

Problem 1:

```
function pdot = twoBodyOde(t,p,mu)
    pos = p(1:3);
    vel = p(4:6);
    rad = norm(pos,2);
    posdot = vel;
    veldot = -mu/(rad^3)*pos;
    pdot = [posdot; veldot];
end

function [t,p]=twoBodyOdeSolver(pos,vel,t0,tf,mu)
%This function solves the two body ODE given initial velocity, position,
time, and final time
%
%Input: pos, a column vector with the initial position
%Input: vel, a column vector with the initial velocity
%Input: t0, the initial time in seconds
%Input: tf, the final time in seconds
%Input: mu, gravitational parameter
%
%Output: t, a column vector with times between t0 and tf
%Output: p, a matrix with the first 3 columns being position vectors, and the
last 3 being velocity vectors
    options = odeset('RelTol',1e-8);
    po=[pos,vel];
    trange=[t0,tf];
    [t,p] = ode113(@twoBodyOde,trange,po,options,mu);
end
```

```

clc;clear;
r1=[68524.298;-17345.863;-51486.409];
v1=[-0.578936;0.957665;0.357759];
r2=[2721.965;3522.863;5267.244];
v2=[9.572396;-0.474701;-2.725664];
r3=[6997.56;-34108.00;20765.49];
v3=[0.15599;0.25517;1.80763];
r4=[1882.725;9864.690;4086.088];
v4=[-5.565367;5.451548;2.258105];
r5=[-664.699;8112.75;4479.81];
v5=[-0.87036;-0.068046;-8.290459];
r6=[-10515.45;-5235.37;49.1700];
v6=[-2.10305;-4.18146;5.56329];
t0=60*[1329.16;3.93;242.82;616.79;21.02;27];
ts=60*[3885.73;1771.58;612.69;1880.41;1913.38;57];
r=[r1,r2,r3,r4,r5,r6]';
v=[v1,v2,v3,v4,v5,v6]';
mu=398600;
positions={};
times=[];

for i=1:length(t0)
    pos=r(i,:);
    vel=v(i,:);
    ti=t0(i);
    tf=ts(i);
    [t,p]=twoBodyOdeSolver(pos,vel,ti,tf,mu);
    positions{i}=p;
    for j=1:length(t)
        times(j,i)=t(j);
    end
end

for i=1:length(positions)
    figure(i)
    pandv=positions{i};
    plot3(pandv(:,1),pandv(:,2),pandv(:,3))
    tf=times(size(pandv,1),i);
    fprintf('%i) The postion and velocity at tf = %g sec is :\n',i,tf)
    table =
array2table([tf,pandv(size(pandv,1),:)],"VariableNames",["Time","X
Position","Y Position","Z Position","X Velocity","Y Velocity","Z Velocity"])
end

```

Results:

1) The position and velocity at $t_f = 233144$ sec is:

Time	X Position	Y Position	Z Position	X Velocity	Y Velocity	Z Velocity
2.3314e+05	-5513	-1054.5	4375.5	-0.29208	-10.138	1.1918

2) The position and velocity at $t_f = 106295$ sec is:

Time	X Position	Y Position	Z Position	X Velocity	Y Velocity	Z Velocity
1.0629e+05	-17050	-15006	-21330	-0.64889	1.4825	2.5805

3) The position and velocity at $t_f = 36761.4$ sec is:

Time	X Position	Y Position	Z Position	X Velocity	Y Velocity	Z Velocity
36761	-442.97	8019.8	6446.1	-0.92912	0.77949	-7.722

4) The position and velocity at $t_f = 112825$ sec is:

Time	X Position	Y Position	Z Position	X Velocity	Y Velocity	Z Velocity
1.1282e+05	-88561	-12407	-5139.2	0.84727	-0.61711	-0.25562

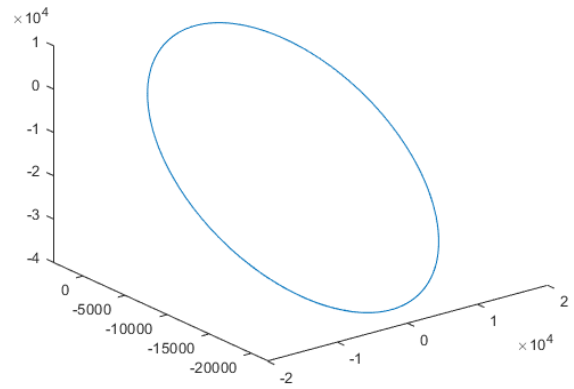
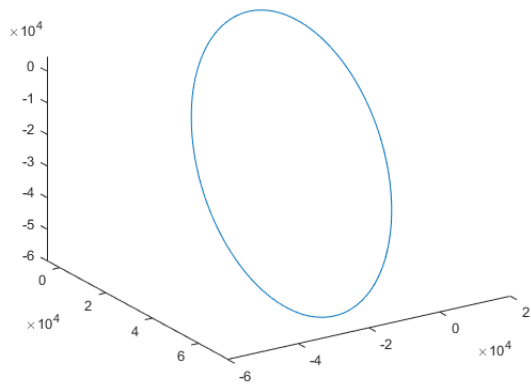
5) The position and velocity at $t_f = 114803$ sec is:

Time	X Position	Y Position	Z Position	X Velocity	Y Velocity	Z Velocity
1.148e+05	-152.2	7659.3	8708	-0.95798	1.519	-7.0144

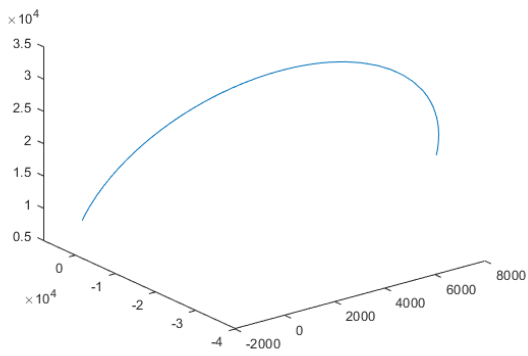
6) The position and velocity at $t_f = 3420$ sec is:

Time	X Position	Y Position	Z Position	X Velocity	Y Velocity	Z Velocity
3420	-11503	-11006	9407.5	0.46744	-2.418	4.6943

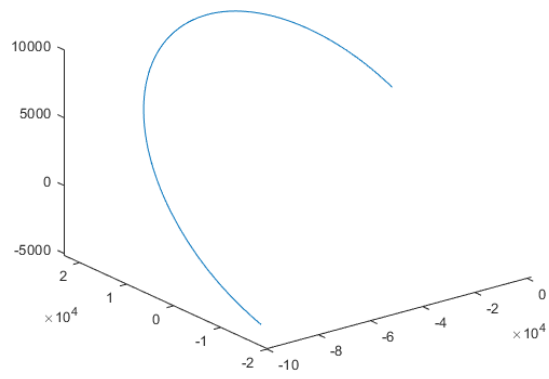
ODE113 Plot



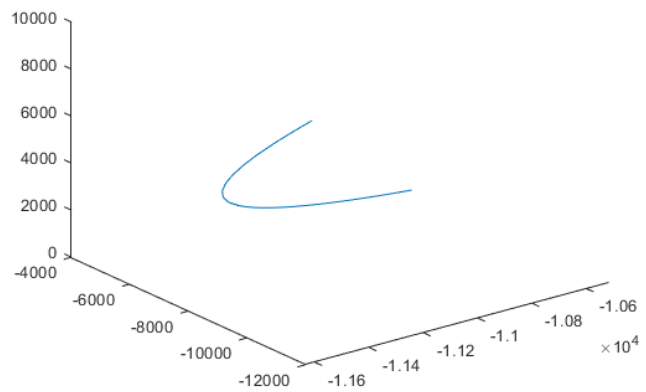
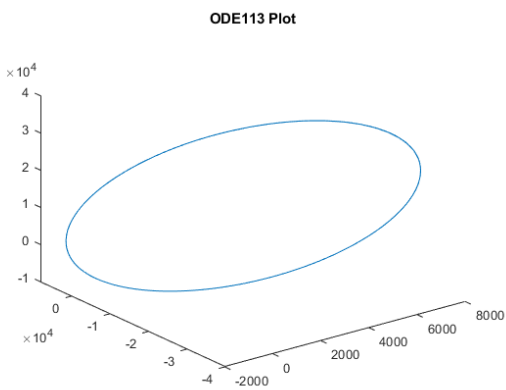
ODE113 Plot



ODE113 Plot



ODE113 Plot



Problem 2:

```
function [r,v,E,nu] = propagateKepler_Hackbardt_Chris(r0,v0,t0,t,mu)
%This function finds the position and velocity in an orbit at final time, t
%
%Input: r0, a column vector with the initial position
%Input: v0, a column vector with the initial velocity
%Input: t0, the initial time in seconds
%Input: t, the final time in seconds
%Input: mu, gravitational parameter
%
%Output: r, a column vector with the position
%Output: v, a column vector with the velocity
%Output: E, eccentric anomaly
%Output: nu, true anomaly

oe = rv2oe_Hackbardt_Chris(r0,v0,mu);
a = oe(1);
e = oe(2);
nu0 = oe(6);
E0 = 2*atan2(sqrt(1-e)*sin(nu0/2),sqrt(1+e)*cos(nu0/2));
tau=2*pi*sqrt(a^3/mu);
k=floor((t)/tau);
E = KeplerSolver_Hackbardt_Chris(a,e,mu,t0,t,E0,k);
nu= 2*atan2(sqrt(1+e)*sin(E/2),sqrt(1-e)*cos(E/2));
oe(6)=nu;
[r,v] = oe2rv_Hackbardt_Chris(oe,mu);
end

function E = KeplerSolver_Hackbardt_Chris(a,e,mu,t0,t,E0,k)
%This function solves Kepler's equation using fixed point iteration
%
%Input: a, semi-major axis
%Input: e, eccentricity
%Input: mu, gravitational parameter
%Input: t0, the initial time in seconds
%Input: t, the final time in seconds
%Input: E0, initial eccentric anomaly
%Input: k, number of periapsis crossings
%
%Output: E, eccentric anomaly

C=sqrt(mu/a^3)*(t-t0)-(2*pi*k)+(E0-(e*sin(E0)));
f = @(x) e*sin(x)+C;
n=10*ceil(1/(1-e));
guessE=E0-(e*sin(E0));
for i=1:n
    guessE=f(guessE);
end
E=guessE;
end
```

