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Objective

The objectives of this experiment are to familiarize myself with the ECP Model 220 system and to use MATLAB for control system applications. This involves understanding the lab equipment, software, and procedures to obtain typical system responses.

Theory

In this experiment, the ECP Model 220 system is used to study the dynamics of a rotational mass driven by a servo DC motor. The system can be modeled with open-loop and closed-loop block diagrams, where the open-loop system includes the motor torque constant (Kt) and the trans-conductance gain (Ka). The angular position is measured using an encoder with a gain (Ke). The transfer function of the DC motor in the open-loop configuration is derived from the relationship between torque, inertia, and viscous friction. In the closed-loop system, a PID controller is implemented to achieve desired system responses. MATLAB is utilized to analyze and design control systems, providing tools for creating transfer functions, simulating system behavior, and tuning controller parameters. This theoretical foundation is essential for understanding the behavior and control of dynamic systems in practical applications.

Tasks/Results/Discussion

Task 1: Familiarization with ECP Model 220 System

1. **Initializing and Selecting Units:** The controller was reset, and COUNTS were selected as the unit.
2. **Data Acquisition Setup:** Data acquisition was configured to include Commanded Position and Encoder #1 Position with a sample period of 2.
3. **Control Algorithm Setup:** The "PI with Velocity Feedback" control algorithm was implemented with Ts = 0.00442 sec, Kp = 0.2, Kd = 0.01, and Ki = 0.
4. **System Input Command:** The step input was configured with a step size of 4000 counts and a dwell time of 1000ms.

5. **Execute the Command:** From the COMMAND menu, "Execute Trajectory" was selected with only NORMAL DATA SAMPLING checked.
6. **Plot the Input and Output of the Step Response:** From the PLOTTING menu, "Setup Plot" was selected with Commanded Position and Encoder #1 Position chosen for the Left Axis variables and Encoder #1 Following Error chosen for the Right Axis.
7. **Display the 'Control Effort':** Step 2 was repeated to add ‘Control Effort’ (CE) to the list of available variables. Step 6 was repeated with ‘Control Effort’ chosen as the Right Axis variable instead of the Encoder #1 Error.
8. **Export Raw Data:** After collecting data, 'Export Raw Data' was chosen from the Data menu. The data was saved as a text file as “sinesweep220”. And The m-file was opened in MATLAB for editing, the data column indices were adjusted as necessary, and the data was plotted using MATLAB.

