A PERFECT CUBE.
THERE IS NO ROTATIONAL MOTION IN THE BLOCK AT C.
THERE IS NO FRICTION IN THE PINS AT A, B, OR C.

SOLUTION

$$\overrightarrow{V_B} = l_1\omega_1 \cos\theta_1\,\vec{j} - l_1\omega_1 \sin\theta_1\vec{\imath}$$

$$V_B\vec{\imath} = -l_1\omega_1 \sin\theta_1 = V_{Bx}$$
$$V_B\vec{j} = -l_1\omega_1 \cos\theta_1 = V_{By}$$

$$\overrightarrow{V_B} = \sqrt{{V_{Bx}}^2 + {V_{By}}^2}$$

$$\overrightarrow{V_C} = l_1\omega_1 \cos\theta_1\,\vec{j} - l_1\omega_1 \sin\theta_1\vec{\imath} + l_2\omega_2 \cos\theta_2\,\vec{j} - l_2\omega_2 \sin\theta_2\vec{\imath}$$
$$V_C\vec{\imath} = -(l_1\omega_1 \sin\theta_1 + l_2\omega_2 \sin\theta_2) = V_{Cx}$$
$$V_C\vec{j} = 0 = (l_1\omega_1 \cos\theta_1 + l_2\omega_2 \cos\theta_2) = V_{Cy}$$

$$\omega_2 = -\frac{\omega_1 l_1 \cos\theta_1}{l_2 \cos\theta_2}$$

$$V_{Cx} = \overrightarrow{V_C}$$

$$\overrightarrow{a_B} = l_1\alpha_1 \cos\theta_1\,\vec{j} - l_1\alpha_1 \sin\theta_1\vec{\imath} - l_1\omega_1^2 \cos\theta_1\vec{\imath} - \omega_1^2 l_1 \sin\theta_1\vec{j}$$

$$a_B\vec{\imath} = -(l_1\alpha_1 \sin\theta_1 + l_1\omega_1^2 \cos\theta_1) = a_{Bx}$$
$$a_B\vec{j} = (l_1\alpha_1 \cos\theta_1 - \omega_1^2 l_1 \sin\theta_1) = a_{By}$$

$$\overrightarrow{a_C} = l_1\alpha_1 \cos\theta_1\,\vec{j} - l_1\alpha_1 \sin\theta_1\vec{\imath} - l_1\omega_1^2 \cos\theta_1\vec{\imath} - \omega_1^2 l_1 \sin\theta_1\vec{j} - \omega_2^2(l_2 \cos\theta_2\,\vec{\imath} + l_2 \sin\theta_2\,\vec{j}) + l_s\alpha_2 \cos\theta_2\,\vec{j} - l_2\alpha_2 \sin\theta_2\vec{\imath}$$
$$a_C\vec{\imath} = -(l_1\alpha_1 \sin\theta_1 + l_1\omega_1^2 \cos\theta_1 + \omega_2^2 l_2 \cos\theta_2 + l_2\alpha_2 \sin\theta_2) = a_{Cx}$$
$$a_C\vec{j} = 0 = (l_1\alpha_1 \cos\theta_1 - l_2\omega_1^2 \sin\theta_1 - l_2\omega_2^2 \sin\theta_2 + l_s\alpha_2 \cos\theta_2) = a_{Cy}$$

$$\alpha_2 = -\frac{\alpha_1 l_1 \cos\theta_1 + \omega_1^2 l_1 \sin\theta_1 + l_2\omega_2^2 \sin\theta_2}{l_2 \cos\theta_2}$$

$$a_{Cx} = \overrightarrow{a_C}$$

$$\sum F_{x3}: C_x = -\mu_K N - m_3 a_{CG3x}$$

$$\sum F_{y3}: C_y = N - m_3 g$$

$$\sum F_{x2}: B_x = C_x - m_2 a_{CG2x}$$

$$\sum F_{y2}: B_y = C_y - m_2 a_{CG2y} - m_2 g$$

$$\sum M_{CG2}: I_{CG2}\alpha_2 = (C_y + B_y)(\frac{l_2}{2}\cos\theta_2) + (C_x + B_x)(\frac{l_2}{2}\sin\theta_2)$$

$$: I_{CG2}\alpha_2 = (N - m_3 g + C_y - m_2 a_{CG2y} - m_2 g)(\tfrac{l_2}{2}\cos\theta_2) + (-\mu_K N - m_3 a_{CG3x} + C_x - - m_2 a_{CG2x})(\tfrac{l_2}{2}\sin\theta_2)$$

$$: N = \frac{I_{CG2}\alpha_2 + (\frac{l_2}{2}\cos\theta_2)[2m_3 g + m_2 g + m_2 a_{CG2y}] + (\frac{l_2}{2}\sin\theta_2)[2m_3 a_{CG3x} + m_2 a_{CG2x}]}{(l_2\cos\theta_2 - \mu_K l_2 \sin\theta_2)}$$

$$C_x = -\mu_K N - m_3 a_{CG3x}$$

$$C_y = N - m_3 g$$

$$B_x = C_x - m_2 a_{CG2x}$$

$$B_y = C_y - m_2 a_{CG2y} - m_2 g$$

$$\sum F_{x1}: A_x = B_x - m_1 a_{CG1x}$$

$$\sum F_{y1}: A_y = m_1 a_{CG1y} + m_1 g - B_y$$

$$\sum M_{CG1}: T = I_{CG1}\alpha_1 - (-A_y + B_y)(\frac{l_1}{2}\cos\theta_1) + (A_x + B_x)(\frac{l_1}{2}\sin\theta_1)$$

$$f = \mu_K N$$

ENGR
2120-01

PROJECT #1

08/05/13

[redacted]