Problem 3:

```
clc;clear;
%Defines variables
r0=[68524.298;-17345.863;-51486.409];
v0=[-0.578936;0.957665;0.357759];
t0=1329.16;
tf=3885.73;
t0=t0*60;
tf=tf*60;
mu=398600;

%Calculates position and velocity at tf
[r,v,E,nu] = propagateKepler_Hackbardt_Chris(r0,v0,t0,tf,mu);

%Calculates position and velocity at 100 times between t0 and tf
times=linspace(t0,tf)';
randv=zeros(length(times),6);
for i=1:length(times)
    t=times(i);
    [r,v] = propagateKepler_Hackbardt_Chris(r0,v0,t0,t,mu);
    randv(i,:)=[r',v'];
end

%Plots positions at the 100 times
plot3(randv(:,1),randv(:,2),randv(:,3))
%Creates a table with all positions and velocities at the 100 times
table = array2table([times,randv],"VariableNames",["Time","X Position","Y Position","Z Position","X Velocity","Y Velocity","Z Velocity"]);
table

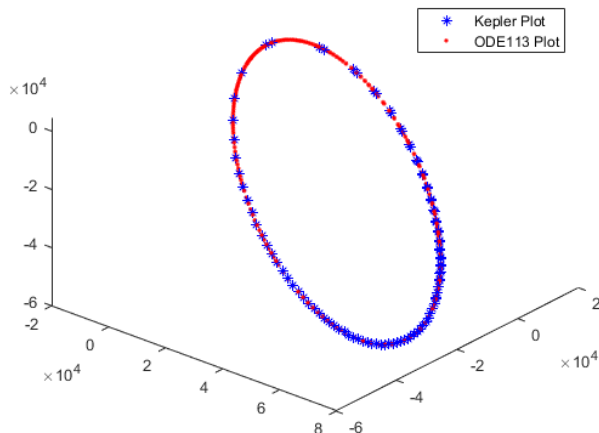
%Prints values at tf
fprintf('The eccentric anomaly E is %g\n',E)
fprintf('The true anomaly nu is %g\n',nu)
vector = array2table(randv(i,:),["VariableNames",["X Position","Y Position","Z Position","X Velocity","Y Velocity","Z Velocity"]]);
vector
```

Results:

The eccentric anomaly E is 0.140753

The true anomaly nu is 0.523527

X Position	Y Position	Z Position	X Velocity	Y Velocity	Z Velocity
-5512.9	-1051.6	4375.2	-0.29383	-10.138	1.1931



Time	X Position	Y Position	Z Position	X Velocity	Y Velocity	Z Velocity
79749.6	68524.3	-17345.9	-51486.4	-0.57894	0.957665	0.357759
81299.04	67577.7	-15849.8	-50894.8	-0.64328	0.973355	0.406164
82848.47	66529.65	-14329.9	-50226.8	-0.70994	0.988349	0.456424
84397.91	65376.35	-12787.4	-49479.3	-0.77919	1.00258	0.508773
85947.35	64113.52	-11223.5	-48649	-0.85139	1.015959	0.563485
87496.78	62736.29	-9639.58	-47731.8	-0.92692	1.028374	0.620878
89046.22	61239.13	-8037.27	-46723.4	-1.00627	1.039675	0.681329
90595.65	59615.74	-6418.43	-45618.6	-1.08997	1.049674	0.745286
92145.09	57858.86	-4785.26	-44411.7	-1.1787	1.058119	0.813288
93694.53	55960.09	-3140.42	-43095.9	-1.27326	1.064683	0.885993
95243.96	53909.66	-1487.14	-41663.3	-1.37465	1.068927	0.964214
96793.4	51696.05	170.5467	-40104.6	-1.48412	1.070257	1.048972
98342.84	49305.6	1827.528	-38408.6	-1.60323	1.067855	1.141566
99892.27	46721.83	3477.179	-36562.1	-1.73403	1.060567	1.243691
101441.7	43924.65	5110.719	-34548.5	-1.87922	1.046724	1.357601
102991.1	40889.06	6716.194	-32347.4	-2.04248	1.023831	1.48638
104540.6	37583.33	8276.806	-29932.5	-2.22894	0.98801	1.634382
106090	33966.09	9768.038	-27269.5	-2.44607	0.932926	1.808007
107639.5	29981.66	11152.34	-24311.5	-2.70525	0.847563	2.017116
109188.9	25551.93	12368.48	-20992.2	-3.02475	0.711085	2.277874
110738.3	20561.35	13307.64	-17211.6	-3.43609	0.479296	2.618919
112287.8	14827.22	13750.5	-12807.2	-3.99768	0.041213	3.096126
113837.2	8040.844	13156.63	-7488.08	-4.81586	-0.96748	3.826637
115386.6	-194.413	9627.811	-765.95	-5.68452	-4.38082	4.825249
116936.1	-5464.81	-2963.39	4519.915	0.753693	-9.76203	0.34503
118485.5	-1532.56	-14573.3	2576.042	3.222712	-5.62162	-1.96383
120034.9	3477.492	-21656.3	-634.66	3.170179	-3.75939	-2.1004
121584.4	8218.226	-26667.5	-3833.78	2.94579	-2.79569	-2.01816
123133.8	12612.01	-30502.4	-6875.85	2.72974	-2.19493	-1.90782
124683.3	16690.98	-33562.1	-9747.62	2.539671	-1.77673	-1.80025
126232.7	20494.46	-36062.3	-12459	2.373427	-1.4643	-1.70108
127782.1	24055.97	-38134.3	-15023.5	2.226639	-1.21924	-1.61058
129331.6	27402.58	-39864.2	-17454	2.095466	-1.02008	-1.52783
130881	30556.04	-41312.3	-19761.5	1.976893	-0.8538	-1.45171
132430.4	33534.01	-42522.6	-21955.6	1.868597	-0.71201	-1.38123
133979.9	36350.96	-43528.4	-24044.2	1.768788	-0.58902	-1.31554
135529.3	39018.92	-44355.5	-26034.4	1.676066	-0.48083	-1.25394
137078.7	41547.97	-45024.6	-27931.9	1.589326	-0.38456	-1.19585
138628.2	43946.67	-45552.2	-29741.7	1.50768	-0.29802	-1.14077
140177.6	46222.33	-45952.3	-31468.3	1.430406	-0.21957	-1.08832
141727.1	48381.26	-46236.2	-33115.5	1.356909	-0.14793	-1.03815
143276.5	50428.91	-46413.7	-34686.4	1.286696	-0.08208	-0.98997
144825.9	52370.05	-46493.1	-36184.2	1.219348	-0.0212	-0.94354
146375.4	54208.82	-46481.6	-37611.1	1.154513	0.035375	-0.89865
147924.8	55948.87	-46385.4	-38969.7	1.091884	0.088182	-0.85511
149474.2	57593.43	-46210	-40261.6	1.0312	0.137679	-0.81277
151023.7	59145.31	-45960.3	-41488.8	0.972228	0.184247	-0.77147
152573.1	60607.02	-45640.4	-42652.8	0.914766	0.228206	-0.73109
154122.5	61980.74	-45254.3	-43754.8	0.858632	0.269832	-0.69153
155672	63268.41	-44805.3	-44796.1	0.803665	0.30936	-0.65267
157221.4	64471.72	-44296.6	-45777.7	0.749717	0.346994	-0.61442
158770.9	65592.15	-43730.9	-46700.4	0.696656	0.382909	-0.57669

160320.3	66630.97	-43110.8	-47565	0.644358	0.417259	-0.5394
161869.7	67589.27	-42438.6	-48372.1	0.592709	0.450181	-0.50249
163419.2	68467.98	-41716.4	-49122.3	0.541604	0.481793	-0.46587
164968.6	69267.87	-40946.2	-49815.9	0.490942	0.5122	-0.42948
166518	69989.54	-40129.7	-50453.3	0.440627	0.541494	-0.39325
168067.5	70633.48	-39268.7	-51034.6	0.390568	0.569759	-0.35712
169616.9	71199.99	-38364.6	-51560	0.340677	0.597068	-0.32103
171166.3	71689.28	-37418.8	-52029.5	0.290866	0.623487	-0.28492
172715.8	72101.39	-36432.8	-52443	0.241052	0.649072	-0.24873
174265.2	72436.25	-35407.8	-52800.2	0.19115	0.673875	-0.21239
175814.7	72693.66	-34344.9	-53101	0.141075	0.697942	-0.17585
177364.1	72873.28	-33245.3	-53345	0.090741	0.721313	-0.13905
178913.5	72974.66	-32110.1	-53531.7	0.040057	0.744025	-0.1019
180463	72997.18	-30940.1	-53660.6	-0.01107	0.766107	-0.06436
182012.4	72940.08	-29736.4	-53730.9	-0.06273	0.787586	-0.02634
183561.8	72802.45	-28499.9	-53741.9	-0.11503	0.808484	0.012224
185111.3	72583.23	-27231.4	-53692.7	-0.16808	0.828817	0.051423
186660.7	72281.16	-25931.8	-53582.2	-0.22198	0.848597	0.09134
188210.1	71894.83	-24602	-53409.2	-0.27687	0.867832	0.132068
189759.6	71422.61	-23242.8	-53172.5	-0.33286	0.886523	0.173712
191309	70862.68	-21855	-52870.4	-0.39012	0.904668	0.216383
192858.5	70212.96	-20439.6	-52501.3	-0.44879	0.922255	0.260208
194407.9	69471.11	-18997.4	-52063.4	-0.50906	0.939268	0.305324
195957.3	68634.52	-17529.2	-51554.4	-0.57112	0.955678	0.351889
197506.8	67700.24	-16036.2	-50972.1	-0.6352	0.97145	0.40008
199056.2	66664.93	-14519.2	-50313.7	-0.70156	0.986534	0.450098
200605.6	65524.88	-12979.4	-49576.2	-0.77047	1.000864	0.502175
202155.1	64275.84	-11418.1	-48756.3	-0.84228	1.014354	0.556578
203704.5	62913.05	-9836.56	-47850.1	-0.91738	1.026895	0.613621
205253.9	61431.06	-8236.43	-46853.2	-0.99623	1.038343	0.673671
206803.4	59823.66	-6619.52	-45760.7	-1.07936	1.048515	0.737166
208352.8	58083.72	-4988	-44566.8	-1.16742	1.057169	0.804635
209902.3	56203.01	-3344.44	-43264.9	-1.26122	1.063986	0.876717
211451.7	54171.92	-1692	-41847.2	-1.3617	1.068546	0.954206
213001.1	51979.19	-34.6094	-40304.6	-1.47009	1.070276	1.038091
214550.6	49611.44	1622.782	-38626.3	-1.5879	1.06839	1.129633
216100	47052.6	3273.765	-36799.2	-1.71713	1.061784	1.230471
217649.4	44283.06	4909.869	-34807.3	-1.86037	1.048867	1.342776
219198.9	41278.52	6519.607	-32630.7	-2.02114	1.027268	1.46951
220748.3	38008.22	8086.904	-30243.9	-2.20439	0.993325	1.614839
222297.7	34432.19	9588.419	-27613.8	-2.41721	0.941095	1.784848
223847.2	30496.87	10988.64	-24695.4	-2.67038	0.86033	1.988859
225396.6	26127.52	12230.17	-21425.4	-2.98107	0.731881	2.242017
226946.1	21214.46	13212.22	-17709	-3.37861	0.515788	2.570877
228495.5	15585.73	13735.49	-13394	-3.91697	0.114184	3.026592
230044.9	8952.454	13323.83	-8210.91	-4.6965	-0.78126	3.716344
231594.4	894.0956	10394.1	-1683.01	-5.66034	-3.63824	4.735792
233143.8	-5512.9	-1051.61	4375.176	-0.29383	-10.1381	1.193149