Results and Observations

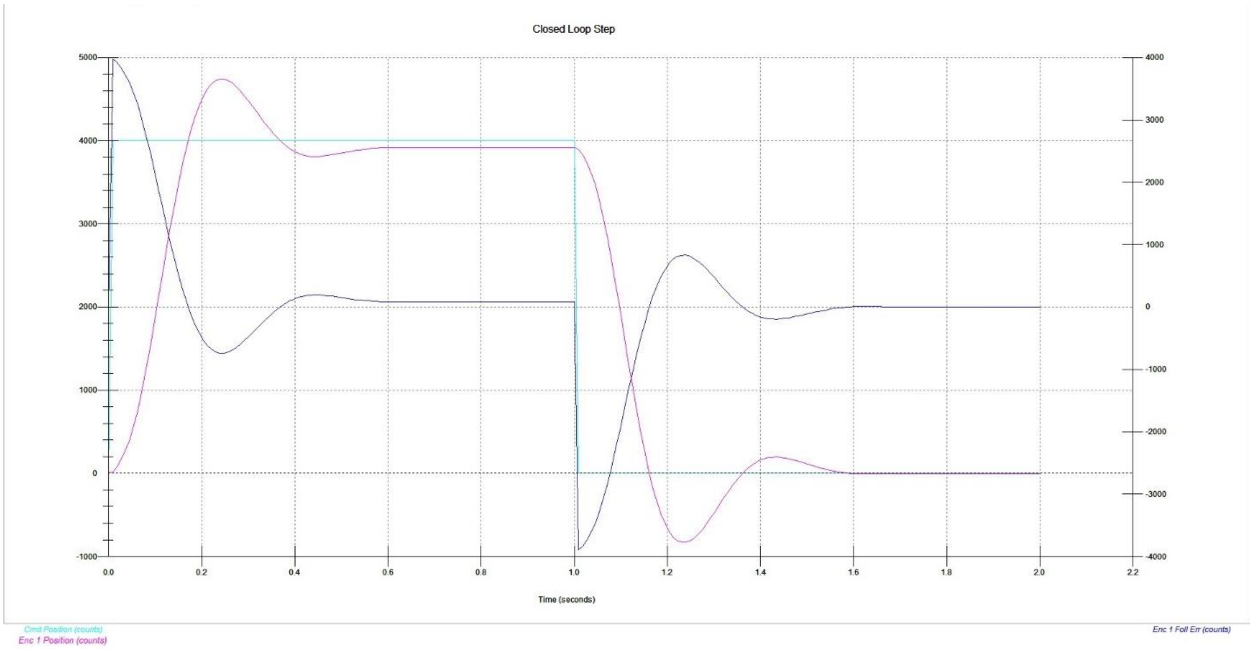

Figure 1: input and output plot of the step response

The step response was plotted, showing the system's behavior under the specified control algorithm. The error between the commanded position and the encoder position varied in the opposite direction of the output and approached zero in the steady state, indicating effective control. Observations revealed that the control effort anticipated output variations, as shown in the plot.

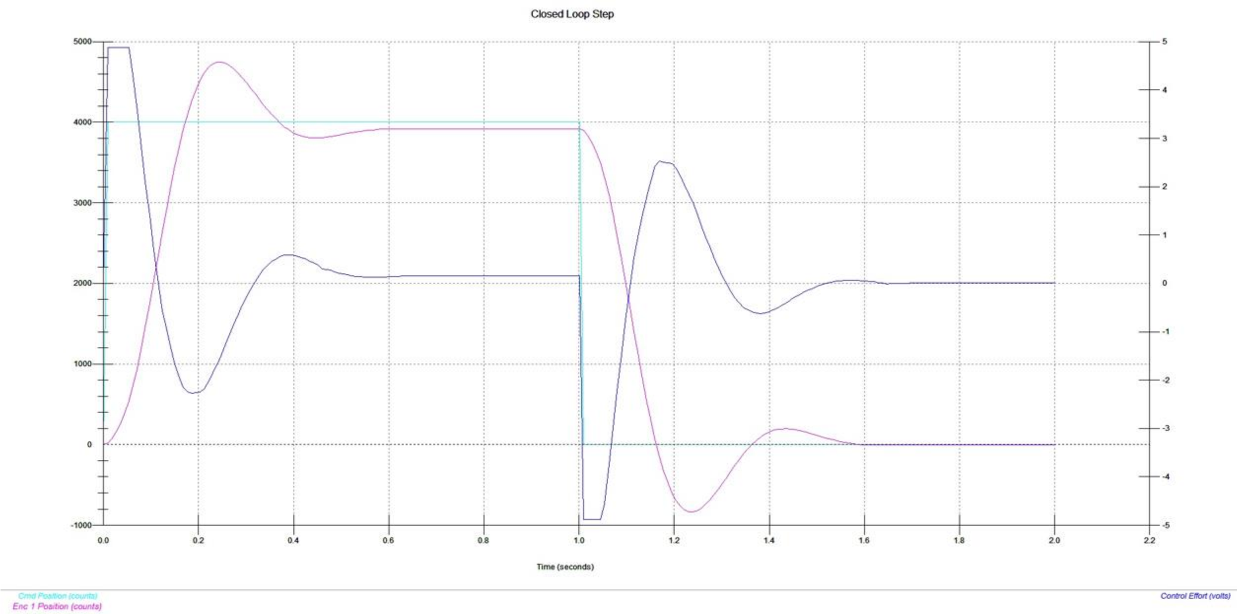

Figure 2: input and output plot of the step response closed loop with the Control Effort

The control effort (CE), which is the input to the servomotor, was plotted and observed to vary similarly to the error but anticipated the output variation with an observable lead time. This behavior indicates that the control system is proactively adjusting the input to maintain the desired output. The control effort is crucial when the system is operated in the open-loop mode, providing insight into how the system responds to control inputs without feedback.

