EXAMPLE 5.4(a)
Short-term INS error growth standard deviation
Tactical-grade sensors

INPUTS:

Error standard deviations per axis

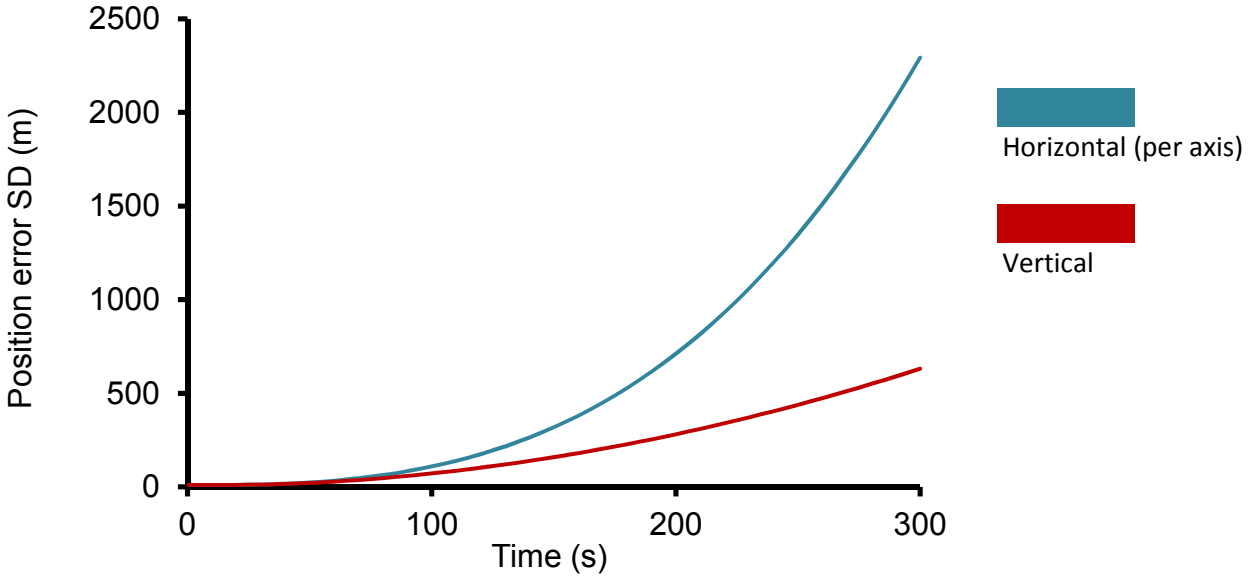
Initial position error	10	m
Initial velocity error	0.1	$m\,s^{-1}$
Initial roll and pitch error	0.001	rad
Accelerometer bias	0.01	$m\,s^{-2}$
Gyro bias	5.00E-05	$rad\,s^{-1}$

Noise power spectral density per axis

Accelerometer noise	1.00E-06	m^2s^{-3}
Gyro noise	1.00E-09	rad^2s^{-1}

Note: The time interval would normally be much shorter.

See Section 5.7.1 for the equations describing short-term straight-line propagation errors



Error standard deviations (meters)

Time (s)	From initial velocity error	From acceleration error	From accelerometer bias	From gyro bias	From accelerometer noise	From gyro noise	Total per horizontal axis	Total vertical
0	0	0	0	0	0	0	10	10
5	0.5	0.125	0.1225	0.010208	0.006455	0.000791	10.01403	10.01402
10	1	0.5	0.49	0.081667	0.018257	0.004472	10.07458	10.07425
15	1.5	1.125	1.1025	0.275625	0.033541	0.012324	10.2376	10.23388
20	2	2	1.96	0.653333	0.05164	0.025298	10.59584	10.57564
25	2.5	3.125	3.0625	1.276042	0.072169	0.044194	11.27076	11.1982
30	3	4.5	4.41	2.205	0.094868	0.069714	12.3925	12.19455
35	3.5	6.125	6.0025	3.501458	0.119548	0.102491	14.07411	13.63121
40	4	8	7.84	5.226667	0.146059	0.143108	16.3959	15.53985
45	4.5	10.125	9.9225	7.441875	0.174284	0.192108	19.408	17.9235
50	5	12.5	12.25	10.20833	0.204124	0.25	23.14361	20.76907