θ1	t	θ2	VBx	VBy	VB	VC	ω2	aBx	aBy	aB	aC	α2	aCG1x	aCG1y	aCG2x	aCG2y	Ax	Ay	Bx	By	Cx	Cy	N	f	T
(deg)	(sec)	(deg)	(m/s)	(m/s)	(m/s)	(m/s)	(rad/s)	(m/s*s)	(m/s*s)	(m/s*s)	(m/s*s)	(rad/s*s)	(m/s*s)	(m/s*s)	(m/s*s)	(m/s*s)	(N)	(N)	(N)	(N)	(N)	(N)	(N)	(N)	(N*m)
0	0.000	0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.200	0.200	0.000	-1.333	0.000	0.100	0.000	0.100	27.781	148.025	27.781	247.125	27.781	248.375	277.805	27.781	2.475
3	0.162	-1.0	-0.002	0.032	0.032	-0.002	-0.215	-0.031	0.199	0.201	-0.042	-1.325	-0.016	0.099	-0.037	0.099	29.594	148.480	29.437	247.573	27.607	247.892	277.322	27.732	2.395
6	0.229	-2.0	-0.005	0.046	0.046	-0.006	-0.304	-0.063	0.195	0.204	-0.083	-1.301	-0.031	0.097	-0.073	0.097	31.391	148.877	31.078	247.949	27.435	247.414	276.844	27.684	2.298
9	0.280	-3.0	-0.009	0.055	0.056	-0.012	-0.370	-0.093	0.188	0.210	-0.124	-1.260	-0.047	0.094	-0.109	0.094	33.158	149.214	32.691	248.253	27.266	246.940	276.370	27.637	2.186
12	0.324	-4.0	-0.013	0.063	0.065	-0.018	-0.423	-0.124	0.178	0.217	-0.163	-1.203	-0.062	0.089	-0.143	0.089	34.878	149.494	34.260	248.485	27.102	246.470	275.900	27.590	2.059
15	0.362	-4.9	-0.019	0.070	0.072	-0.025	-0.468	-0.153	0.166	0.226	-0.200	-1.130	-0.076	0.083	-0.177	0.083	36.536	149.719	35.771	248.650	26.943	246.003	275.433	27.543	1.919
18	0.396	-5.9	-0.024	0.075	0.079	-0.032	-0.505	-0.181	0.151	0.236	-0.235	-1.041	-0.091	0.076	-0.208	0.076	38.117	149.892	37.210	248.749	26.790	245.536	274.966	27.497	1.766
21	0.428	-6.9	-0.031	0.080	0.086	-0.040	-0.537	-0.209	0.134	0.248	-0.268	-0.936	-0.104	0.067	-0.238	0.067	39.607	150.016	38.564	248.787	26.645	245.068	274.498	27.450	1.603
24	0.458	-7.8	-0.037	0.084	0.092	-0.049	-0.563	-0.234	0.115	0.261	-0.298	-0.814	-0.117	0.057	-0.266	0.057	40.991	150.095	39.819	248.768	26.509	244.596	274.026	27.403	1.430
27	0.485	-8.7	-0.044	0.087	0.097	-0.057	-0.583	-0.259	0.093	0.275	-0.325	-0.677	-0.129	0.046	-0.292	0.046	42.258	150.135	40.964	248.698	26.381	244.118	273.548	27.355	1.249
30	0.512	-9.6	-0.051	0.089	0.102	-0.066	-0.599	-0.281	0.068	0.290	-0.348	-0.524	-0.141	0.034	-0.314	0.034	43.394	150.140	41.987	248.583	26.263	243.630	273.060	27.306	1.062
33	0.537	-10.5	-0.058	0.090	0.107	-0.075	-0.610	-0.302	0.042	0.305	-0.367	-0.355	-0.151	0.021	-0.334	0.021	44.389	150.116	42.878	248.428	26.156	243.129	272.559	27.256	0.871
36	0.560	-11.3	-0.066	0.091	0.112	-0.084	-0.617	-0.321	0.014	0.321	-0.382	-0.172	-0.160	0.007	-0.351	0.007	45.231	150.070	43.627	248.240	26.059	242.612	272.042	27.204	0.678
39	0.583	-12.1	-0.073	0.091	0.117	-0.093	-0.618	-0.337	-0.016	0.338	-0.393	0.027	-0.169	-0.008	-0.365	-0.008	45.913	150.006	44.226	248.026	25.973	242.076	271.506	27.151	0.484
42	0.605	-12.9	-0.081	0.090	0.121	-0.102	-0.615	-0.352	-0.048	0.355	-0.399	0.239	-0.176	-0.024	-0.375	-0.024	46.427	149.930	44.669	247.792	25.898	241.518	270.948	27.095	0.292
45	0.627	-13.6	-0.089	0.089	0.125	-0.110	-0.608	-0.364	-0.081	0.372	-0.401	0.464	-0.182	-0.040	-0.382	-0.040	46.766	149.849	44.949	247.545	25.834	240.937	270.367	27.037	0.104
48	0.647	-14.3	-0.096	0.087	0.129	-0.118	-0.596	-0.373	-0.115	0.390	-0.398	0.702	-0.186	-0.058	-0.386	-0.058	46.926	149.768	45.062	247.292	25.781	240.328	269.758	26.976	0.080
51	0.667	-15.0	-0.104	0.084	0.133	-0.126	-0.580	-0.379	-0.151	0.408	-0.391	0.951	-0.190	-0.075	-0.385	-0.075	46.904	149.691	45.006	247.037	25.739	239.692	269.122	26.912	0.256
54	0.686	-15.6	-0.111	0.081	0.137	-0.134	-0.559	-0.383	-0.187	0.427	-0.380	1.210	-0.192	-0.094	-0.381	-0.094	46.697	149.624	44.780	246.787	25.707	239.028	268.458	26.846	0.424
57	0.705	-16.2	-0.118	0.077	0.141	-0.141	-0.533	-0.384	-0.225	0.445	-0.363	1.478	-0.192	-0.112	-0.374	-0.112	46.307	149.570	44.384	246.546	25.686	238.334	267.764	26.776	0.583
60	0.724	-16.8	-0.125	0.072	0.145	-0.147	-0.504	-0.383	-0.263	0.464	-0.343	1.753	-0.191	-0.131	-0.363	-0.131	45.734	149.532	43.821	246.318	25.675	237.613	267.043	26.704	0.731