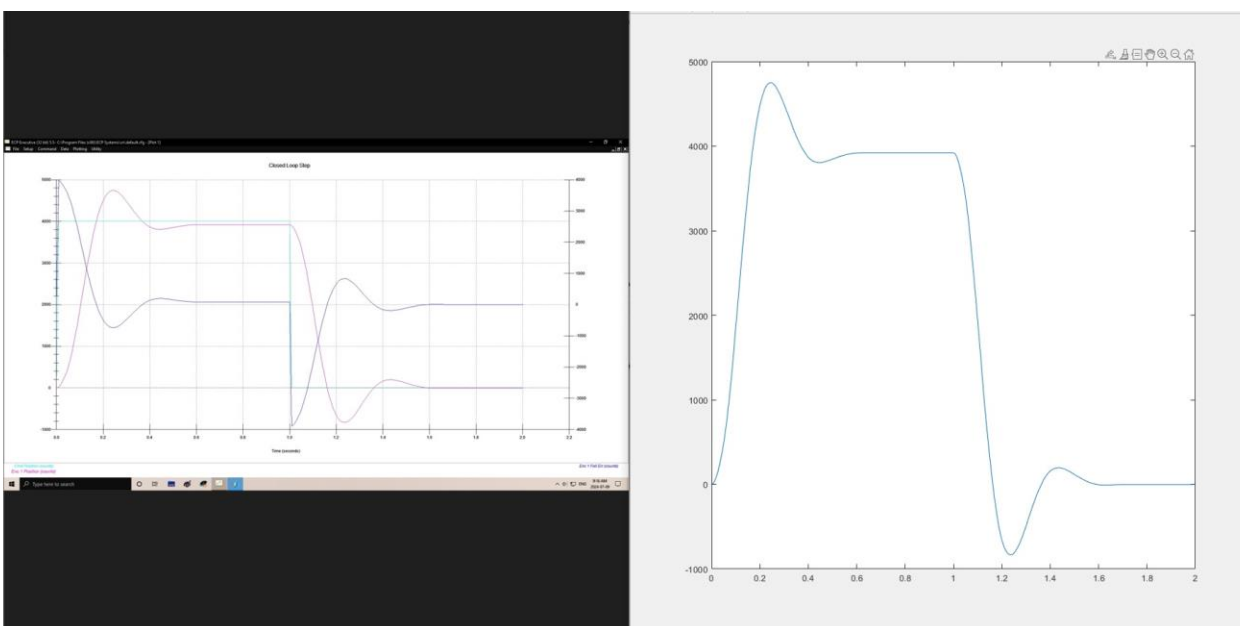

Figure 3: input and output plot of the step response closed loop MATLAB compared with ECP

A comparison of the MATLAB simulation and the ECP system plots was conducted. The comparison shows that while there are slight differences in the response curves, the overall behavior and trends are consistent. This validates the simulation model and highlights the accuracy of the ECP system in reflecting real-world dynamics.

Task 2: Open-Loop Test and Simulation

1. **MATLAB Simulation:** Physical constants were defined as K = 5.0, B = 0.002, J = 0.0043. Step response for speed and position was plotted using MATLAB.
2. **Obtain the Open-Loop Step Response:** From the COMMAND menu, “Trajectory” was selected and then “Trajectory Configuration”. OPEN LOOP was chosen with a Step Size of 0.4v, Dwell Time of 5000 ms, and number of Repetitions set to 1.
3. **Execute the Test:** The test was executed by selecting ‘Execute’ and displaying the plot. Axis-scaling was used to display only the section of the response within the dwell period of 5 seconds to make the display appear as a step response. A 0.4v input was used instead of the 1.0v used in the simulation to avoid exceeding motor speed safety limits.
4. **Velocity Response:** The plot was set up again to display Encoder #1 Velocity on the left axis and CE on the right axis and the data was plotted.