Problem 4:

```
clc;clear;
%Defines variables
r0=[2721.965;3522.863;5267.244];
v0=[9.572396;-0.474701;-2.725664];
t0=3.93;
tf=1771.58;
t0=t0*60;
tf=tf*60;
mu=398600;

%Calculates position and velocity at tf
[r,v,E,nu] = propagateKepler_Hackbardt_Chris(r0,v0,t0,tf,mu);

%Calculates position and velocity at 100 times between t0 and tf
times=linspace(t0,tf)';
randv=zeros(length(times),6);
for i=1:length(times)
    t=times(i);
    [r,v] = propagateKepler_Hackbardt_Chris(r0,v0,t0,t,mu);
    randv(i,:)=r',v';
end

%Calculates orbit using Kepler and ODE113
[time,p]=twoBodyOdeSolver(r0,v0,t0,tf,mu);

%Plots positions at the 100 times
plot3(randv(:,1),randv(:,2),randv(:,3),'b*',p(:,1),p(:,2),p(:,3),'r.')
legend('Kepler Plot','ODE113 Plot','Location','northeast')

%Creates a table with all positions and velocities at the 100 times
saveTable =[times,randv];
table = array2table(saveTable, "VariableNames", ["Time", "X Position", "Y Position", "Z Position", "X Velocity", "Y Velocity", "Z Velocity"]);
table
xlswrite('Orbit2.xlsx',saveTable)

%Prints values at tf
fprintf('The eccentric anomaly E is %g\n',E)
fprintf('The true anomaly nu is %g\n',nu)
vector = array2table(randv(i,:), "VariableNames", ["X Position", "Y Position", "Z Position", "X Velocity", "Y Velocity", "Z Velocity"]);
vector
```

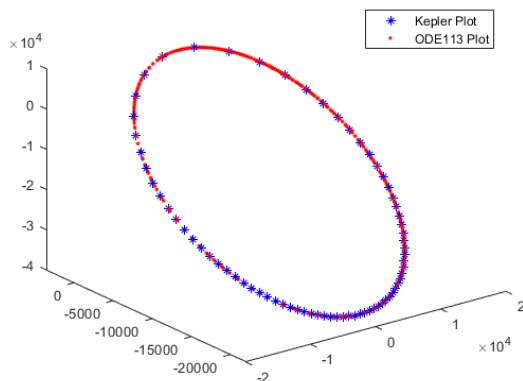
Results:

The eccentric anomaly E is 4.32372

The true anomaly nu is 3.6652

X Position Y Position Z Position X Velocity Y Velocity Z Velocity

-17050 -15006 -21330 -0.64891 1.4825 2.5805



	X	Y	Z	X	Y	Z
Time	Position	Position	Position	Velocity	Velocity	Velocity
235.8	2721.962	3522.863	5267.245	9.572397	-0.4747	-2.72566
1307.103	10354.93	1426.997	256.9848	4.754888	-2.72616	-5.46767
2378.406	13838.19	-1577.66	-5412.83	2.094398	-2.76905	-4.99891
3449.709	15313.13	-4414.16	-10397.5	0.793998	-2.51544	-4.31623
4521.012	15733.23	-6964.19	-14695	0.051134	-2.24814	-3.72401
5592.315	15517.03	-9239.89	-18410.4	-0.42272	-2.0048	-3.22593
6663.618	14880.07	-11268.8	-21632.8	-0.74752	-1.787	-2.80029
7734.921	13947.71	-13076.4	-24429.5	-0.98099	-1.59069	-2.42865
8806.224	12799.59	-14683.2	-26850.9	-1.15415	-1.41158	-2.09767
9877.527	11489.82	-16105.7	-28935	-1.28507	-1.24609	-1.79773
10948.83	10057.22	-17356.9	-30711.3	-1.38495	-1.09135	-1.52187
12020.13	8530.893	-18447.1	-32202.5	-1.46104	-0.94509	-1.26484
13091.44	6933.531	-19384.2	-33426.6	-1.51822	-0.80548	-1.02263
14162.74	5283.498	-20174.7	-34397.7	-1.55983	-0.67101	-0.79205
15234.04	3596.163	-20823.3	-35126.9	-1.58817	-0.54038	-0.57052
16305.35	1884.831	-21333.5	-35622.6	-1.60484	-0.41249	-0.35589
17376.65	161.4198	-21707.8	-35891.2	-1.61086	-0.28634	-0.14627
18447.95	-1563.03	-21947.3	-35937.2	-1.60685	-0.16098	0.059988
19519.25	-3277.92	-22052.6	-35763.3	-1.59304	-0.03552	0.264432
20590.56	-4972.76	-22023.1	-35370.8	-1.56936	0.090944	0.468533
21661.86	-6636.76	-21857.1	-34759.1	-1.53536	0.219355	0.673757
22733.16	-8258.47	-21552	-33926.2	-1.49025	0.350725	0.881613
23804.47	-9825.37	-21104.2	-32868.6	-1.43277	0.486185	1.093717
24875.77	-11323.3	-20508.4	-31580.7	-1.36111	0.627041	1.311859
25947.07	-12735.7	-19758.2	-30054.9	-1.27269	0.774848	1.538084
27018.38	-14042.9	-18845.1	-28281.4	-1.16387	0.931512	1.774803
28089.68	-15220.3	-17758.3	-26247.4	-1.02941	1.099439	2.024924
29160.98	-16236.7	-16484.3	-23936.7	-0.86162	1.281745	2.292038
30232.28	-17050.4	-15005.4	-21328.8	-0.64881	1.482583	2.580636
31303.59	-17604.2	-13299.1	-18397.8	-0.37242	1.707626	2.89632
32374.89	-17814.8	-11335.2	-15111.1	-0.00113	1.964751	3.245749
33446.19	-17553	-9074.09	-11429.1	0.522239	2.264755	3.635167
34517.5	-16601.8	-6462.83	-7308.53	1.313425	2.620372	4.062129
35588.8	-14551.9	-3439.18	-2729.62	2.641106	3.030374	4.470114
36660.1	-10510.3	1.692313	2134.548	5.213434	3.330586	4.444295
37731.41	-2582.27	3134.912	5702.228	9.635353	1.862071	1.121619
38802.71	7217.775	2764.127	3102.047	7.080397	-2.13961	-4.97045
39874.01	12446.75	-72.9509	-2645.01	3.165989	-2.83169	-5.31973
40945.32	14747.54	-3029.83	-7996.05	1.343707	-2.65031	-4.65052
42016.62	15621.86	-5724.53	-12624.7	0.377192	-2.37959	-4.00729
43087.92	15688.32	-8134.17	-16618.6	-0.20968	-2.12316	-3.46466
44159.22	15242.02	-10283.1	-20077.9	-0.5992	-1.89297	-3.00542
45230.53	14445.26	-12198.5	-23080.3	-0.87328	-1.68648	-2.60873
46301.83	13397.02	-13903.5	-25684	-1.07374	-1.49927	-2.25882
47373.13	12162.47	-15416.3	-27932.7	-1.22405	-1.32736	-1.94436
48444.44	10787.16	-16751.8	-29859.7	-1.33835	-1.16756	-1.65721
49515.74	9304.538	-17921.4	-31491	-1.4256	-1.01731	-1.39133
50587.04	7740.177	-18934.2	-32846.8	-1.49174	-0.87459	-1.14214
51658.35	6114.407	-19797.3	-33942.9	-1.5408	-0.73772	-0.9061
52729.65	4443.957	-20516.4	-34791.8	-1.57554	-0.60531	-0.68034
53800.95	2743.065	-21095.5	-35403.4	-1.59789	-0.47619	-0.46251