63	0.741	-17.3	-0.132	0.067	0.148	-0.153	-0.470	-0.378	-0.301	0.483	-0.319	2.033	-0.189	-0.151	-0.348	-0.151	44.982	149.513	43.093	246.108	25.673	236.865	266.295	26.629	0.868
66	0.759	-17.7	-0.139	0.062	0.152	-0.158	-0.432	-0.370	-0.340	0.502	-0.291	2.317	-0.185	-0.170	-0.331	-0.170	44.057	149.515	42.206	245.917	25.679	236.093	265.523	26.552	0.992
69	0.776	-18.1	-0.145	0.056	0.155	-0.163	-0.390	-0.359	-0.378	0.522	-0.260	2.602	-0.180	-0.189	-0.309	-0.189	42.964	149.537	41.168	245.747	25.694	235.302	264.732	26.473	1.104
72	0.793	-18.5	-0.151	0.049	0.159	-0.167	-0.344	-0.346	-0.416	0.541	-0.225	2.886	-0.173	-0.208	-0.285	-0.208	41.712	149.581	39.984	245.600	25.717	234.494	263.924	26.392	1.203
75	0.809	-18.8	-0.156	0.042	0.162	-0.171	-0.295	-0.329	-0.454	0.560	-0.188	3.167	-0.164	-0.227	-0.258	-0.227	40.310	149.644	38.666	245.474	25.746	233.676	263.106	26.311	1.289
78	0.825	-19.0	-0.161	0.034	0.165	-0.173	-0.242	-0.309	-0.491	0.580	-0.149	3.443	-0.154	-0.246	-0.229	-0.246	38.767	149.725	37.222	245.370	25.782	232.854	262.284	26.228	1.363
81	0.841	-19.2	-0.166	0.026	0.168	-0.175	-0.186	-0.286	-0.527	0.600	-0.108	3.710	-0.143	-0.264	-0.197	-0.264	37.095	149.822	35.665	245.286	25.823	232.033	261.463	26.146	1.425
84	0.856	-19.4	-0.170	0.018	0.171	-0.177	-0.126	-0.260	-0.562	0.620	-0.065	3.968	-0.130	-0.281	-0.163	-0.281	35.305	149.931	34.004	245.220	25.870	231.223	260.653	26.065	1.476
87	0.871	-19.4	-0.174	0.009	0.174	-0.177	-0.064	-0.232	-0.596	0.639	-0.022	4.213	-0.116	-0.298	-0.127	-0.298	33.410	150.049	32.252	245.169	25.921	230.429	259.859	25.986	1.517
90	0.886	-19.5	-0.177	0.000	0.177	-0.177	0.000	-0.200	-0.628	0.659	0.022	4.443	-0.100	-0.314	-0.089	-0.314	31.422	150.172	30.422	245.131	25.976	229.661	259.091	25.909	1.548
93	0.901	-19.4	-0.180	-0.009	0.180	-0.177	0.067	-0.166	-0.659	0.679	0.066	4.656	-0.083	-0.329	-0.050	-0.329	29.353	150.297	28.525	245.102	26.034	228.927	258.357	25.836	1.571
96	0.915	-19.4	-0.182	-0.019	0.183	-0.175	0.135	-0.129	-0.687	0.699	0.110	4.851	-0.064	-0.344	-0.010	-0.344	27.216	150.417	26.572	245.080	26.096	228.234	257.664	25.766	1.587
99	0.929	-19.2	-0.184	-0.029	0.186	-0.173	0.205	-0.089	-0.714	0.720	0.153	5.026	-0.045	-0.357	0.032	-0.357	25.023	150.531	24.576	245.062	26.160	227.590	257.020	25.702	1.596
102	0.943	-19.0	-0.185	-0.039	0.189	-0.171	0.277	-0.048	-0.738	0.740	0.195	5.179	-0.024	-0.369	0.074	-0.369	22.784	150.634	22.546	245.043	26.228	227.004	256.434	25.643	1.601
105	0.957	-18.8	-0.185	-0.050	0.191	-0.168	0.349	-0.003	-0.760	0.760	0.236	5.309	-0.002	-0.380	0.116	-0.380	20.511	150.722	20.493	245.023	26.298	226.482	255.912	25.591	1.602
108	0.971	-18.5	-0.185	-0.060	0.194	-0.165	0.422	0.043	-0.779	0.780	0.275	5.416	0.021	-0.389	0.159	-0.389	18.213	150.792	18.426	244.998	26.371	226.030	255.460	25.546	1.601
111	0.984	-18.1	-0.184	-0.071	0.197	-0.161	0.495	0.091	-0.795	0.800	0.313	5.498	0.045	-0.398	0.202	-0.398	15.899	150.841	16.354	244.966	26.447	225.656	255.086	25.509	1.598
114	0.997	-17.7	-0.182	-0.081	0.199	-0.156	0.568	0.141	-0.808	0.821	0.349	5.555	0.071	-0.404	0.245	-0.404	13.579	150.868	14.284	244.926	26.525	225.364	254.794	25.479	1.595
117	1.010	-17.3	-0.180	-0.092	0.202	-0.152	0.641	0.193	-0.819	0.841	0.383	5.587	0.096	-0.409	0.288	-0.409	11.259	150.869	12.222	244.876	26.607	225.159	254.589	25.459	1.592
120	1.023	-16.8	-0.177	-0.102	0.205	-0.146	0.713	0.246	-0.826	0.861	0.415	5.595	0.123	-0.413	0.330	-0.413	8.947	150.844	10.175	244.816	26.693	225.046	254.476	25.448	1.591
123	1.036	-16.2	-0.174	-0.113	0.207	-0.141	0.784	0.300	-0.829	0.882	0.445	5.578	0.150	-0.415	0.373	-0.415	6.648	150.792	8.148	244.746	26.782	225.026	254.456	25.446	1.592
126	1.049	-15.6	-0.170	-0.123	0.210	-0.135	0.853	0.355	-0.829	0.902	0.474	5.537	0.178	-0.415	0.415	-0.415	4.368	150.711	6.144	244.665	26.875	225.105	254.535	25.453	1.595