Results and Observations

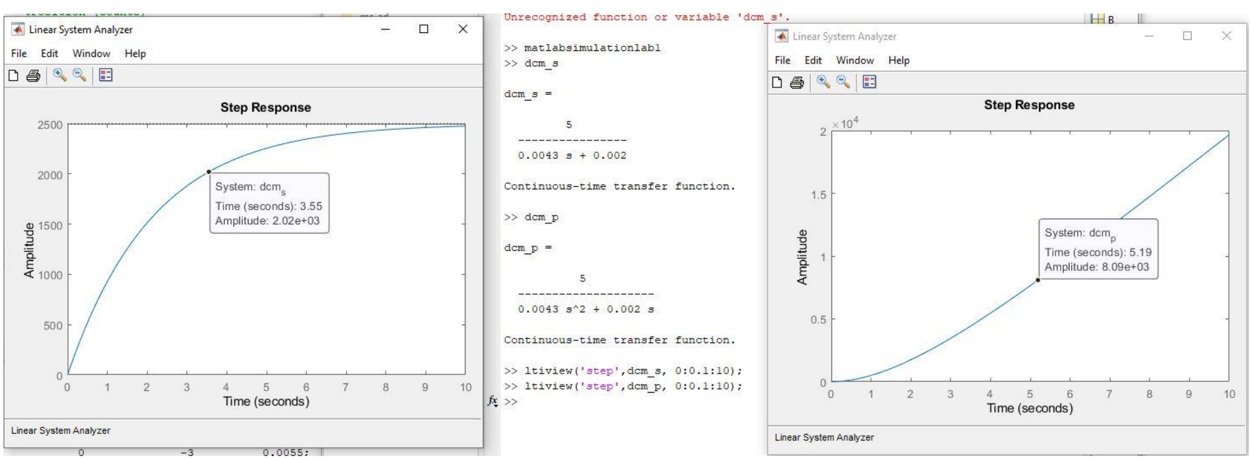

Figure 4: step response MATLAB ‘LTIview’ graphs

The LTIView graphs show that the speed response (dcm_s) reaches a steady state at approximately 3.55 seconds with an amplitude of 2020 counts, while the position response (dcm_p) continues to increase, reaching around 8090 counts at 5.19 seconds. These results confirm the accuracy of the MATLAB simulation model and align well with theoretical expectations.