55	5.5	15.125	14.8225	13.58729	0.235496	0.317265	27.63137	24.0578
60	6	18	17.64	17.64	0.268328	0.39436	32.90238	27.77124
65	6.5	21.125	20.7025	22.42771	0.302559	0.481724	38.99275	31.89358
70	7	24.5	24.01	28.01167	0.338132	0.579776	45.94381	36.41215
75	7.5	28.125	27.5625	34.45313	0.375	0.688919	53.80139	41.31704
80	8	32	31.36	41.81333	0.413118	0.809543	62.61494	46.60065
85	8.5	36.125	35.4025	50.15354	0.452447	0.942025	72.43668	52.25713
90	9	40.5	39.69	59.535	0.49295	1.086729	83.32098	58.28198
95	9.5	45.125	44.2225	70.01896	0.534595	1.24401	95.32383	64.67172
100	10	50	49	81.66667	0.57735	1.414214	108.5024	71.42362
105	10.5	55.125	54.0225	94.53938	0.621188	1.597674	122.9149	78.53555
110	11	60.5	59.29	108.6983	0.666083	1.79472	138.6202	86.0058
115	11.5	66.125	64.8025	124.2048	0.71201	2.005671	155.6775	93.83303
120	12	72	70.56	141.12	0.758947	2.230838	174.1468	102.0161
125	12.5	78.125	76.5625	159.5052	0.806872	2.470529	194.0882	110.5542
130	13	84.5	82.81	179.4217	0.855765	2.725043	215.5621	119.4466
135	13.5	91.125	89.3025	200.9306	0.905608	2.994673	238.6291	128.6925
140	14	98	96.04	224.0933	0.956382	3.279707	263.3499	138.2917
145	14.5	105.125	103.0225	248.971	1.008072	3.580428	289.7854	148.2436
150	15	112.5	110.25	275.625	1.06066	3.897114	317.9965	158.5479
155	15.5	120.125	117.7225	304.1165	1.114133	4.230038	348.0443	169.2043
160	16	128	125.44	334.5067	1.168475	4.579467	379.9898	180.2125
165	16.5	136.125	133.4025	366.8569	1.223673	4.945667	413.8942	191.5724
170	17	144.5	141.61	401.2283	1.279714	5.328897	449.8187	203.2837
175	17.5	153.125	150.0625	437.6823	1.336585	5.729413	487.8244	215.3464
180	18	162	158.76	476.28	1.394274	6.147468	527.9726	227.7601
185	18.5	171.125	167.7025	517.0827	1.45277	6.58331	570.3246	240.525
190	19	180.5	176.89	560.1517	1.512063	7.037186	614.9415	253.6407
195	19.5	190.125	186.3225	605.5481	1.57214	7.509336	661.8846	267.1073
200	20	200	196	653.3333	1.632993	8	711.2152	280.9247
205	20.5	210.125	205.9225	703.5685	1.694612	8.509414	762.9946	295.0927
210	21	220.5	216.09	756.315	1.756986	9.037811	817.2841	309.6114
215	21.5	231.125	226.5025	811.634	1.820108	9.58542	874.1449	324.4807
220	22	242	237.16	869.5867	1.883967	10.15247	933.6383	339.7005
225	22.5	253.125	248.0625	930.2344	1.948557	10.73918	995.8256	355.2708
230	23	264.5	259.21	993.6383	2.013869	11.34579	1060.768	371.1915
235	23.5	276.125	270.6025	1059.86	2.079894	11.97249	1128.527	387.4626
240	24	288	282.24	1128.96	2.146625	12.61953	1199.164	404.0842
245	24.5	300.125	294.1225	1201	2.214055	13.2871	1272.74	421.0561
250	25	312.5	306.25	1276.042	2.282177	13.97542	1349.316	438.3783
255	25.5	325.125	318.6225	1354.146	2.350984	14.68471	1428.954	456.0508
260	26	338	331.24	1435.373	2.420468	15.41517	1511.714	474.0736
265	26.5	351.125	344.1025	1519.786	2.490624	16.16701	1597.659	492.4467
270	27	364.5	357.21	1607.445	2.561445	16.94043	1686.849	511.17
275	27.5	378.125	370.5625	1698.411	2.632925	17.73563	1779.347	530.2436
280	28	392	384.16	1792.747	2.705057	18.55283	1875.212	549.6674
285	28.5	406.125	398.0025	1890.512	2.777836	19.3922	1974.506	569.4414
290	29	420.5	412.09	1991.768	2.851257	20.25396	2077.291	589.5656
295	29.5	435.125	426.4225	2096.577	2.925313	21.1383	2183.628	610.0399
300	30	450	441	2205	3	22.04541	2293.578	630.8645