129	1.061	-15.0	-0.165	-0.134	0.212	-0.129	0.922	0.411	-0.825	0.923	0.501	5.472	0.206	-0.413	0.456	-0.413	2.113	150.602	4.169	244.574	26.974	225.283	254.713	25.471	1.603
132	1.073	-14.3	-0.160	-0.144	0.215	-0.123	0.988	0.468	-0.819	0.943	0.526	5.384	0.234	-0.409	0.497	-0.409	0.114	150.465	2.226	244.472	27.077	225.562	254.992	25.499	1.618
135	1.085	-13.6	-0.153	-0.153	0.217	-0.116	1.053	0.525	-0.808	0.963	0.550	5.273	0.263	-0.404	0.537	-0.404	2.309	150.300	0.316	244.361	27.187	225.943	255.373	25.537	1.711
138	1.097	-12.9	-0.147	-0.163	0.219	-0.110	1.115	0.582	-0.793	0.984	0.572	5.141	0.291	-0.397	0.577	-0.397	1.355	150.108	1.556	244.241	27.302	226.427	255.857	25.586	1.800
141	1.109	-12.1	-0.140	-0.172	0.222	-0.103	1.176	0.639	-0.775	1.004	0.593	4.987	0.320	-0.387	0.616	-0.387	0.193	149.888	3.388	244.114	27.424	227.014	256.444	25.644	1.889
144	1.121	-11.3	-0.132	-0.181	0.224	-0.096	1.233	0.696	-0.753	1.025	0.614	4.813	0.348	-0.376	0.655	-0.376	1.700	149.643	5.179	243.979	27.554	227.703	257.133	25.713	2.011
147	1.133	-10.5	-0.123	-0.190	0.227	-0.088	1.288	0.752	-0.727	1.046	0.633	4.620	0.376	-0.363	0.692	-0.363	3.167	149.372	6.925	243.839	27.691	228.495	257.925	25.792	2.120
150	1.144	-9.6	-0.114	-0.198	0.229	-0.081	1.340	0.807	-0.697	1.066	0.652	4.408	0.403	-0.348	0.729	-0.348	4.591	149.077	8.626	243.693	27.836	229.387	258.817	25.882	2.216
153	1.155	-8.7	-0.105	-0.206	0.231	-0.073	1.389	0.861	-0.663	1.087	0.670	4.177	0.430	-0.332	0.765	-0.332	5.973	148.759	10.277	243.543	27.990	230.379	259.809	25.981	2.298
156	1.167	-7.8	-0.095	-0.213	0.233	-0.066	1.434	0.914	-0.626	1.107	0.688	3.929	0.457	-0.313	0.801	-0.313	7.311	148.418	11.879	243.390	28.153	231.468	260.898	26.090	2.366
159	1.178	-6.9	-0.084	-0.220	0.236	-0.058	1.477	0.965	-0.585	1.128	0.705	3.662	0.482	-0.292	0.835	-0.292	8.604	148.056	13.427	243.234	28.325	232.653	262.083	26.208	2.421
162	1.189	-5.9	-0.073	-0.226	0.238	-0.050	1.516	1.014	-0.540	1.149	0.723	3.379	0.507	-0.270	0.869	-0.270	9.851	147.674	14.920	243.076	28.506	233.932	263.362	26.336	2.462
165	1.200	-4.9	-0.062	-0.232	0.240	-0.042	1.551	1.061	-0.491	1.169	0.741	3.079	0.530	-0.246	0.901	-0.246	11.051	147.273	16.355	242.917	28.696	235.300	264.730	26.473	2.489
168	1.211	-4.0	-0.050	-0.237	0.242	-0.034	1.583	1.106	-0.439	1.190	0.759	2.763	0.553	-0.220	0.933	-0.220	12.202	146.854	17.730	242.757	28.897	236.756	266.186	26.619	2.503
171	1.222	-3.0	-0.038	-0.241	0.244	-0.026	1.611	1.148	-0.384	1.210	0.778	2.430	0.574	-0.192	0.963	-0.192	13.302	146.419	19.041	242.597	29.107	238.295	267.725	26.773	2.503
174	1.232	-2.0	-0.026	-0.245	0.246	-0.017	1.635	1.187	-0.326	1.231	0.797	2.081	0.594	-0.163	0.992	-0.163	14.351	145.968	20.286	242.438	29.326	239.915	269.345	26.934	2.491
177	1.243	-1.0	-0.013	-0.248	0.249	-0.009	1.655	1.224	-0.264	1.252	0.817	1.715	0.612	-0.132	1.020	-0.132	15.345	145.503	21.463	242.281	29.556	241.609	271.039	27.104	2.466
180	1.253	0.0	0.000	-0.251	0.251	0.000	1.671	1.257	-0.200	1.272	0.838	1.333	0.628	-0.100	1.047	-0.100	16.283	145.025	22.566	242.125	29.794	243.375	272.805	27.281	2.430
183	1.264	1.0	0.013	-0.252	0.253	0.009	1.683	1.286	-0.133	1.293	0.859	0.935	0.643	-0.066	1.073	-0.066	17.162	144.536	23.594	241.972	30.041	245.206	274.636	27.464	2.381
186	1.274	2.0	0.027	-0.253	0.255	0.018	1.690	1.312	-0.063	1.314	0.881	0.521	0.656	-0.032	1.097	-0.032	17.980	144.039	24.542	241.823	30.296	247.098	276.528	27.653	2.322
189	1.284	3.0	0.040	-0.254	0.257	0.027	1.694	1.335	0.009	1.335	0.904	0.091	0.667	0.004	1.119	0.004	18.734	143.534	25.407	241.678	30.560	249.044	278.474	27.847	2.253
192	1.294	4.0	0.054	-0.253	0.259	0.036	1.692	1.353	0.083	1.355	0.928	-0.356	0.676	0.042	1.140	0.042	19.421	143.024	26.184	241.539	30.830	251.037	280.467	28.047	2.174