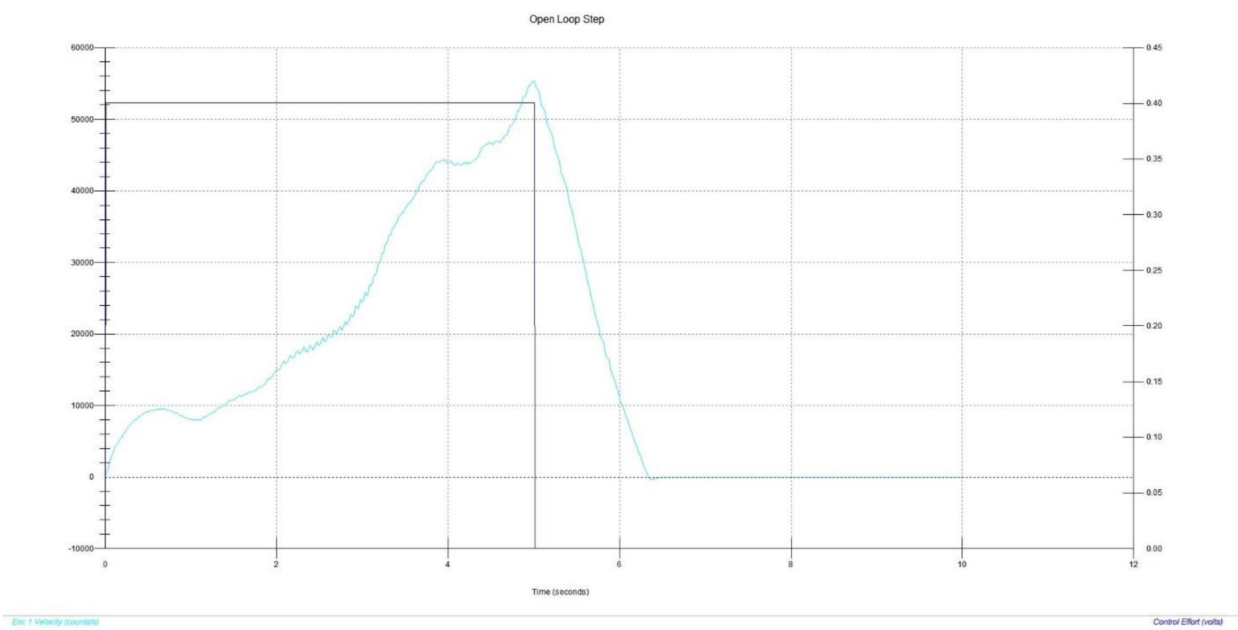

Figure 5: Verification of Equipment Velocity

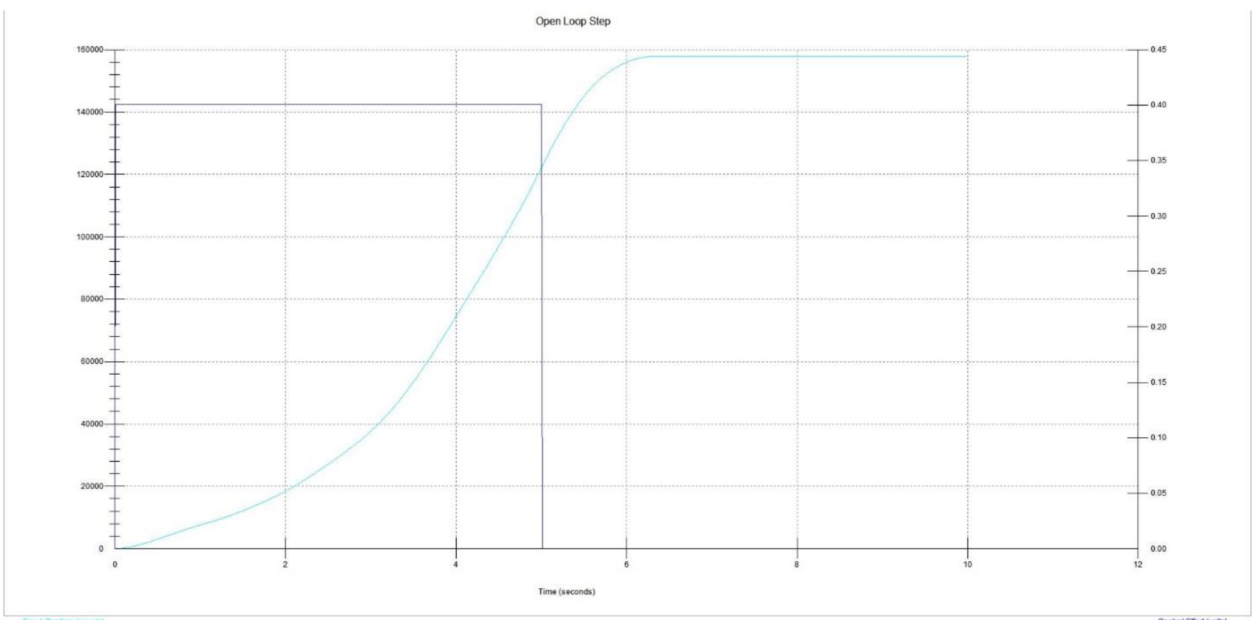

Figure 6: Verification of Equipment Position

The verification plots for equipment position and velocity show some discrepancies likely due to equipment errors. The position response (top image) displays an unexpected overshoot and settling behavior, while the velocity response (bottom image) reveals oscillations and noise. These inconsistencies highlight potential issues such as sensor inaccuracies, unmodeled dynamics, or mechanical imperfections in the equipment, emphasizing the need for careful calibration and parameter tuning to ensure accurate system performance. Ultimately, compared to the plot of 3.5.1, the overall behavior and trends are consistent. This validates the simulation model and highlights the accuracy of the ECP system in reflecting real-world dynamics.

Conclusion

This experiment provided hands-on experience with the ECP Model 220 system and demonstrated the use of MATLAB for control system analysis. The closed-loop system showed effective control with minimal steady-state error, while the open-loop tests validated the theoretical models. However, equipment errors highlighted the need for careful calibration. Overall, the experiment reinforced key concepts in dynamic system behavior and control, confirming the effectiveness of the implemented control strategies.

Appendix

Matlabsimulationlab1

```
K = 5.0;    % Plant gain
B = 0.002;  %Viscous friction (N.m.s/rad)
J = 0.0043; %kg.m^2

s = tf('s');
dcm_s = K/(J*s+B);  %Speed (counts/s)
dcm_p = dcm_s/s;    %Position (counts)
```

Lab1plotsamplecode

```
time=data(:,2);   %read Time
y=data(:,4);        %set Encode1 Pos as y