EXAMPLE 5.4(b)
Short-term INS error growth standard deviation
Aviation-grade sensors

INPUTS:

Error standard deviations per axis

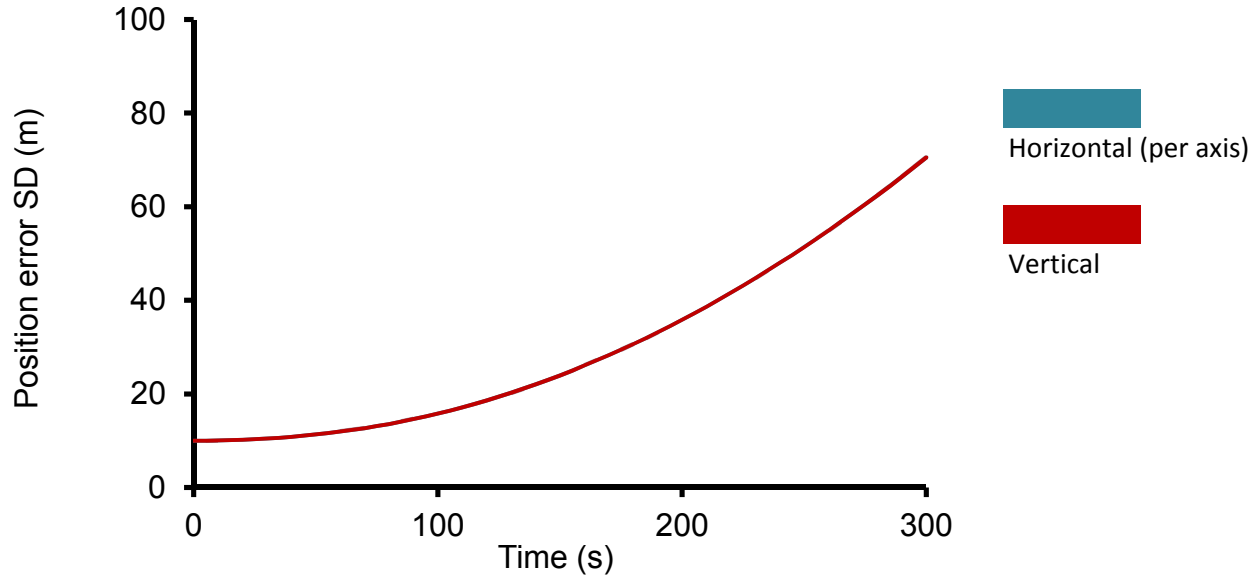
Initial position error	10	m
Initial velocity error	0.1	$m\,s^{-1}$
Initial roll and pitch error	0.0001	rad
Accelerometer bias	0.001	$m\,s^{-2}$
Gyro bias	5.00E-08	$rad\,s^{-1}$

Noise power spectral density per axis

Accelerometer noise	1.00E-07	m^2s^{-3}
Gyro noise	1.00E-12	rad^2s^{-1}

Note: The time interval would normally be much shorter.