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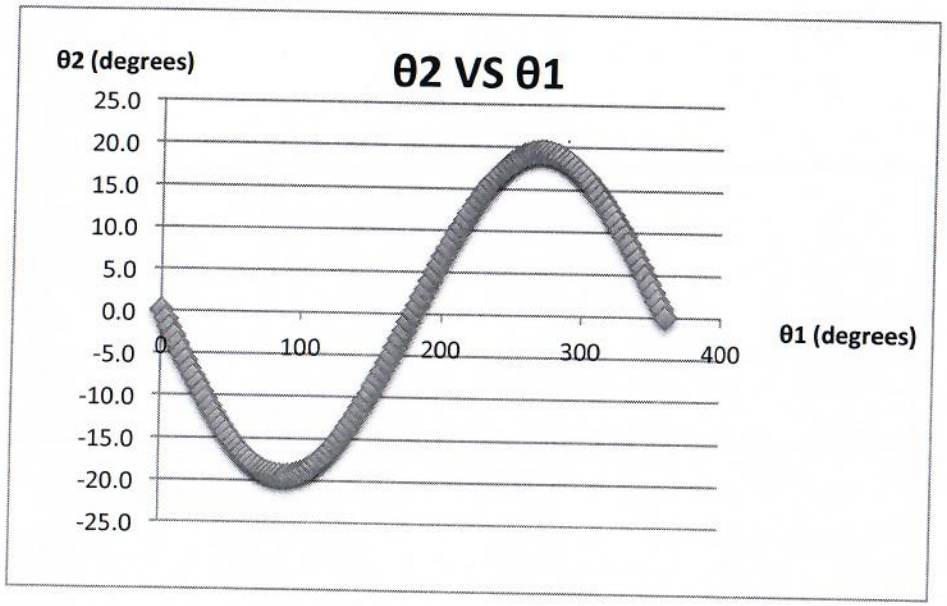
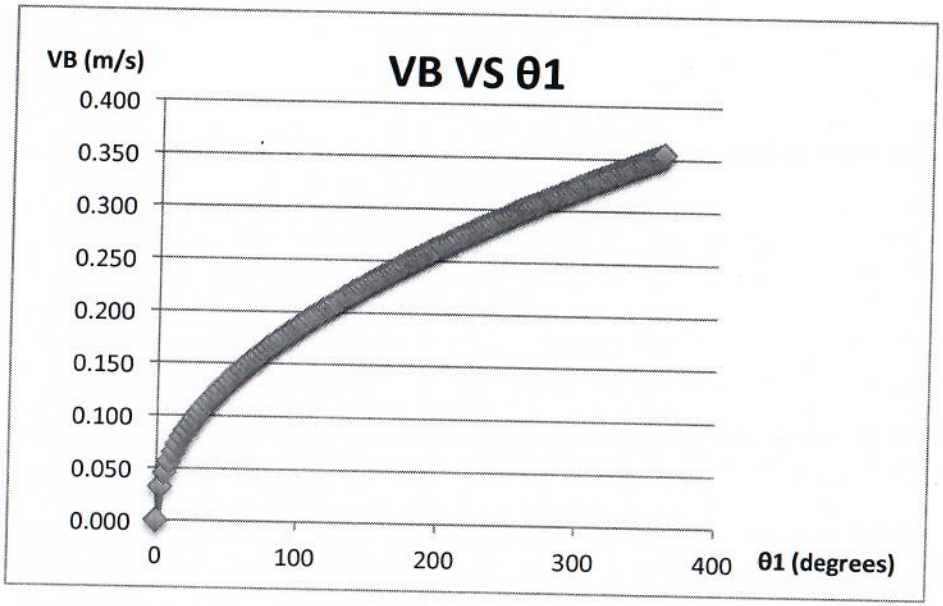
PROJECT #1