u=data(:,4);        %Control Effort as input
plot(time,y);       %Plot data
```

Sinesweep220

```
% Sample   Time     Commanded Pos   Encoder 1 Pos   Control Effort

data = [    0    0.000            4000              0          0.0000;
     1    0.009            4000               15        4.8840;
     2    0.018            4000               73        4.8840;
     3    0.027            4000              152        4.8840;
     4    0.035            4000              254        4.8840;
     5    0.044            4000              377        4.8840;
     6    0.053            4000              534        4.8840;
     7    0.062            4000              727        4.3132;
     8    0.071            4000              949        3.5653;
     9    0.080            4000             1197        2.8205;
    10    0.089            4000             1465        2.0891;
    11    0.097            4000             1747        1.4005;
    12    0.106            4000             2040        0.6941;
    13    0.115            4000             2343        0.0079;
    14    0.124            4000             2644       -0.5611;
    15    0.133            4000             2931       -0.9664;
    16    0.142            4000             3202       -1.3303;
    17    0.151            4000             3458       -1.6685;
    18    0.159            4000             3698       -1.9505;
    19    0.168            4000             3916       -2.1526;
    20    0.177            4000             4108       -2.2515;
    21    0.186            4000             4272       -2.2662;
    22    0.195            4000             4410       -2.2576;
    23    0.204            4000             4525       -2.2454;
```