See Section 5.7.1 for the equations describing short-term straight-line propagation errors



Error standard deviations (meters)

Time (s)	From initial velocity error	From acceleration error	From accelerometer bias	From gyro bias	From accelerometer noise	From gyro noise	Total per horizontal axis	Total vertical
0	0	0	0	0	0	0	10	10
5	0.5	0.0125	0.01225	1.02E-05	0.002041	0.000025	10.01251	10.01251
10	1	0.05	0.049	8.17E-05	0.005774	0.000141	10.05012	10.05012
15	1.5	0.1125	0.11025	0.000276	0.010607	0.00039	10.11311	10.11311
20	2	0.2	0.196	0.000653	0.01633	0.0008	10.2019	10.2019
25	2.5	0.3125	0.30625	0.001276	0.022822	0.001398	10.31707	10.31707
30	3	0.45	0.441	0.002205	0.03	0.002205	10.45934	10.45934
35	3.5	0.6125	0.60025	0.003501	0.037804	0.003241	10.62953	10.62953
40	4	0.8	0.784	0.005227	0.046188	0.004525	10.82852	10.82852
45	4.5	1.0125	0.99225	0.007442	0.055114	0.006075	11.05725	11.05725
50	5	1.25	1.225	0.010208	0.06455	0.007906	11.31669	11.31668