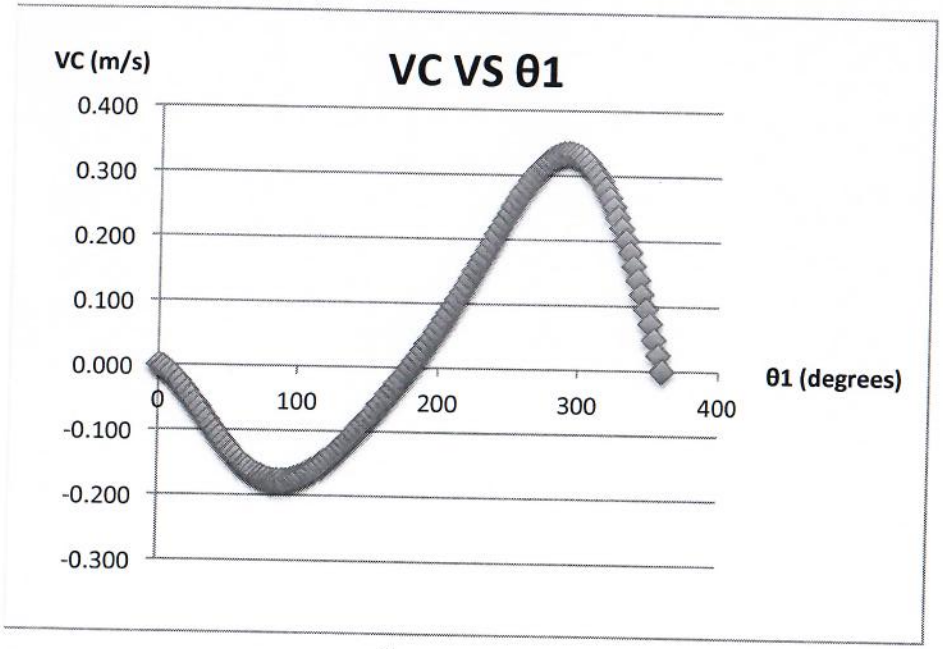
08/05/13

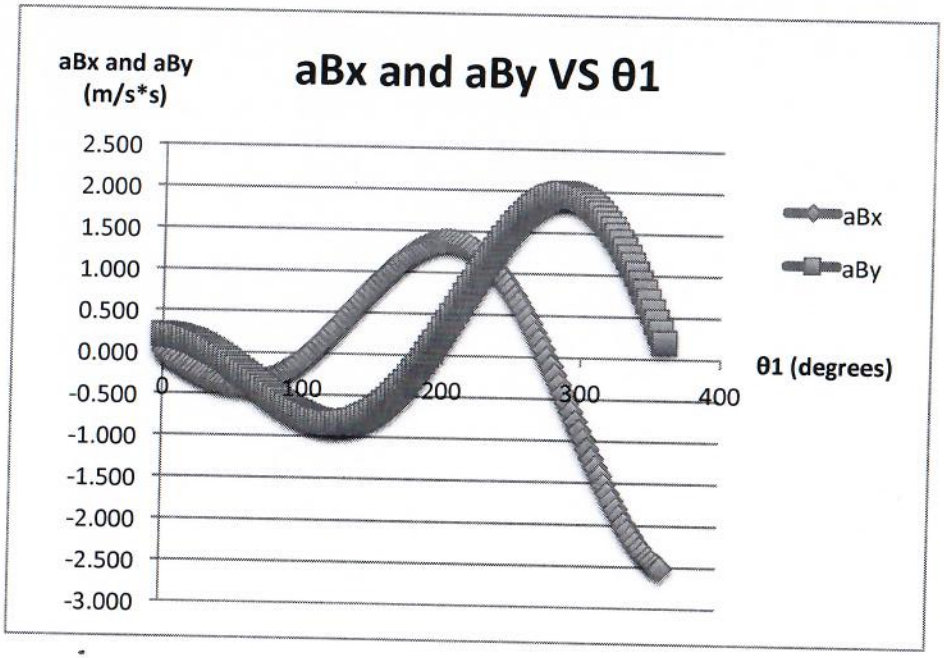
[redacted]