24	0.213	4000	4617	-2.1758;
25	0.221	4000	4683	-2.0293;
26	0.230	4000	4725	-1.8553;
27	0.239	4000	4746	-1.6752;
28	0.248	4000	4750	-1.4933;
29	0.257	4000	4733	-1.2442;
30	0.266	4000	4702	-1.0415;
31	0.274	4000	4660	-0.8443;
32	0.283	4000	4609	-0.6380;
33	0.292	4000	4551	-0.4493;
34	0.301	4000	4487	-0.2759;
35	0.310	4000	4421	-0.1166;
36	0.319	4000	4353	0.0348;
37	0.328	4000	4285	0.1667;
38	0.336	4000	4218	0.2839;
39	0.345	4000	4155	0.3779;
40	0.354	4000	4094	0.4542;
41	0.363	4000	4039	0.5134;
42	0.372	4000	3988	0.5562;
43	0.381	4000	3944	0.5800;
44	0.390	4000	3906	0.5849;
45	0.398	4000	3874	0.5855;
46	0.407	4000	3848	0.5659;
47	0.416	4000	3829	0.5366;
48	0.425	4000	3815	0.5018;
49	0.434	4000	3807	0.4609;
50	0.443	4000	3804	0.4255;
51	0.452	4000	3804	0.3828;
52	0.460	4000	3809	0.2967;
53	0.469	4000	3816	0.2851;
54	0.478	4000	3823	0.2686;
55	0.487	4000	3832	0.2344;
56	0.496	4000	3841	0.2015;
57	0.505	4000	3851	0.1911;
58	0.514	4000	3860	0.1770;
59	0.522	4000	3869	0.1551;
60	0.531	4000	3878	0.1410;
61	0.540	4000	3886	0.1380;
62	0.549	4000	3893	0.1337;
63	0.558	4000	3900	0.1276;
64	0.567	4000	3905	0.1245;
65	0.576	4000	3910	0.1233;
66	0.584	4000	3913	0.1288;
67	0.593	4000	3916	0.1300;
68	0.602	4000	3918	0.1410;
69	0.611	4000	3919	0.1471;
70	0.620	4000	3920	0.1447;
71	0.629	4000	3920	0.1557;
72	0.638	4000	3920	0.1557;
73	0.646	4000	3920	0.1557;
74	0.655	4000	3920	0.1557;
75	0.664	4000	3920	0.1557;
76	0.673	4000	3920	0.1557;
77	0.682	4000	3920	0.1557;
78	0.691	4000	3920	0.1557;

79	0.699	4000	3920	0.1557;
80	0.708	4000	3920	0.1557;
81	0.717	4000	3920	0.1557;
82	0.726	4000	3920	0.1557;
83	0.735	4000	3920	0.1557;
84	0.744	4000	3920	0.1557;
85	0.753	4000	3920	0.1557;
86	0.761	4000	3920	0.1557;
87	0.770	4000	3920	0.1557;
88	0.779	4000	3920	0.1557;
89	0.788	4000	3920	0.1557;
90	0.797	4000	3920	0.1557;
91	0.806	4000	3920	0.1557;
92	0.815	4000	3920	0.1557;
93	0.823	4000	3920	0.1557;
94	0.832	4000	3920	0.1557;
95	0.841	4000	3920	0.1557;
96	0.850	4000	3920	0.1557;
97	0.859	4000	3920	0.1557;
98	0.868	4000	3920	0.1557;
99	0.877	4000	3920	0.1557;
100	0.885	4000	3920	0.1557;
101	0.894	4000	3920	0.1557;
102	0.903	4000	3920	0.1557;
103	0.912	4000	3920	0.1557;
104	0.921	4000	3920	0.1557;
105	0.930	4000	3920	0.1557;
106	0.939	4000	3920	0.1557;
107	0.947	4000	3920	0.1557;
108	0.956	4000	3920	0.1557;
109	0.965	4000	3920	0.1557;
110	0.974	4000	3920	0.1557;
111	0.983	4000	3920	0.1557;
112	0.992	4000	3920	0.1557;
113	1.001	4000	3920	0.1557;
114	1.009	0	3902	-4.8840;
115	1.018	0	3839	-4.8840;
116	1.027	0	3748	-4.8840;
117	1.036	0	3633	-4.8840;
118	1.045	0	3492	-4.8840;
119	1.054	0	3314	-4.5562;
120	1.063	0	3099	-3.7454;
121	1.071	0	2857	-2.9835;
122	1.080	0	2591	-2.2271;
123	1.089	0	2308	-1.4817;
124	1.098	0	2011	-0.7589;
125	1.107	0	1705	-0.0714;
126	1.116	0	1398	0.5385;
127	1.124	0	1100	1.0263;
128	1.133	0	817	1.4194;
129	1.142	0	550	1.7650;
130	1.151	0	296	2.1276;
131	1.160	0	58	2.4206;
132	1.169	0	-153	2.5275;
133	1.178	0	-329	2.5067;