54872.25	1024.271	-21537.5	-35784.9	-1.60913	-0.34928	-0.2506
55943.56	-700.999	-21844.3	-35941.8	-1.61008	-0.22364	-0.04286
57014.86	-2421.98	-22016.8	-35877.7	-1.60117	-0.09834	0.162303
58086.16	-4128.17	-22054.8	-35594.4	-1.58246	0.027503	0.366394
59157.47	-5808.98	-21957.3	-35092.5	-1.5537	0.15482	0.570871
60228.77	-7453.33	-21722.2	-34370.6	-1.51427	0.284577	0.777217
61300.07	-9049.3	-21346.3	-33426	-1.46317	0.41784	0.986985
62371.38	-10583.6	-20825.3	-32254.1	-1.39887	0.55582	1.201869
63442.68	-12041.1	-20153.2	-30848.4	-1.31921	0.699936	1.423775
64513.98	-13403.6	-19322.8	-29200.2	-1.22114	0.851905	1.654917
65585.28	-14649.4	-18324.4	-27298.3	-1.10028	1.013859	1.897932
66656.59	-15750.7	-17145.9	-25128.3	-0.95032	1.188528	2.156047
67727.89	-16671.8	-15772	-22671.9	-0.76183	1.379496	2.433272
68799.19	-17364.1	-14182.7	-19906.2	-0.52018	1.591604	2.734633
69870.5	-17759	-12351.9	-16801.9	-0.20144	1.831527	3.066309
70941.8	-17753.7	-10245.3	-13323	0.236209	2.108538	3.43513
72013.1	-17182.8	-7816.58	-9426.9	0.872899	2.43484	3.845003
73084.41	-15753.2	-5006.75	-5075.38	1.881638	2.820706	4.277809
74155.71	-12871.9	-1762.56	-300.79	3.695142	3.226203	4.579815
75227.01	-7171.67	1746.393	4339.413	7.364131	3.089055	3.609103
76298.32	2717.893	3523.065	5268.403	9.573802	-0.47288	-2.72294
77369.62	10352.91	1428.156	259.3089	4.756423	-2.72594	-5.46764
78440.92	13837.3	-1576.49	-5410.7	2.095101	-2.76913	-4.99919
79512.22	15312.79	-4413.09	-10395.7	0.794375	-2.51554	-4.31648
80583.53	15733.21	-6963.23	-14693.5	0.051364	-2.24824	-3.72423
81654.83	15517.21	-9239.03	-18409	-0.42256	-2.00489	-3.22612
82726.13	14880.39	-11268.1	-21631.6	-0.74741	-1.78708	-2.80044
83797.44	13948.13	-13075.7	-24428.5	-0.98091	-1.59077	-2.42879
84868.74	12800.08	-14682.6	-26850	-1.15409	-1.41165	-2.09779
85940.04	11490.37	-16105.2	-28934.3	-1.28503	-1.24615	-1.79785
87011.35	10057.81	-17356.5	-30710.6	-1.38491	-1.09141	-1.52197
88082.65	8531.514	-18446.7	-32202	-1.46101	-0.94515	-1.26494
89153.95	6934.176	-19383.9	-33426.2	-1.5182	-0.80554	-1.02272
90225.25	5284.161	-20174.4	-34397.4	-1.55981	-0.67106	-0.79214
91296.56	3596.838	-20823.1	-35126.7	-1.58816	-0.54043	-0.57061
92367.86	1885.513	-21333.4	-35622.5	-1.60483	-0.41254	-0.35597
93439.16	162.1046	-21707.6	-35891.2	-1.61086	-0.28639	-0.14635
94510.47	-1562.34	-21947.3	-35937.2	-1.60685	-0.16103	0.059906
95581.77	-3277.24	-22052.6	-35763.4	-1.59305	-0.03557	0.264351
96653.07	-4972.09	-22023.1	-35371	-1.56937	0.090894	0.468452
97724.38	-6636.11	-21857.2	-34759.3	-1.53538	0.219304	0.673675
98795.68	-8257.84	-21552.2	-33926.6	-1.49027	0.350672	0.88153
99866.98	-9824.76	-21104.4	-32869.1	-1.4328	0.48613	1.093632
100938.3	-11322.7	-20508.7	-31581.2	-1.36114	0.626983	1.311771
102009.6	-12735.2	-19758.5	-30055.6	-1.27273	0.774787	1.537992
103080.9	-14042.4	-18845.5	-28282.2	-1.16392	0.931448	1.774706
104152.2	-15219.9	-17758.8	-26248.3	-1.02947	1.099369	2.024821
105223.5	-16236.3	-16484.8	-23937.7	-0.86169	1.281669	2.291928
106294.8	-17050.1	-15006.1	-21329.9	-0.64891	1.482499	2.580516

Problem 5:

```
clc;clear;
%Defines variables
r0=[6997.56;-34108.00;20765.49];
v0=[0.15599;0.25517;1.80763];
t0=242.82;
tf=612.69;
t0=t0*60;
tf=tf*60;
mu=398600;

%Calculates position and velocity at tf
[r,v,E,nu] = propagateKepler_Hackbardt_Chris(r0,v0,t0,tf,mu);

%Calculates position and velocity at 100 times between t0 and tf
times=linspace(t0,tf)';
randv=zeros(length(times),6);
for i=1:length(times)
    t=times(i);
    [r,v] = propagateKepler_Hackbardt_Chris(r0,v0,t0,t,mu);
    randv(i,:)=['r','v'];
end

%Calculates orbit using Kepler and ODE113
[time,p]=twoBodyOdeSolver(r0,v0,t0,tf,mu);

%Plots positions at the 100 times
plot3(randv(:,1),randv(:,2),randv(:,3),'b*',p(:,1),p(:,2),p(:,3),'r.')
legend('Kepler Plot','ODE113 Plot','Location','northeast')

%Creates a table with all positions and velocities at the 100 times
saveTable =[times,randv];
table = array2table(saveTable, "VariableNames", ["Time", "X Position", "Y Position", "Z Position", "X Velocity", "Y Velocity", "Z Velocity"]);
table
xlswrite('Orbit3.xlsx',saveTable)

%Prints values at tf
fprintf('The eccentric anomaly E is %g\n',E)
fprintf('The true anomaly nu is %g\n',nu)
vector = array2table(randv(i,:), "VariableNames", ["X Position", "Y Position", "Z Position", "X Velocity", "Y Velocity", "Z Velocity"]);
vector
```

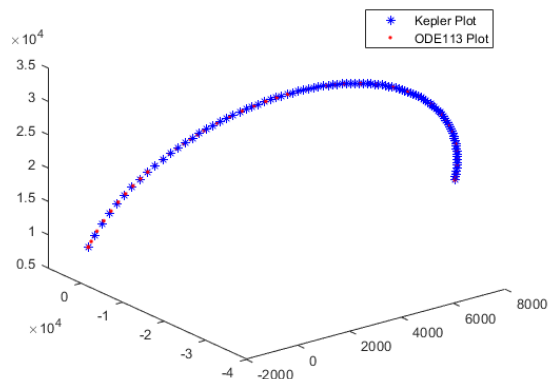
Results:

The eccentric anomaly E is 5.63661

The true anomaly nu is 4.88688

X Position Y Position Z Position X Velocity Y Velocity Z Velocity

-442.97 8019.8 6446.1 -0.92912 0.77949 -7.722



Time	X Position	Y Position	Z Position	X Velocity	Y Velocity	Z Velocity
14569.2	6997.56	-34108	20765.49	0.15599	0.25517	1.80763
14793.36	7031.478	-34045.7	21167.57	0.146639	0.300596	1.779681
15017.53	7063.307	-33973.3	21563.35	0.137353	0.345411	1.751528
15241.69	7093.062	-33890.9	21952.81	0.128127	0.38964	1.723168
15465.85	7120.754	-33798.6	22335.88	0.118958	0.433306	1.694598
15690.02	7146.397	-33696.7	22712.52	0.109842	0.476433	1.665814
15914.18	7170.003	-33585.1	23082.69	0.100775	0.519042	1.636813
16138.35	7191.581	-33464	23446.33	0.091755	0.561154	1.607589
16362.51	7211.142	-33333.5	23803.4	0.082778	0.602788	1.57814
16586.67	7228.695	-33193.8	24153.84	0.073841	0.643963	1.548458
16810.84	7244.25	-33044.9	24497.6	0.064941	0.684698	1.51854
17035	7257.813	-32886.9	24834.62	0.056074	0.725009	1.488378
17259.16	7269.391	-32719.9	25164.85	0.047238	0.764914	1.457966
17483.33	7278.993	-32544	25488.24	0.03843	0.804428	1.427298
17707.49	7286.622	-32359.2	25804.73	0.029646	0.843566	1.396367
17931.65	7292.285	-32165.8	26114.25	0.020884	0.882345	1.365165
18155.82	7295.987	-31963.7	26416.74	0.012142	0.920777	1.333684
18379.98	7297.73	-31753	26712.15	0.003416	0.958876	1.301916
18604.15	7297.519	-31533.8	27000.4	-0.0053	0.996656	1.269851
18828.31	7295.356	-31306.2	27281.43	-0.014	1.034129	1.237481
19052.47	7291.243	-31070.2	27555.17	-0.02269	1.071308	1.204797
19276.64	7285.182	-30825.9	27821.55	-0.03138	1.108204	1.171787
19500.8	7277.174	-30573.4	28080.49	-0.04007	1.144829	1.138441
19724.96	7267.218	-30312.7	28331.92	-0.04876	1.181194	1.104748
19949.13	7255.315	-30043.9	28575.75	-0.05745	1.217308	1.070697
20173.29	7241.463	-29767	28811.92	-0.06614	1.253183	1.036275
20397.45	7225.661	-29482	29040.32	-0.07484	1.288829	1.00147
20621.62	7207.907	-29189.1	29260.88	-0.08356	1.324254	0.966268
20845.78	7188.198	-28888.3	29473.5	-0.09229	1.359468	0.930655
21069.95	7166.531	-28579.7	29678.08	-0.10103	1.39448	0.894617
21294.11	7142.9	-28263.2	29874.55	-0.1098	1.429299	0.858139
21518.27	7117.303	-27938.9	30062.78	-0.11859	1.463932	0.821204
21742.44	7089.733	-27606.9	30242.68	-0.1274	1.498388	0.783795
21966.6	7060.184	-27267.1	30414.14	-0.13624	1.532674	0.745895
22190.76	7028.65	-26919.7	30577.05	-0.14511	1.566797	0.707486
22414.93	6995.123	-26564.7	30731.29	-0.15402	1.600765	0.668549
22639.09	6959.596	-26202.1	30876.74	-0.16296	1.634585	0.629062
22863.25	6922.059	-25831.9	31013.27	-0.17195	1.668263	0.589004
23087.42	6882.503	-25454.2	31140.76	-0.18098	1.701804	0.548354
23311.58	6840.919	-25068.9	31259.07	-0.19005	1.735216	0.507088
23535.75	6797.294	-24676.2	31368.05	-0.19918	1.768503	0.46518
23759.91	6751.618	-24276.1	31467.57	-0.20836	1.80167	0.422605
23984.07	6703.877	-23868.5	31557.47	-0.2176	1.834723	0.379335
24208.24	6654.059	-23453.5	31637.58	-0.2269	1.867666	0.335341
24432.4	6602.149	-23031.2	31707.75	-0.23626	1.900503	0.290592
24656.56	6548.132	-22601.5	31767.81	-0.24569	1.933238	0.245057
24880.73	6491.993	-22164.5	31817.56	-0.2552	1.965873	0.1987
25104.89	6433.713	-21720.1	31856.82	-0.26478	1.998413	0.151486
25329.05	6373.277	-21268.5	31885.41	-0.27445	2.030858	0.103376
25553.22	6310.664	-20809.6	31903.1	-0.2842	2.06321	0.054329
25777.38	6245.854	-20343.5	31909.69	-0.29405	2.095471	0.004302