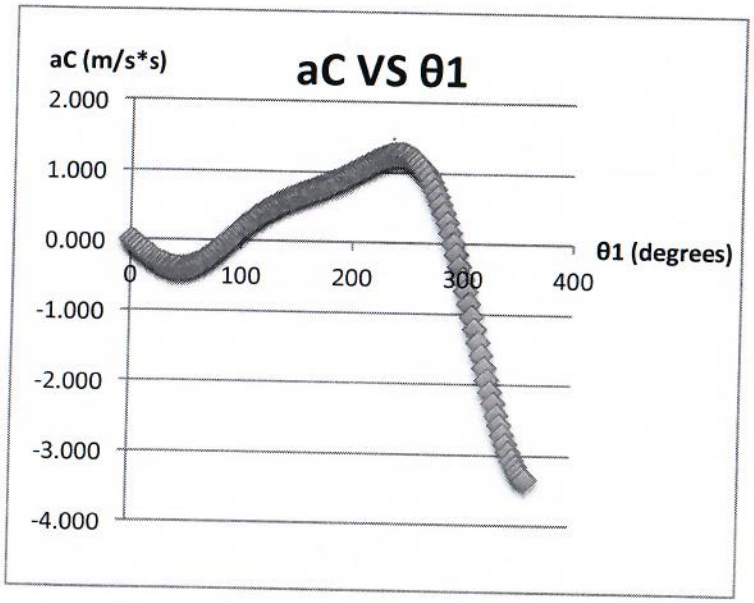
θ1	t	θ2	VBx	VBy	VB	VC	ω2	aBx	aBy	aB	aC	α2	aCG1x	aCG1y	aCG2x	aCG2y	Ax	Ay	Bx	By	Cx	Cy	N	f	T
(deg)	(sec)	(deg)	(m/s)	(m/s)	(m/s)	(m/s)	(rad/s)	(m/s*s)	(m/s*s)	(m/s*s)	(m/s*s)	(rad/s*s)	(m/s*s)	(m/s*s)	(m/s*s)	(m/s*s)	(N)	(N)	(N)	(N)	(N)	(N)	(N)	(N)	(N*m)
195	1.304	4.9	0.068	-0.252	0.261	0.046	1.686	1.367	0.159	1.376	0.952	-0.819	0.683	0.080	1.160	0.080	20.036	142.512	26.870	241.408	31.107	253.071	282.501	28.250	2.087
198	1.314	5.9	0.081	-0.250	0.263	0.055	1.676	1.376	0.237	1.397	0.977	-1.297	0.688	0.118	1.177	0.118	20.577	142.001	27.459	241.286	31.389	255.138	284.568	28.457	1.992
201	1.324	6.9	0.095	-0.247	0.265	0.065	1.660	1.382	0.316	1.417	1.003	-1.791	0.691	0.158	1.192	0.158	21.039	141.494	27.947	241.175	31.676	257.229	286.659	28.666	1.890
204	1.334	7.8	0.109	-0.244	0.267	0.075	1.640	1.382	0.397	1.438	1.029	-2.300	0.691	0.198	1.206	0.198	21.416	140.994	28.328	241.077	31.965	259.337	288.767	28.877	1.782
207	1.344	8.7	0.122	-0.240	0.269	0.085	1.615	1.378	0.478	1.459	1.056	-2.823	0.689	0.239	1.217	0.239	21.704	140.506	28.596	240.995	32.255	261.452	290.882	29.088	1.670
210	1.354	9.6	0.135	-0.234	0.271	0.096	1.585	1.370	0.560	1.480	1.082	-3.360	0.685	0.280	1.226	0.280	21.897	140.034	28.745	240.933	32.545	263.563	292.993	29.299	1.554
213	1.363	10.5	0.149	-0.229	0.273	0.106	1.550	1.356	0.642	1.500	1.108	-3.910	0.678	0.321	1.232	0.321	21.988	139.583	28.768	240.894	32.833	265.660	295.090	29.509	1.435
216	1.373	11.3	0.161	-0.222	0.275	0.117	1.510	1.338	0.725	1.521	1.133	-4.470	0.669	0.362	1.235	0.362	21.969	139.159	28.657	240.882	33.116	267.732	297.162	29.716	1.316
219	1.382	12.1	0.174	-0.215	0.276	0.128	1.465	1.314	0.807	1.542	1.158	-5.040	0.657	0.403	1.236	0.403	21.834	138.768	28.404	240.901	33.393	269.767	299.197	29.920	1.196
222	1.392	12.9	0.186	-0.207	0.278	0.139	1.415	1.286	0.888	1.563	1.181	-5.618	0.643	0.444	1.233	0.444	21.573	138.416	28.001	240.958	33.661	271.753	301.183	30.118	1.078
225	1.401	13.6	0.198	-0.198	0.280	0.150	1.359	1.252	0.969	1.583	1.202	-6.201	0.626	0.485	1.227	0.485	21.176	138.110	27.437	241.057	33.917	273.676	303.106	30.311	0.963
228	1.411	14.3	0.210	-0.189	0.282	0.161	1.299	1.214	1.049	1.604	1.221	-6.787	0.607	0.525	1.217	0.525	20.635	137.859	26.703	241.204	34.157	275.522	304.952	30.495	0.851
231	1.420	15.0	0.221	-0.179	0.284	0.173	1.233	1.170	1.127	1.625	1.236	-7.374	0.585	0.564	1.203	0.564	19.937	137.669	25.789	241.406	34.380	277.280	306.710	30.671	0.746
234	1.429	15.6	0.231	-0.168	0.286	0.184	1.163	1.122	1.204	1.646	1.249	-7.957	0.561	0.602	1.185	0.602	19.072	137.549	24.682	241.669	34.582	278.933	308.363	30.836	0.647
237	1.438	16.2	0.241	-0.157	0.288	0.196	1.088	1.069	1.279	1.667	1.256	-8.534	0.534	0.639	1.163	0.639	18.028	137.506	23.372	241.999	34.759	280.468	309.898	30.990	0.557
240	1.447	16.8	0.251	-0.145	0.289	0.207	1.008	1.011	1.351	1.687	1.259	-9.101	0.505	0.676	1.135	0.676	16.792	137.549	21.847	242.404	34.908	281.872	311.302	31.130	0.476
243	1.456	17.3	0.260	-0.132	0.291	0.218	0.923	0.948	1.421	1.708	1.256	-9.654	0.474	0.710	1.102	0.710	15.353	137.685	20.095	242.889	35.025	283.130	312.560	31.256	0.407
246	1.465	17.7	0.268	-0.119	0.293	0.230	0.834	0.881	1.488	1.729	1.247	-10.189	0.441	0.744	1.064	0.744	13.698	137.921	18.104	243.459	35.108	284.231	313.661	31.366	0.349
249	1.474	18.1	0.275	-0.106	0.295	0.241	0.741	0.810	1.551	1.750	1.231	-10.702	0.405	0.776	1.020	0.776	11.815	138.263	15.864	244.119	35.152	285.161	314.591	31.459	0.304
252	1.483	18.5	0.282	-0.092	0.297	0.251	0.644	0.734	1.611	1.771	1.207	-11.188	0.367	0.806	0.970	0.806	9.694	138.717	13.363	244.874	35.155	285.911	315.341	31.534	0.274
255	1.492	18.8	0.288	-0.077	0.298	0.262	0.544	0.654	1.668	1.791	1.174	-11.644	0.327	0.834	0.914	0.834	7.323	139.285	10.593	245.724	35.113	286.471	315.901	31.590	0.258
258	1.500	19.0	0.294	-0.062	0.300	0.272	0.440	0.570	1.720	1.812	1.133	-12.064	0.285	0.860	0.851	0.860	4.695	139.970	7.546	246.671	35.025	286.835	316.265	31.627	0.257
261	1.509	19.2	0.298	-0.047	0.302	0.282	0.333	0.483	1.768	1.833	1.082	-12.447	0.241	0.884	0.782	0.884	1.802	140.770	4.215	247.712	34.887	286.998	316.428	31.643	0.272
264	1.518	19.4	0.302	-0.032	0.304	0.291	0.224	0.392	1.812	1.854	1.020	-12.787	0.196	0.906	0.706	0.906	1.361	141.684	0.596	248.845	34.700	286.957	316.387	31.639	0.233
267	1.526	19.4	0.305	-0.016	0.305	0.299	0.113	0.297	1.851	1.875	0.949	-13.082	0.149	0.925	0.623	0.925	1.825	142.707	3.312	250.062	34.460	286.713	316.143	31.614	0.014
270	1.535	19.5	0.307	0.000	0.307	0.307	0.000	0.200	1.885	1.896	0.866	-13.329	0.100	0.942	0.533	0.942	6.508	143.831	7.508	251.355	34.169	286.268	315.698	31.570	0.348
273	1.543	19.4	0.308	0.016	0.309	0.314	-0.114	0.100	1.914	1.916	0.773	-13.525	0.050	0.957	0.437	0.957	11.490	145.045	11.990	252.714	33.826	285.630	315.060	31.506	0.725
276	1.552	19.4	0.309	0.032	0.310	0.320	-0.229	-0.003	1.937	1.937	0.670	-13.670	-0.001	0.969	0.334	0.969	16.763	146.338	16.750	254.124	33.433	284.806	314.236	31.424	1.113
279	1.560	19.2	0.308	0.049	0.312	0.325	-0.345	-0.107	1.955	1.958	0.556	-13.762	-0.054	0.978	0.224	0.978	22.315	147.694	21.779	255.569	32.991	283.808	313.238	31.324	1.509