55	5.5	1.5125	1.48225	0.013587	0.07447	0.010033	11.60778	11.60777
60	6	1.8	1.764	0.01764	0.084853	0.012471	11.93144	11.93142
65	6.5	2.1125	2.07025	0.022428	0.095677	0.015233	12.28855	12.28852
70	7	2.45	2.401	0.028012	0.106927	0.018334	12.6799	12.67986
75	7.5	2.8125	2.75625	0.034453	0.118585	0.021786	13.10621	13.10615
80	8	3.2	3.136	0.041813	0.130639	0.0256	13.56812	13.56803
85	8.5	3.6125	3.54025	0.050154	0.143076	0.029789	14.06618	14.06606
90	9	4.05	3.969	0.059535	0.155885	0.034365	14.60084	14.60068
95	9.5	4.5125	4.42225	0.070019	0.169054	0.039339	15.17247	15.17226
100	10	5	4.9	0.081667	0.182574	0.044721	15.78138	15.78111
105	10.5	5.5125	5.40225	0.094539	0.196437	0.050523	16.42778	16.42743
110	11	6.05	5.929	0.108698	0.210634	0.056754	17.11184	17.1114
115	11.5	6.6125	6.48025	0.124205	0.225157	0.063425	17.83365	17.8331
120	12	7.2	7.056	0.14112	0.24	0.070545	18.59327	18.5926
125	12.5	7.8125	7.65625	0.159505	0.255155	0.078125	19.39072	19.38991
130	13	8.45	8.281	0.179422	0.270617	0.086173	20.22598	20.225
135	13.5	9.1125	8.93025	0.200931	0.286378	0.0947	21.09901	21.09784
140	14	9.8	9.604	0.224093	0.302435	0.103713	22.00975	22.00837
145	14.5	10.5125	10.30225	0.248971	0.31878	0.113223	22.95812	22.95649
150	15	11.25	11.025	0.275625	0.33541	0.123238	23.94403	23.94213
155	15.5	12.0125	11.77225	0.304116	0.35232	0.133766	24.96739	24.96518
160	16	12.8	12.544	0.334507	0.369504	0.144815	26.02809	26.02553
165	16.5	13.6125	13.34025	0.366857	0.386959	0.156396	27.12602	27.12309
170	17	14.45	14.161	0.401228	0.404681	0.168515	28.2611	28.25775
175	17.5	15.3125	15.00625	0.437682	0.422665	0.18118	29.4332	29.42939
180	18	16.2	15.876	0.47628	0.440908	0.1944	30.64223	30.63791
185	18.5	17.1125	16.77025	0.517083	0.459406	0.208183	31.8881	31.88322
190	19	18.05	17.689	0.560152	0.478156	0.222535	33.1707	33.16522
195	19.5	19.0125	18.63225	0.605548	0.497154	0.237466	34.48994	34.48381
200	20	20	19.6	0.653333	0.516398	0.252982	35.84575	35.8389
205	20.5	21.0125	20.59225	0.703569	0.535883	0.269091	37.23803	37.23041
210	21	22.05	21.609	0.756315	0.555608	0.285801	38.6667	38.65825
215	21.5	23.1125	22.65025	0.811634	0.575569	0.303118	40.1317	40.12235
220	22	24.2	23.716	0.869587	0.595763	0.321049	41.63295	41.62263
225	22.5	25.3125	24.80625	0.930234	0.616188	0.339603	43.1704	43.15904
230	23	26.45	25.921	0.993638	0.636841	0.358785	44.74396	44.73149
235	23.5	27.6125	27.06025	1.05986	0.65772	0.378604	46.3536	46.33994
240	24	28.8	28.224	1.12896	0.678823	0.399065	47.99926	47.98432
245	24.5	30.0125	29.41225	1.201	0.700146	0.420175	49.68088	49.66458
250	25	31.25	30.625	1.276042	0.721688	0.441942	51.39842	51.38068
255	25.5	32.5125	31.86225	1.354146	0.743446	0.464371	53.15184	53.13255
260	26	33.8	33.124	1.435373	0.765419	0.487471	54.94109	54.92017
265	26.5	35.1125	34.41025	1.519786	0.787604	0.511246	56.76614	56.74349
270	27	36.45	35.721	1.607445	0.81	0.535703	58.62695	58.60246
275	27.5	37.8125	37.05625	1.698411	0.832604	0.56085	60.52349	60.49706
280	28	39.2	38.416	1.792747	0.855414	0.586692	62.45574	62.42724
285	28.5	40.6125	39.80025	1.890512	0.878429	0.613235	64.42365	64.39299
290	29	42.05	41.209	1.991768	0.901647	0.640487	66.42721	66.39426
295	29.5	43.5125	42.64225	2.096577	0.925065	0.668452	68.4664	68.43102
300	30	45	44.1	2.205	0.948683	0.697137	70.54118	70.50326

EXAMPLE 5.4(c)
Short-term INS error growth standard deviation
Calibrated Tactical-grade sensors

INPUTS:

Error standard deviations per axis

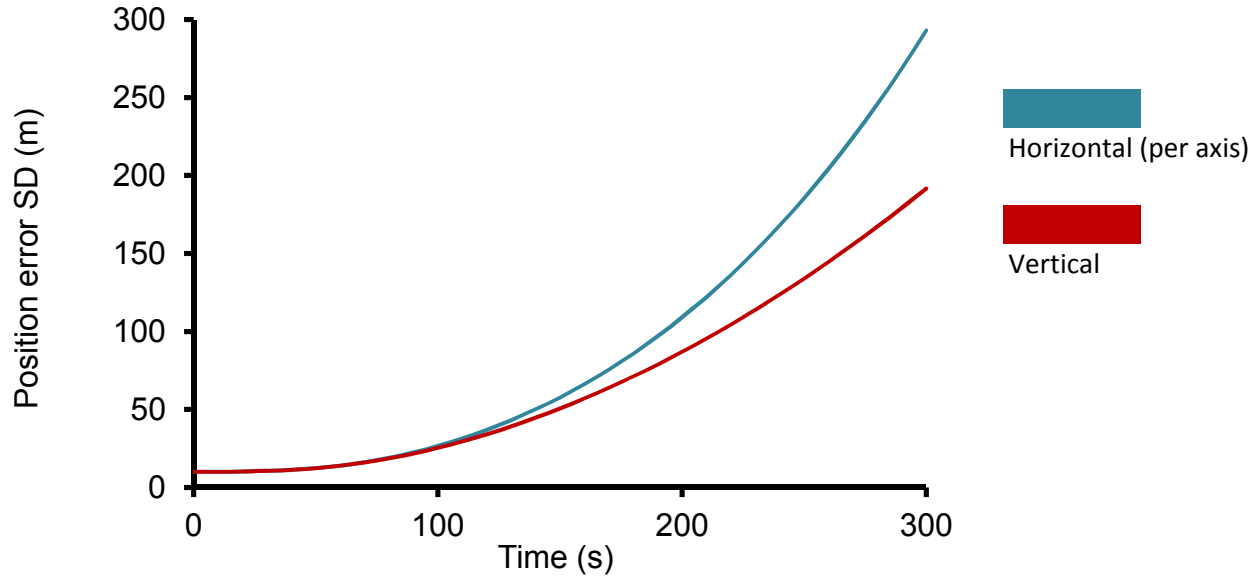
Initial position error	10	m
Initial velocity error	0.1	$m\,s^{-1}$
Initial roll and pitch error	0.0003	rad
Accelerometer bias	0.003	$m\,s^{-2}$
Gyro bias	5.00E-06	$rad\,s^{-1}$

Noise power spectral density per axis

Accelerometer noise	1.00E-06	m^2s^{-3}
Gyro noise	1.00E-09	rad^2s^{-1}

Note: The time interval would normally be much shorter.

See Section 5.7.1 for the equations describing short-term straight-line propagation errors



Error standard deviations (meters)

Time (s)	From initial velocity error	From acceleration error	From accelerometer bias	From gyro bias	From accelerometer noise	From gyro noise	Total per horizontal axis	Total vertical
0	0	0	0	0	0	0	10	10
5	0.5	0.0375	0.03675	0.001021	0.006455	0.000791	10.01263	10.01263
10	1	0.15	0.147	0.008167	0.018257	0.004472	10.05209	10.05209
15	1.5	0.3375	0.33075	0.027563	0.033541	0.012324	10.12301	10.12297
20	2	0.6	0.588	0.065333	0.05164	0.025298	10.23295	10.23271
25	2.5	0.9375	0.91875	0.127604	0.072169	0.044194	10.39213	10.39126
30	3	1.35	1.323	0.2205	0.094868	0.069714	10.61298	10.61046
35	3.5	1.8375	1.80075	0.350146	0.119548	0.102491	10.90947	10.90337
40	4	2.4	2.352	0.522667	0.146059	0.143108	11.29632	11.28332
45	4.5	3.0375	2.97675	0.744188	0.174284	0.192108	11.78807	11.76299
50	5	3.75	3.675	1.020833	0.204124	0.25	12.39816	12.35353