134	1.186	0	-477	2.4963;
135	1.195	0	-600	2.4762;
136	1.204	0	-698	2.3895;
137	1.213	0	-767	2.2234;
138	1.222	0	-810	2.0269;
139	1.231	0	-831	1.8449;
140	1.240	0	-836	1.6770;
141	1.248	0	-820	1.4206;
142	1.257	0	-788	1.1880;
143	1.266	0	-743	0.9707;
144	1.275	0	-689	0.7552;
145	1.284	0	-625	0.5372;
146	1.293	0	-554	0.3303;
147	1.302	0	-480	0.1477;
148	1.310	0	-404	-0.0208;
149	1.319	0	-328	-0.1722;
150	1.328	0	-253	-0.3028;
151	1.337	0	-182	-0.4096;
152	1.346	0	-114	-0.4902;
153	1.355	0	-53	-0.5549;
154	1.364	0	3	-0.5928;
155	1.372	0	51	-0.6148;
156	1.381	0	93	-0.6209;
157	1.390	0	127	-0.6105;
158	1.399	0	154	-0.5873;
159	1.408	0	174	-0.5482;
160	1.417	0	187	-0.5067;
161	1.426	0	194	-0.4542;
162	1.434	0	197	-0.4035;
163	1.443	0	194	-0.3492;
164	1.452	0	187	-0.2863;
165	1.461	0	178	-0.2448;
166	1.470	0	166	-0.1984;
167	1.479	0	152	-0.1502;
168	1.488	0	138	-0.1136;
169	1.496	0	123	-0.0806;
170	1.505	0	107	-0.0464;
171	1.514	0	92	-0.0159;
172	1.523	0	77	0.0061;
173	1.532	0	63	0.0256;
174	1.541	0	50	0.0452;
175	1.549	0	38	0.0556;
176	1.558	0	27	0.0611;
177	1.567	0	17	0.0672;
178	1.576	0	9	0.0684;
179	1.585	0	3	0.0611;
180	1.594	0	-2	0.0531;
181	1.603	0	-6	0.0482;
182	1.611	0	-8	0.0366;
183	1.620	0	-9	0.0336;
184	1.629	0	-9	0.0171;
185	1.638	0	-9	0.0171;
186	1.647	0	-7	-0.0189;
187	1.656	0	-6	-0.0037;
188	1.665	0	-5	-0.0031;

```
189     1.673                0                -4          -0.0012;
190     1.682                0                -4           0.0018;
191     1.691                0                -3          -0.0024;
192     1.700                0                -3           0.0055;
193     1.709                0                -3           0.0055;
194     1.718                0                -3           0.0055;
195     1.727                0                -3           0.0055;
196     1.735                0                -3           0.0055;
197     1.744                0                -3           0.0055;
198     1.753                0                -3           0.0055;
199     1.762                0                -3           0.0055;
200     1.771                0                -3           0.0055;
201     1.780                0                -3           0.0055;
202     1.789                0                -3           0.0055;
203     1.797                0                -3           0.0055;
204     1.806                0                -3           0.0055;
205     1.815                0                -3           0.0055;
206     1.824                0                -3           0.0055;
207     1.833                0                -3           0.0055;
208     1.842                0                -3           0.0055;
209     1.851                0                -3           0.0055;
210     1.859                0                -3           0.0055;
211     1.868                0                -3           0.0055;
212     1.877                0                -3           0.0055;
213     1.886                0                -3           0.0055;
214     1.895                0                -3           0.0055;
215     1.904                0                -3           0.0055;
216     1.913                0                -3           0.0055;
217     1.921                0                -3           0.0055;
218     1.930                0                -3           0.0055;
219     1.939                0                -3           0.0055;
220     1.948                0                -3           0.0055;
221     1.957                0                -3           0.0055;
222     1.966                0                -3           0.0055;
223     1.974                0                -3           0.0055;
224     1.983                0                -3           0.0055;
225     1.992                0                -3           0.0055];
```