26001.55	6178.827	-19870.2	31904.95	-0.30399	2.127642	-0.04675
26225.71	6109.561	-19389.7	31888.65	-0.31403	2.15972	-0.09888
26449.87	6038.033	-18901.9	31860.54	-0.32417	2.191706	-0.15213
26674.04	5964.217	-18407.1	31820.36	-0.33443	2.223597	-0.20657
26898.2	5888.088	-17905	31767.84	-0.34481	2.25539	-0.26224
27122.36	5809.62	-17395.9	31702.69	-0.35531	2.28708	-0.31922
27346.53	5728.782	-16879.7	31624.62	-0.36594	2.318662	-0.37758
27570.69	5645.546	-16356.4	31533.3	-0.37671	2.350128	-0.43738
27794.85	5559.88	-15826.1	31428.42	-0.38763	2.381471	-0.4987
28019.02	5471.751	-15288.7	31309.6	-0.39869	2.412678	-0.56163
28243.18	5381.124	-14744.4	31176.5	-0.40992	2.443737	-0.62626
28467.35	5287.962	-14193.2	31028.7	-0.42131	2.474632	-0.69268
28691.51	5192.227	-13635	30865.81	-0.43288	2.505346	-0.761
28915.67	5093.878	-13070	30687.38	-0.44463	2.535857	-0.83133
29139.84	4992.874	-12498.1	30492.94	-0.45658	2.566139	-0.9038
29364	4889.168	-11919.5	30282.01	-0.46873	2.596162	-0.97853
29588.16	4782.714	-11334.2	30054.06	-0.48109	2.625893	-1.05569
29812.33	4673.463	-10742.3	29808.52	-0.49369	2.655291	-1.13541
30036.49	4561.363	-10143.8	29544.82	-0.50652	2.684307	-1.21789
30260.65	4446.358	-9538.86	29262.29	-0.5196	2.712888	-1.3033
30484.82	4328.392	-8927.57	28960.28	-0.53295	2.740968	-1.39185
30708.98	4207.404	-8310.05	28638.04	-0.54657	2.768472	-1.48377
30933.15	4083.329	-7686.44	28294.79	-0.56048	2.795311	-1.57932
31157.31	3956.102	-7056.89	27929.69	-0.5747	2.821381	-1.67878
31381.47	3825.651	-6421.6	27541.84	-0.58924	2.84656	-1.78244
31605.64	3691.904	-5780.78	27130.24	-0.60412	2.870703	-1.89066
31829.8	3554.781	-5134.68	26693.83	-0.61935	2.893639	-2.00381
32053.96	3414.203	-4483.59	26231.47	-0.63496	2.915164	-2.12233
32278.13	3270.084	-3827.85	25741.9	-0.65095	2.935036	-2.2467
32502.29	3122.334	-3167.88	25223.74	-0.66735	2.952965	-2.37744
32726.45	2970.863	-2504.13	24675.5	-0.68416	2.9686	-2.51518
32950.62	2815.574	-1837.17	24095.54	-0.70141	2.98152	-2.66059
33174.78	2656.368	-1167.67	23482.05	-0.71911	2.99121	-2.81447
33398.95	2493.145	-496.422	22833.04	-0.73725	2.997042	-2.97771
33623.11	2325.805	175.6354	22146.29	-0.75585	2.99824	-3.15134
33847.27	2154.246	847.3538	21419.35	-0.77488	2.993843	-3.33651
34071.44	1978.373	1517.35	20649.47	-0.79433	2.982649	-3.5346
34295.6	1798.097	2183.937	19833.61	-0.81415	2.963142	-3.74717
34519.76	1613.345	2845.043	18968.3	-0.83426	2.93339	-3.97602
34743.93	1424.064	3498.107	18049.68	-0.85453	2.890912	-4.22324
34968.09	1230.239	4139.928	17073.35	-0.87476	2.832479	-4.49125
35192.25	1031.91	4766.478	16034.37	-0.89465	2.753849	-4.78281
35416.42	829.2003	5372.627	14927.1	-0.91375	2.649372	-5.10103
35640.58	622.3645	5951.771	13745.19	-0.93133	2.511438	-5.44933
35864.75	411.8536	6495.307	12481.5	-0.94631	2.329659	-5.83125
36088.91	198.4234	6991.888	11128.13	-0.95703	2.089703	-6.24994
36313.07	-16.697	7426.36	9676.591	-0.96086	1.771624	-6.7072
36537.24	-231.539	7778.267	8118.345	-0.9537	1.347633	-7.2012
36761.4	-442.972	8019.801	6446.057	-0.92912	0.779493	-7.72198

Problem 6:

```
clc;clear;
%Defines variables
r0=[1882.725;9864.690;4086.088];
v0=[-5.565367;5.451548;2.258105];
t0=616.79;
tf=1880.41;
t0=t0*60;
tf=tf*60;
mu=398600;

%Calculates position and velocity at tf
[r,v,E,nu] = propagateKepler_Hackbardt_Chris(r0,v0,t0,tf,mu);

%Calculates position and velocity at 100 times between t0 and tf
times=linspace(t0,tf)';
randv=zeros(length(times),6);
for i=1:length(times)
    t=times(i);
    [r,v] = propagateKepler_Hackbardt_Chris(r0,v0,t0,t,mu);
    randv(i,:)= [r',v'];
end

%Calculates orbit using Kepler and ODE113
[time,p]=twoBodyOdeSolver(r0,v0,t0,tf,mu);

%Plots positions at the 100 times
plot3(randv(:,1),randv(:,2),randv(:,3),'b*',p(:,1),p(:,2),p(:,3),'r.')
legend('Kepler Plot','ODE113 Plot','Location','northeast')

%Creates a table with all positions and velocities at the 100 times
saveTable =[times,randv];
table = array2table(saveTable, "VariableNames", ["Time", "X Position", "Y Position", "Z Position", "X Velocity", "Y Velocity", "Z Velocity"]);
table
xlswrite('Orbit4.xlsx',saveTable)

%Prints values at tf
fprintf('The eccentric anomaly E is %g\n',E)
fprintf('The true anomaly nu is %g\n',nu)
vector = array2table(randv(i,:), "VariableNames", ["X Position", "Y Position", "Z Position", "X Velocity", "Y Velocity", "Z Velocity"]);
vector
```

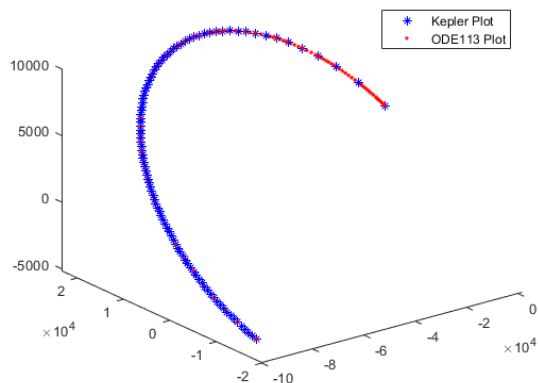
Results:

The eccentric anomaly E is 3.69968

The true anomaly nu is 3.29209

X Position Y Position Z Position X Velocity Y Velocity Z Velocity

-88561 -12407 -5139.2 0.84727 -0.61711 -0.25562



	X	Y	Z	X	Y	Z
Time	Position	Position	Position	Velocity	Velocity	Velocity
37007.4	1882.725	9864.69	4086.088	-5.56537	5.451548	2.258105
37773.23	-2424.04	13293.2	5506.223	-5.57269	3.67755	1.523291
38539.06	-6581.24	15686.74	6497.662	-5.26925	2.658001	1.10098
39304.89	-10489.8	17457.73	7231.227	-4.94095	2.010839	0.832917
40070.72	-14156.5	18817.41	7794.425	-4.64044	1.565131	0.648298
40836.55	-17606.2	19885.25	8236.741	-4.37421	1.239213	0.513299
41602.38	-20864.2	20734.91	8588.68	-4.13897	0.99006	0.410096
42368.21	-23952.4	21414.92	8870.349	-3.92995	0.793035	0.328486
43134.04	-26889.1	21958.98	9095.708	-3.74274	0.633055	0.26222
43899.87	-29689.6	22391.49	9274.857	-3.57369	0.500375	0.207262
44665.7	-32366.7	22730.66	9415.348	-3.41988	0.388419	0.160889
45431.53	-34931	22990.52	9522.984	-3.27895	0.292586	0.121193
46197.36	-37391.7	23182.07	9602.326	-3.14899	0.209559	0.086802
46963.19	-39756.6	23314.13	9657.028	-3.02848	0.136883	0.056699
47729.02	-42032.4	23393.89	9690.066	-2.91616	0.072702	0.030114
48494.85	-44225	23427.29	9703.899	-2.81098	0.015586	0.006456
49260.68	-46339.5	23419.28	9700.583	-2.7121	-0.03559	-0.01474
50026.52	-48380.4	23374.07	9681.856	-2.61878	-0.0817	-0.03384
50792.35	-50351.8	23295.24	9649.204	-2.53041	-0.12349	-0.05115
51558.18	-52257.3	23185.88	9603.906	-2.44647	-0.16153	-0.06691
52324.01	-54100	23048.67	9547.072	-2.36651	-0.19629	-0.08131
53089.84	-55882.9	22885.95	9479.673	-2.29014	-0.2282	-0.09452
53855.67	-57608.5	22699.79	9402.562	-2.21703	-0.25757	-0.10669
54621.5	-59279.4	22492.02	9316.498	-2.14688	-0.2847	-0.11793
55387.33	-60897.5	22264.24	9222.151	-2.07943	-0.30982	-0.12833
56153.16	-62465	22017.93	9120.125	-2.01445	-0.33315	-0.138
56918.99	-63983.6	21754.38	9010.96	-1.95175	-0.35486	-0.14699
57684.82	-65454.9	21474.78	8895.144	-1.89114	-0.37511	-0.15537
58450.65	-66880.6	21180.18	8773.119	-1.83245	-0.39403	-0.16321
59216.48	-68262.1	20871.57	8645.289	-1.77555	-0.41173	-0.17055
59982.31	-69600.6	20549.83	8512.018	-1.72031	-0.42834	-0.17742
60748.14	-70897.4	20215.77	8373.645	-1.66659	-0.44392	-0.18388
61513.97	-72153.6	19870.13	8230.477	-1.61431	-0.45858	-0.18995
62279.8	-73370.3	19513.6	8082.8	-1.56335	-0.47237	-0.19566
63045.63	-74548.5	19146.82	7930.875	-1.51363	-0.48536	-0.20104
63811.46	-75689	18770.38	7774.946	-1.46507	-0.49762	-0.20612
64577.29	-76792.7	18384.81	7615.24	-1.4176	-0.50919	-0.21091
65343.12	-77860.5	17990.64	7451.966	-1.37114	-0.52012	-0.21544
66108.95	-78893.1	17588.32	7285.322	-1.32563	-0.53045	-0.21972
66874.78	-79891.2	17178.31	7115.49	-1.28101	-0.54022	-0.22377
67640.61	-80855.4	16761.02	6942.644	-1.23724	-0.54946	-0.22759
68406.44	-81786.4	16336.85	6766.944	-1.19425	-0.55821	-0.23122
69172.27	-82684.8	15906.15	6588.544	-1.15199	-0.5665	-0.23465
69938.1	-83551	15469.28	6407.586	-1.11044	-0.57434	-0.2379
70703.93	-84385.7	15026.56	6224.207	-1.06954	-0.58177	-0.24098
71469.76	-85189.4	14578.31	6038.534	-1.02926	-0.5888	-0.24389
72235.59	-85962.4	14124.81	5850.691	-0.98955	-0.59546	-0.24665
73001.42	-86705.2	13666.36	5660.792	-0.9504	-0.60176	-0.24926
73767.25	-87418.2	13203.21	5468.948	-0.91175	-0.60773	-0.25173
74533.08	-88101.8	12735.61	5275.263	-0.87359	-0.61337	-0.25406
75298.92	-88756.3	12263.82	5079.84	-0.83589	-0.6187	-0.25627

76064.75	-89382.2	11788.05	4882.773	-0.79862	-0.62373	-0.25836
76830.58	-89979.7	11308.55	4684.155	-0.76174	-0.62848	-0.26032
77596.41	-90549	10825.51	4484.074	-0.72525	-0.63295	-0.26218
78362.24	-91090.6	10339.15	4282.616	-0.6891	-0.63716	-0.26392
79128.07	-91604.6	9849.656	4079.862	-0.6533	-0.64112	-0.26556
79893.9	-92091.3	9357.229	3875.892	-0.6178	-0.64483	-0.2671
80659.73	-92550.9	8862.051	3670.783	-0.58259	-0.64831	-0.26854
81425.56	-92983.7	8364.3	3464.607	-0.54765	-0.65155	-0.26988
82191.39	-93389.8	7864.151	3257.439	-0.51296	-0.65457	-0.27113
82957.22	-93769.4	7361.771	3049.347	-0.4785	-0.65738	-0.27229
83723.05	-94122.7	6857.327	2840.399	-0.44426	-0.65997	-0.27337
84488.88	-94449.9	6350.976	2630.662	-0.41022	-0.66235	-0.27436
85254.71	-94751.1	5842.877	2420.2	-0.37636	-0.66453	-0.27526
86020.54	-95026.4	5333.183	2209.078	-0.34266	-0.66652	-0.27608
86786.37	-95276	4822.043	1997.357	-0.30912	-0.66831	-0.27682
87552.2	-95499.9	4309.605	1785.098	-0.2757	-0.66991	-0.27749
88318.03	-95698.3	3796.016	1572.362	-0.24241	-0.67132	-0.27807
89083.86	-95871.2	3281.417	1359.209	-0.20922	-0.67255	-0.27858
89849.69	-96018.8	2765.951	1145.696	-0.17612	-0.67359	-0.27901
90615.52	-96141	2249.757	931.8813	-0.14309	-0.67445	-0.27937
91381.35	-96238	1732.974	717.8228	-0.11013	-0.67513	-0.27965
92147.18	-96309.7	1215.739	503.5768	-0.07721	-0.67564	-0.27986
92913.01	-96356.2	698.1859	289.1994	-0.04432	-0.67596	-0.27999
93678.84	-96377.6	180.451	74.74665	-0.01145	-0.67611	-0.28006
94444.67	-96373.8	-337.332	-139.726	0.02141	-0.67609	-0.28004
95210.5	-96344.8	-855.028	-354.163	0.054282	-0.67588	-0.27996
95976.33	-96290.6	-1372.5	-568.508	0.087177	-0.6755	-0.2798
96742.16	-96211.3	-1889.62	-782.705	0.120109	-0.67495	-0.27957
97507.99	-96106.7	-2406.25	-996.698	0.153092	-0.67421	-0.27927
98273.82	-95976.8	-2922.24	-1210.43	0.18614	-0.67329	-0.27889
99039.65	-95821.5	-3437.46	-1423.84	0.219268	-0.67219	-0.27843
99805.48	-95640.9	-3951.78	-1636.88	0.252488	-0.67091	-0.2779
100571.3	-95434.8	-4465.04	-1849.48	0.285818	-0.66944	-0.27729
101337.1	-95203.1	-4977.1	-2061.58	0.31927	-0.66779	-0.27661
102103	-94945.7	-5487.82	-2273.13	0.35286	-0.66594	-0.27584
102868.8	-94662.6	-5997.05	-2484.06	0.386605	-0.66389	-0.27499
103634.6	-94353.5	-6504.63	-2694.31	0.420519	-0.66165	-0.27406
104400.5	-94018.4	-7010.42	-2903.81	0.45462	-0.6592	-0.27305
105166.3	-93657.1	-7514.26	-3112.51	0.488923	-0.65655	-0.27195
105932.1	-93269.5	-8015.98	-3320.33	0.523447	-0.65368	-0.27076
106698	-92855.3	-8515.42	-3527.2	0.558209	-0.65059	-0.26948
107463.8	-92414.5	-9012.41	-3733.06	0.593228	-0.64728	-0.26811
108229.6	-91946.6	-9506.77	-3937.83	0.628523	-0.64373	-0.26664
108995.4	-91451.7	-9998.33	-4141.44	0.664114	-0.63995	-0.26508
109761.3	-90929.4	-10486.9	-4343.81	0.700022	-0.63591	-0.2634
110527.1	-90379.4	-10972.3	-4544.86	0.736269	-0.63162	-0.26163
111292.9	-89801.6	-11454.3	-4744.51	0.772877	-0.62707	-0.25974
112058.8	-89195.5	-11932.7	-4942.67	0.809869	-0.62223	-0.25774
112824.6	-88561	-12407.2	-5139.25	0.847272	-0.61711	-0.25562

Problem 7:

```
clc;clear;
%Defines variables
r0=[-664.699;8112.75;4479.81];
v0=[-0.87036;-0.068046;-8.290459];
t0=21.02;
tf=1913.38;
t0=t0*60;
tf=tf*60;
mu=398600;

%Calculates position and velocity at tf
[r,v,E,nu] = propagateKepler_Hackbardt_Chris(r0,v0,t0,tf,mu);

%Calculates position and velocity at 100 times between t0 and tf
times=linspace(t0,tf)';
randv=zeros(length(times),6);
for i=1:length(times)
    t=times(i);
    [r,v] = propagateKepler_Hackbardt_Chris(r0,v0,t0,t,mu);
    randv(i,:)= [r',v'];
end

%Calculates orbit using Kepler and ODE113
[time,p]=twoBodyOdeSolver(r0,v0,t0,tf,mu);

%Plots positions at the 100 times
plot3(randv(:,1),randv(:,2),randv(:,3),'b*',p(:,1),p(:,2),p(:,3),'r.')
legend('Kepler Plot','ODE113 Plot','Location','northeast')

%Creates a table with all positions and velocities at the 100 times
saveTable =[times,randv];
table = array2table(saveTable, "VariableNames", ["Time", "X Position", "Y Position", "Z Position", "X Velocity", "Y Velocity", "Z Velocity"]);
table
xlswrite('Orbit5.xlsx',saveTable)

%Prints values at tf
fprintf('The eccentric anomaly E is %g\n',E)
fprintf('The true anomaly nu is %g\n',nu)
vector = array2table(randv(i,:), "VariableNames", ["X Position", "Y Position", "Z Position", "X Velocity", "Y Velocity", "Z Velocity"]);
vector
```

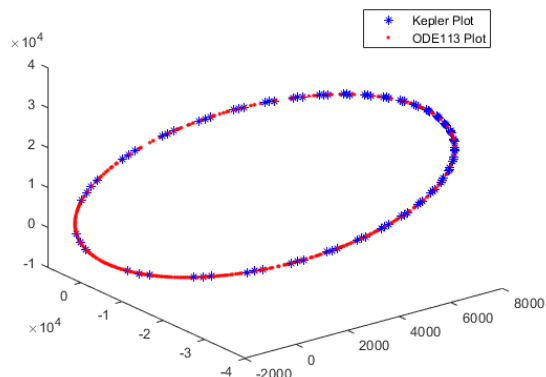
Results:

The eccentric anomaly E is 5.52316

The true anomaly nu is 4.71201

X Position Y Position Z Position X Velocity Y Velocity Z Velocity

-152.16 7659.2 8708.4 -0.95798 1.5191 -7.0143



	X	Y	Z	X	Y	Z
Time	Position	Position	Position	Velocity	Velocity	Velocity
1261.2	-664.699	8112.75	4479.81	-0.87036	-0.06805	-8.29046
2408.085	-1134.82	4094.852	-5269.88	0.317072	-7.4061	-6.81937
3554.97	-175.983	-5377.89	-8779.19	1.068039	-7.74193	-0.18861
4701.855	1023.367	-13010.1	-7585.38	0.992082	-5.66844	1.841357
5848.739	2082.188	-18642.9	-5067.96	0.855699	-4.24863	2.43641
6995.624	2993.123	-22920	-2148.89	0.736262	-3.26378	2.615183
8142.509	3778.22	-26224.5	872.547	0.635608	-2.53089	2.637302
9289.394	4456.576	-28784.5	3874.13	0.549412	-1.95403	2.589028
10436.28	5042.532	-30745.8	6797.72	0.473943	-1.48051	2.504979
11583.16	5546.748	-32207.9	9612.405	0.406492	-1.07919	2.400879
12730.05	5977.248	-33241.3	12300.12	0.34512	-0.73043	2.284449
13876.93	6340.151	-33898.4	14849.22	0.28841	-0.42119	2.15963
15023.82	6640.168	-34219	17251.38	0.235302	-0.1424	2.028411
16170.7	6880.939	-34234.1	19499.83	0.184972	0.112468	1.891694
17317.59	7065.262	-33968.3	21588.48	0.136765	0.348265	1.749723
18464.47	7195.249	-33441.1	23511.22	0.090137	0.568702	1.602299
19611.36	7272.442	-32668.6	25261.51	0.044626	0.776681	1.448899
20758.24	7297.881	-31663.5	26832.07	-0.00018	0.974522	1.288714
21905.13	7272.153	-30436.4	28214.52	-0.04466	1.164112	1.120656
23052.01	7195.419	-28995.8	29399.06	-0.08919	1.347014	0.943331
24198.9	7067.418	-27348.7	30374.09	-0.13413	1.524525	0.754973
25345.78	6887.455	-25500.6	31125.72	-0.17987	1.697725	0.553347
26492.67	6654.371	-23455.8	31637.18	-0.22684	1.867484	0.335595
27639.55	6366.486	-21218.1	31887.93	-0.27552	2.034445	0.098
28786.44	6021.518	-18790.2	31852.52	-0.32649	2.198953	-0.16437
29933.32	5616.458	-16175.1	31498.89	-0.38044	2.360901	-0.45825
31080.21	5147.405	-13376.2	30785.82	-0.43825	2.519393	-0.79305
32227.09	4609.314	-10398.4	29658.99	-0.50104	2.672047	-1.18255
33373.98	3995.666	-7251.32	28044.55	-0.57029	2.813441	-1.64771
34520.86	3298.031	-3953.82	25837.95	-0.64785	2.931365	-2.22238
35667.75	2505.639	-547.008	22883.3	-0.73587	2.996748	-2.96505
36814.63	1605.738	2871.98	18931.87	-0.83509	2.931915	-3.98574
37961.52	589.5473	6039.86	13552.26	-0.93389	2.486078	-5.50702
39108.4	-499.57	8061.99	5968.412	-0.91818	0.592703	-7.86606
40255.28	-1167.82	5359.063	-3906.81	0.03913	-6.2646	-7.92657
41402.17	-371.116	-3918.93	-8685.82	1.047059	-8.0915	-0.84915
42549.05	838.6077	-11939.7	-7908.69	1.013492	-5.95573	1.662654
43695.94	1922.607	-17842.6	-5511.84	0.876792	-4.44086	2.380608
44842.82	2855.848	-22306.2	-2629.4	0.754079	-3.40157	2.600605
45989.71	3659.738	-25748.6	386.4133	0.650689	-2.63628	2.639845
47136.59	4354.161	-28416.7	3396.147	0.562451	-2.03868	2.599783
48283.48	4954.159	-30466.6	6334.824	0.485465	-1.55107	2.520114
49430.36	5470.905	-32003.5	9168.454	0.416874	-1.1397	2.418575
50577.25	5912.792	-33101.8	11877.47	0.354632	-0.78351	2.303791
51724.13	6286.204	-33816.4	14449.46	0.297253	-0.46861	2.180147
52871.02	6596.053	-34188.8	16875.7	0.243627	-0.18542	2.049874
54017.9	6846.133	-34251.2	19149.27	0.192898	0.072924	1.91401
55164.79	7039.364	-34029.1	21264	0.144389	0.311509	1.772886
56311.67	7177.962	-33542.7	23213.81	0.097541	0.5342	1.626366
57458.56	7263.553	-32808.6	24992.27	0.051879	0.74401	1.473974
58605.44	7297.254	-31840.1	26592.23	0.006986	0.943342	1.314944

59752.33	7279.724	-30648.1	28005.52	-0.03752	1.134146	1.148236
60899.21	7211.19	-29241.3	29222.57	-0.08202	1.318028	0.972508
62046.1	7091.459	-27627	30232.13	-0.12687	1.496327	0.786059
63192.98	6919.909	-25810.8	31020.7	-0.17245	1.670155	0.586739
64339.87	6695.457	-23797.4	31572.01	-0.21919	1.840417	0.371802
65486.75	6416.512	-21590.4	31866.21	-0.26756	2.007795	0.13769
66633.64	6080.895	-19192.9	31878.73	-0.31812	2.17269	-0.12031
67780.52	5685.725	-16607.7	31578.72	-0.37154	2.335084	-0.40857
68927.41	5227.258	-13838	30926.64	-0.42866	2.49424	-0.73601
70074.29	4700.653	-10888.5	29870.65	-0.49056	2.64809	-1.11554
71221.18	4099.656	-7767.66	28340.61	-0.55866	2.791867	-1.5667
72368.06	3416.174	-4492.36	26237.95	-0.63474	2.914881	-2.12069
73514.95	2639.829	-1098.71	23417.09	-0.72095	2.991995	-2.83079
74661.83	1758.06	2329.347	19648.48	-0.81854	2.957571	-3.79582
75808.72	760.3291	5570.262	14539.51	-0.91986	2.607291	-5.21427
76955.6	-327.655	7903.062	7377.715	-0.94526	1.111665	-7.43409
78102.48	-1149.67	6388.807	-2372.28	-0.23193	-4.89223	-8.66325
79249.37	-560.318	-2399.51	-8456.51	1.002122	-8.39101	-1.66913
80396.25	650.0185	-10814.5	-8195.63	1.033524	-6.26258	1.445082
81543.14	1759.095	-17005.9	-5944.42	0.898358	-4.64507	2.313399
82690.02	2715.243	-21666.3	-3106.84	0.772404	-3.54623	2.581709
83836.91	3538.442	-25252.9	-100.014	0.66616	-2.7459	2.640451
84983.79	4249.317	-28033.1	2916.272	0.575778	-2.12613	2.609556
86130.68	4863.643	-30174.2	5869.19	0.497203	-1.62357	2.534702
87277.56	5393.136	-31787.8	8721.274	0.427419	-1.20161	2.435937
88424.45	5846.572	-32952.5	11451.27	0.364269	-0.83764	2.322908
89571.33	6230.619	-33725.6	14045.93	0.306192	-0.51685	2.200496
90718.22	6550.397	-34150.6	16496.09	0.252026	-0.22908	2.071194
91865.1	6809.86	-34261	18794.6	0.200881	0.032872	1.936192
93011.99	7012.057	-34083	20935.25	0.152056	0.274344	1.795912
94158.87	7159.307	-33637.9	22911.97	0.104974	0.499366	1.650283
95305.76	7253.325	-32942.7	24718.42	0.059152	0.71107	1.498877
96452.64	7295.306	-32011	26347.58	0.014162	0.911944	1.340977
97599.53	7285.979	-30854.3	27791.45	-0.03038	1.104001	1.175585
98746.41	7225.64	-29481.5	29040.74	-0.07486	1.288898	1.00141
99893.3	7114.164	-27900	30084.47	-0.11962	1.468014	0.816815
101040.2	6950.999	-26116	30909.56	-0.16506	1.642494	0.61973
102187.1	6735.137	-24134	31500.22	-0.21159	1.813276	0.407517
103334	6465.076	-21957.8	31837.24	-0.25966	1.981082	0.176767
104480.8	6138.737	-19590.8	31896.9	-0.30983	2.146364	-0.07701
105627.7	5753.361	-17035.5	31649.49	-0.36273	2.309185	-0.35989
106774.6	5305.357	-14295.2	31057.09	-0.41919	2.468955	-0.6803
107921.5	4790.077	-11374.1	30070.14	-0.48024	2.623884	-1.05036
109068.4	4201.522	-8279.98	28621.98	-0.54723	2.769785	-1.4883
110215.3	3531.925	-5027.77	26619.58	-0.62189	2.897283	-2.02294
111362.1	2771.299	-1649.28	23926.73	-0.70634	2.984589	-2.70292
112509	1907.348	1782.675	20331.17	-0.80217	2.975987	-3.61719
113655.9	928.404	5080.686	15474.81	-0.9046	2.703851	-4.94264
114802.8	-152.155	7659.22	8708.353	-0.95798	1.519143	-7.01434

Problem 8:

```
clc;clear;
%Defines variables
r0=[-10515.45;-5235.37;49.1700];
v0=[-2.10305;-4.18146;5.56329];
t0=27;
tf=57;
t0=t0*60;
tf=tf*60;
mu=398600;

%Calculates position and velocity at tf
[r,v,E,nu] = propagateKepler_Hackbardt_Chris(r0,v0,t0,tf,mu);

%Calculates position and velocity at 100 times between t0 and tf
times=linspace(t0,tf)';
randv=zeros(length(times),6);
for i=1:length(times)
    t=times(i);
    [r,v] = propagateKepler_Hackbardt_Chris(r0,v0,t0,t,mu);
    randv(i,:)= [r',v'];
end

%Calculates orbit using Kepler and ODE113
[time,p]=twoBodyOdeSolver(r0,v0,t0,tf,mu);

%Plots positions at the 100 times
plot3(randv(:,1),randv(:,2),randv(:,3),'b*',p(:,1),p(:,2),p(:,3),'r.')
legend('Kepler Plot','ODE113 Plot','Location','northeast')

%Creates a table with all positions and velocities at the 100 times
saveTable = [times,randv];
table = array2table(saveTable, "VariableNames", ["Time", "X Position", "Y Position", "Z Position", "X Velocity", "Y Velocity", "Z Velocity"]);
table
xlswrite('Orbit6.xlsx',saveTable)

%Prints values at tf
fprintf('The eccentric anomaly E is %g\n',E)
fprintf('The true anomaly nu is %g\n',nu)
vector = array2table(randv(i,:), "VariableNames", ["X Position", "Y Position", "Z Position", "X Velocity", "Y Velocity", "Z Velocity"]);
vector
```