55	5.5	4.5375	4.44675	1.358729	0.235496	0.317265	13.13829	13.06399
60	6	5.4	5.292	1.764	0.268328	0.39436	14.01801	13.90098
65	6.5	6.3375	6.21075	2.242771	0.302559	0.481724	15.04463	14.86872
70	7	7.35	7.203	2.801167	0.338132	0.579776	16.22352	15.96935
75	7.5	8.4375	8.26875	3.445313	0.375	0.688919	17.55845	17.20332
80	8	9.6	9.408	4.181333	0.413118	0.809543	19.05204	18.5699
85	8.5	10.8375	10.62075	5.015354	0.452447	0.942025	20.70622	20.06755
90	9	12.15	11.907	5.9535	0.49295	1.086729	22.5226	21.69429
95	9.5	13.5375	13.26675	7.001896	0.534595	1.24401	24.50266	23.44795
100	10	15	14.7	8.166667	0.57735	1.414214	26.64804	25.32634
105	10.5	16.5375	16.20675	9.453938	0.621188	1.597674	28.96054	27.32734
110	11	18.15	17.787	10.86983	0.666083	1.79472	31.44229	29.449
115	11.5	19.8375	19.44075	12.42048	0.71201	2.005671	34.09571	31.68953
120	12	21.6	21.168	14.112	0.758947	2.230838	36.92351	34.04732
125	12.5	23.4375	22.96875	15.95052	0.806872	2.470529	39.92873	36.52097
130	13	25.35	24.843	17.94217	0.855765	2.725043	43.11469	39.1092
135	13.5	27.3375	26.79075	20.09306	0.905608	2.994673	46.48497	41.81092
140	14	29.4	28.812	22.40933	0.956382	3.279707	50.04339	44.62517
145	14.5	31.5375	30.90675	24.8971	1.008072	3.580428	53.79398	47.5511
150	15	33.75	33.075	27.5625	1.06066	3.897114	57.74099	50.58797
155	15.5	36.0375	35.31675	30.41165	1.114133	4.230038	61.88883	53.73514
160	16	38.4	37.632	33.45067	1.168475	4.579467	66.24207	56.99204
165	16.5	40.8375	40.02075	36.68569	1.223673	4.945667	70.80543	60.35817
170	17	43.35	42.483	40.12283	1.279714	5.328897	75.58376	63.83311
175	17.5	45.9375	45.01875	43.76823	1.336585	5.729413	80.58202	67.41645
180	18	48.6	47.628	47.628	1.394274	6.147468	85.80529	71.10788
185	18.5	51.3375	50.31075	51.70827	1.45277	6.58331	91.25873	74.90708
190	19	54.15	53.067	56.01517	1.512063	7.037186	96.9476	78.8138
195	19.5	57.0375	55.89675	60.55481	1.57214	7.509336	102.8772	82.8278
200	20	60	58.8	65.33333	1.632993	8	109.053	86.94887
205	20.5	63.0375	61.77675	70.35685	1.694612	8.509414	115.4804	91.17683
210	21	66.15	64.827	75.6315	1.756986	9.037811	122.1649	95.51151
215	21.5	69.3375	67.95075	81.1634	1.820108	9.58542	129.1121	99.95277
220	22	72.6	71.148	86.95867	1.883967	10.15247	136.3277	104.5005
225	22.5	75.9375	74.41875	93.02344	1.948557	10.73918	143.8172	109.1545
230	23	79.35	77.763	99.36383	2.013869	11.34579	151.5865	113.9147
235	23.5	82.8375	81.18075	105.986	2.079894	11.97249	159.6412	118.7811
240	24	86.4	84.672	112.896	2.146625	12.61953	167.9871	123.7534
245	24.5	90.0375	88.23675	120.1	2.214055	13.2871	176.6301	128.8318
250	25	93.75	91.875	127.6042	2.282177	13.97542	185.5759	134.016
255	25.5	97.5375	95.58675	135.4146	2.350984	14.68471	194.8305	139.306
260	26	101.4	99.372	143.5373	2.420468	15.41517	204.3996	144.7018
265	26.5	105.3375	103.2308	151.9786	2.490624	16.16701	214.2893	150.2033
270	27	109.35	107.163	160.7445	2.561445	16.94043	224.5054	155.8104
275	27.5	113.4375	111.1688	169.8411	2.632925	17.73563	235.0538	161.5232
280	28	117.6	115.248	179.2747	2.705057	18.55283	245.9406	167.3415
285	28.5	121.8375	119.4008	189.0512	2.777836	19.3922	257.1717	173.2654
290	29	126.15	123.627	199.1768	2.851257	20.25396	268.7531	179.2947
295	29.5	130.5375	127.9268	209.6577	2.925313	21.1383	280.6907	185.4295
300	30	135	132.3	220.5	3	22.04541	292.9907	191.6697