282	1.569	19.0	0.307	0.065	0.314	0.329	-0.460	-0.214	1.967	1.979	0.431	-13.800	-0.107	0.984	0.109	0.984	28.131	149.096	27.063	257.032	32.502	282.650	312.080	31.208	1.909
285	1.577	18.8	0.305	0.082	0.315	0.332	-0.575	-0.322	1.974	2.000	0.297	-13.785	-0.161	0.987	-0.012	0.987	34.196	150.525	32.587	258.493	31.969	281.348	310.778	31.078	2.309
288	1.585	18.5	0.302	0.098	0.317	0.334	-0.689	-0.431	1.974	2.021	0.154	-13.717	-0.216	0.987	-0.139	0.987	40.486	151.961	38.331	259.931	31.396	279.920	309.350	30.935	2.706
291	1.594	18.1	0.298	0.114	0.319	0.335	-0.801	-0.541	1.968	2.041	0.002	-13.597	-0.271	0.984	-0.270	0.984	46.980	153.381	44.274	261.323	30.787	278.385	307.815	30.781	3.095
294	1.602	17.7	0.293	0.130	0.320	0.334	-0.912	-0.652	1.956	2.062	-0.158	-13.427	-0.326	0.978	-0.405	0.978	53.651	154.765	50.390	262.647	30.146	276.763	306.193	30.619	3.471
297	1.610	17.3	0.287	0.146	0.322	0.332	-1.021	-0.763	1.938	2.083	-0.324	-13.208	-0.382	0.969	-0.543	0.969	60.470	156.090	56.654	263.881	29.479	275.076	304.506	30.451	3.830
300	1.618	16.8	0.280	0.162	0.324	0.329	-1.127	-0.874	1.914	2.104	-0.496	-12.943	-0.437	0.957	-0.685	0.957	67.405	157.333	63.035	265.002	28.790	273.343	302.773	30.277	4.168
303	1.626	16.2	0.273	0.177	0.325	0.324	-1.230	-0.984	1.883	2.125	-0.672	-12.634	-0.492	0.942	-0.828	0.942	74.425	158.474	69.504	265.989	28.084	271.586	301.016	30.102	4.480
306	1.634	15.6	0.264	0.192	0.327	0.318	-1.330	-1.094	1.846	2.146	-0.852	-12.284	-0.547	0.923	-0.973	0.923	81.496	159.494	76.027	266.823	27.368	269.823	299.253	29.925	4.761
309	1.642	15.0	0.255	0.207	0.328	0.311	-1.427	-1.202	1.802	2.166	-1.035	-11.894	-0.601	0.901	-1.118	0.901	88.581	160.374	82.570	267.485	26.646	268.073	297.503	29.750	5.008
312	1.650	14.3	0.245	0.221	0.330	0.302	-1.520	-1.309	1.753	2.187	-1.218	-11.469	-0.654	0.876	-1.264	0.876	95.645	161.097	89.101	267.960	25.924	266.353	295.783	29.578	5.218
315	1.658	13.6	0.234	0.234	0.332	0.291	-1.608	-1.414	1.696	2.208	-1.401	-11.010	-0.707	0.848	-1.408	0.848	102.651	161.651	95.583	268.233	25.206	264.678	294.108	29.411	5.386
318	1.666	12.9	0.223	0.248	0.333	0.280	-1.693	-1.516	1.634	2.229	-1.583	-10.520	-0.758	0.817	-1.550	0.817	109.561	162.024	101.981	268.294	24.499	263.059	292.489	29.249	5.511
321	1.674	12.1	0.211	0.260	0.335	0.266	-1.774	-1.616	1.566	2.250	-1.762	-10.001	-0.808	0.783	-1.689	0.783	116.340	162.206	108.261	268.135	23.807	261.509	290.939	29.094	5.590
324	1.681	11.3	0.198	0.272	0.336	0.252	-1.850	-1.712	1.491	2.271	-1.938	-9.455	-0.856	0.746	-1.825	0.746	122.949	162.192	114.387	267.749	23.133	260.035	289.465	28.946	5.620
327	1.689	10.5	0.184	0.283	0.338	0.236	-1.921	-1.806	1.411	2.292	-2.108	-8.885	-0.903	0.706	-1.957	0.706	129.353	161.978	120.325	267.134	22.483	258.643	288.073	28.807	5.602
330	1.697	9.6	0.170	0.294	0.339	0.219	-1.987	-1.895	1.325	2.312	-2.272	-8.292	-0.948	0.663	-2.084	0.663	135.516	161.564	126.041	266.290	21.861	257.338	286.768	28.677	5.535
333	1.705	8.7	0.155	0.304	0.341	0.201	-2.049	-1.981	1.234	2.333	-2.429	-7.677	-0.990	0.617	-2.205	0.617	141.404	160.952	131.501	265.220	21.269	256.121	285.551	28.555	5.418
336	1.712	7.8	0.139	0.313	0.342	0.182	-2.105	-2.062	1.137	2.354	-2.577	-7.043	-1.031	0.568	-2.319	0.568	146.983	160.145	136.675	263.929	20.711	254.991	284.421	28.442	5.253
339	1.720	6.9	0.123	0.321	0.344	0.162	-2.156	-2.138	1.035	2.375	-2.716	-6.389	-1.069	0.517	-2.427	0.517	152.220	159.152	141.531	262.427	20.190	253.945	283.375	28.337	5.040
342	1.728	5.9	0.107	0.329	0.346	0.141	-2.202	-2.209	0.928	2.396	-2.844	-5.718	-1.104	0.464	-2.527	0.464	157.085	157.982	146.040	260.722	19.708	252.978	282.408	28.241	4.782
345	1.735	4.9	0.090	0.335	0.347	0.119	-2.243	-2.275	0.817	2.417	-2.962	-5.028	-1.137	0.408	-2.618	0.408	161.547	156.646	150.173	258.829	19.267	252.085	281.515	28.151	4.482
348	1.743	4.0	0.072	0.341	0.349	0.096	-2.278	-2.335	0.701	2.438	-3.067	-4.322	-1.167	0.350	-2.701	0.350	165.578	155.159	153.904	256.763	18.869	251.256	280.686	28.069	4.143
351	1.750	3.0	0.055	0.346	0.350	0.073	-2.308	-2.389	0.581	2.459	-3.159	-3.600	-1.194	0.290	-2.774	0.290	169.153	153.535	157.208	254.539	18.515	250.483	279.913	27.991	3.768
354	1.758	2.0	0.037	0.350	0.352	0.049	-2.332	-2.437	0.457	2.479	-3.237	-2.860	-1.218	0.229	-2.837	0.229	172.247	151.792	160.062	252.178	18.206	249.753	279.183	27.918	3.362
357	1.765	1.0	0.018	0.353	0.353	0.025	-2.351	-2.478	0.330	2.500	-3.302	-2.105	-1.239	0.165	-2.890	0.165	174.836	149.949	162.444	249.699	17.944	249.055	278.485	27.848	2.930
360	1.772	0.0	0.000	0.354	0.354	0.000	-2.363	-2.513	0.200	2.521	-3.351	-1.333	-1.257	0.100	-2.932	0.100	176.901	148.025	164.335	247.125	17.727	248.375	277.805	27.781	2.475


θ2 VS θ1
θ2 (degrees)
25.0
20.0
15.0
10.0
5.0
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
0
100
200
300
400
θ1 (degrees)


VB VS θ1
VB (m/s)
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0
100
200
300
400
θ1 (degrees)


VC VS θ1
VC (m/s)
0.400
0.300
0.200
0.100
0.000
-0.100
-0.200
-0.300
0
100
200
300
400
θ1 (degrees)


aBx and aBy VS θ1
aBx and aBy (m/s*s)
2.500
2.000
1.500
1.000
0.500
0.000
-0.500
-1.000
-1.500
-2.000
-2.500
-3.000
0
100
200
300
400
θ1 (degrees)
aBx
aBy


aC VS θ1
aC (m/s*s)
2.000
1.000
0.000
-1.000
-2.000
-3.000
-4.000
0
100
200
300
400
θ1 (degrees)