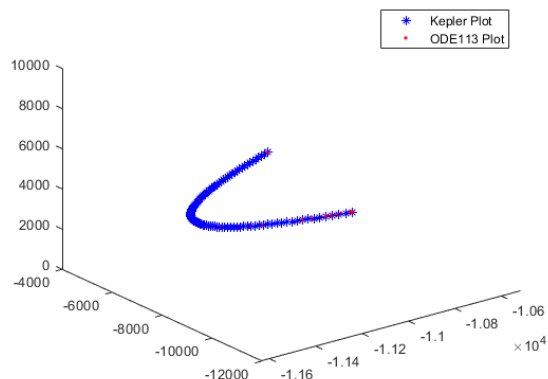
Results:

The eccentric anomaly E is 1.12501

The true anomaly nu is 1.97415

X Position Y Position Z Position X Velocity Y Velocity Z Velocity

-11503 -11006 9407.5 0.46744 -2.418 4.6943



Time	X Position	Y Position	Z Position	X Velocity	Y Velocity	Z Velocity
1620	-10515.4	-5235.37	49.17	-2.10305	-4.18146	5.56329
1638.182	-10553.3	-5311.18	150.3174	-2.05636	-4.15809	5.562849
1656.364	-10590.2	-5386.57	251.4528	-2.01031	-4.13479	5.561974
1674.545	-10626.4	-5461.54	352.5685	-1.9649	-4.11157	5.560682
1692.727	-10661.7	-5536.09	453.657	-1.92012	-4.08844	5.558987
1710.909	-10696.2	-5610.21	554.7111	-1.87595	-4.06539	5.556902
1729.091	-10729.9	-5683.92	655.7238	-1.8324	-4.04243	5.554442
1747.273	-10762.8	-5757.21	756.6886	-1.78946	-4.01957	5.551621
1765.455	-10795	-5830.09	857.5988	-1.74711	-3.99681	5.54845
1783.636	-10826.4	-5902.55	958.4484	-1.70534	-3.97415	5.544943
1801.818	-10857	-5974.6	1059.231	-1.66416	-3.95159	5.541111
1820	-10886.9	-6046.24	1159.941	-1.62355	-3.92914	5.536967
1838.182	-10916	-6117.48	1260.574	-1.5835	-3.90679	5.532521
1856.364	-10944.5	-6188.31	1361.122	-1.54401	-3.88456	5.527785
1874.545	-10972.2	-6258.74	1461.582	-1.50506	-3.86245	5.52277
1892.727	-10999.2	-6328.76	1561.949	-1.46666	-3.84044	5.517485
1910.909	-11025.5	-6398.39	1662.217	-1.42878	-3.81856	5.511942
1929.091	-11051.2	-6467.62	1762.381	-1.39143	-3.79679	5.506148
1947.273	-11076.1	-6536.46	1862.439	-1.3546	-3.77515	5.500115
1965.455	-11100.4	-6604.9	1962.384	-1.31828	-3.75362	5.49385
1983.636	-11124.1	-6672.95	2062.214	-1.28245	-3.73222	5.487363
2001.818	-11147.1	-6740.62	2161.923	-1.24712	-3.71094	5.480663
2020	-11169.4	-6807.9	2261.509	-1.21228	-3.68978	5.473756
2038.182	-11191.1	-6874.79	2360.968	-1.17791	-3.66876	5.466652
2056.364	-11212.3	-6941.31	2460.295	-1.14402	-3.64785	5.459358
2074.545	-11232.7	-7007.44	2559.489	-1.11058	-3.62708	5.451882
2092.727	-11252.6	-7073.2	2658.545	-1.07761	-3.60643	5.44423
2110.909	-11271.9	-7138.58	2757.46	-1.04508	-3.58591	5.43641
2129.091	-11290.6	-7203.6	2856.231	-1.013	-3.56551	5.428428
2147.273	-11308.8	-7268.24	2954.856	-0.98135	-3.54525	5.420291
2165.455	-11326.3	-7332.52	3053.332	-0.95014	-3.52511	5.412005
2183.636	-11343.3	-7396.43	3151.656	-0.91934	-3.5051	5.403576
2201.818	-11359.8	-7459.98	3249.825	-0.88896	-3.48522	5.39501
2220	-11375.7	-7523.16	3347.837	-0.85899	-3.46547	5.386313
2238.182	-11391	-7585.99	3445.69	-0.82942	-3.44585	5.377491
2256.364	-11405.8	-7648.47	3543.381	-0.80025	-3.42635	5.368547
2274.545	-11420.1	-7710.59	3640.909	-0.77147	-3.40699	5.359489
2292.727	-11433.9	-7772.36	3738.271	-0.74307	-3.38775	5.35032
2310.909	-11447.1	-7833.78	3835.466	-0.71505	-3.36864	5.341046
2329.091	-11459.9	-7894.86	3932.49	-0.68741	-3.34966	5.331671
2347.273	-11472.1	-7955.59	4029.344	-0.66012	-3.3308	5.322199
2365.455	-11483.9	-8015.98	4126.024	-0.6332	-3.31207	5.312635
2383.636	-11495.2	-8076.03	4222.53	-0.60664	-3.29347	5.302984
2401.818	-11505.9	-8135.74	4318.86	-0.58042	-3.27499	5.293248
2420	-11516.3	-8195.12	4415.011	-0.55455	-3.25663	5.283433
2438.182	-11526.1	-8254.16	4510.984	-0.52901	-3.2384	5.273541
2456.364	-11535.5	-8312.88	4606.776	-0.50381	-3.2203	5.263577
2474.545	-11544.4	-8371.27	4702.386	-0.47893	-3.20232	5.253544
2492.727	-11552.9	-8429.33	4797.814	-0.45438	-3.18446	5.243445
2510.909	-11561	-8487.07	4893.057	-0.43014	-3.16672	5.233284
2529.091	-11568.6	-8544.48	4988.115	-0.40622	-3.14911	5.223064

2547.273	-11575.7	-8601.58	5082.986	-0.38261	-3.13161	5.212788
2565.455	-11582.5	-8658.36	5177.67	-0.35929	-3.11423	5.202459
2583.636	-11588.8	-8714.82	5272.166	-0.33628	-3.09698	5.19208
2601.818	-11594.7	-8770.98	5366.473	-0.31355	-3.07984	5.181653
2620	-11600.2	-8826.82	5460.59	-0.29112	-3.06282	5.171182
2638.182	-11605.3	-8882.35	5554.515	-0.26897	-3.04592	5.160668
2656.364	-11610	-8937.58	5648.25	-0.2471	-3.02913	5.150115
2674.545	-11614.3	-8992.5	5741.792	-0.22551	-3.01246	5.139525
2692.727	-11618.2	-9047.13	5835.142	-0.20419	-2.9959	5.128899
2710.909	-11621.7	-9101.45	5928.297	-0.18313	-2.97946	5.118242
2729.091	-11624.9	-9155.47	6021.259	-0.16234	-2.96313	5.107553
2747.273	-11627.6	-9209.2	6114.026	-0.1418	-2.94691	5.096836
2765.455	-11630	-9262.63	6206.599	-0.12152	-2.9308	5.086093
2783.636	-11632	-9315.77	6298.975	-0.10149	-2.91481	5.075326
2801.818	-11633.7	-9368.62	6391.156	-0.08171	-2.89892	5.064536
2820	-11635	-9421.19	6483.14	-0.06217	-2.88314	5.053726
2838.182	-11636	-9473.47	6574.927	-0.04287	-2.86747	5.042896
2856.364	-11636.6	-9525.46	6666.518	-0.02381	-2.85191	5.03205
2874.545	-11636.8	-9577.17	6757.911	-0.00498	-2.83645	5.021187
2892.727	-11636.8	-9628.61	6849.106	0.013627	-2.8211	5.010311
2910.909	-11636.3	-9679.76	6940.104	0.032005	-2.80586	4.999423
2929.091	-11635.6	-9730.64	7030.904	0.05016	-2.79071	4.988524
2947.273	-11634.5	-9781.24	7121.505	0.068097	-2.77567	4.977615
2965.455	-11633.1	-9831.57	7211.908	0.085819	-2.76074	4.966698
2983.636	-11631.4	-9881.63	7302.112	0.103329	-2.7459	4.955774
3001.818	-11629.4	-9931.42	7392.118	0.12063	-2.73116	4.944845
3020	-11627	-9980.95	7481.925	0.137725	-2.71652	4.933911
3038.182	-11624.4	-10030.2	7571.533	0.154618	-2.70199	4.922975
3056.364	-11621.4	-10079.2	7660.942	0.171311	-2.68755	4.912036
3074.545	-11618.1	-10127.9	7750.152	0.187807	-2.6732	4.901097
3092.727	-11614.6	-10176.4	7839.163	0.20411	-2.65895	4.890158
3110.909	-11610.7	-10224.6	7927.976	0.220222	-2.6448	4.87922
3129.091	-11606.6	-10272.6	8016.59	0.236145	-2.63074	4.868285
3147.273	-11602.1	-10320.3	8105.005	0.251883	-2.61678	4.857353
3165.455	-11597.4	-10367.7	8193.221	0.267438	-2.60291	4.846425
3183.636	-11592.4	-10414.9	8281.238	0.282814	-2.58913	4.835502
3201.818	-11587.1	-10461.9	8369.057	0.298012	-2.57544	4.824585
3220	-11581.6	-10508.6	8456.678	0.313035	-2.56184	4.813675
3238.182	-11575.7	-10555.1	8544.1	0.327886	-2.54833	4.802773
3256.364	-11569.6	-10601.3	8631.324	0.342566	-2.53492	4.791879
3274.545	-11563.3	-10647.2	8718.35	0.35708	-2.52158	4.780993
3292.727	-11556.7	-10693	8805.178	0.371429	-2.50834	4.770118
3310.909	-11549.8	-10738.4	8891.809	0.385614	-2.49518	4.759254
3329.091	-11542.6	-10783.7	8978.242	0.39964	-2.48211	4.7484
3347.273	-11535.2	-10828.7	9064.478	0.413507	-2.46912	4.737558
3365.455	-11527.6	-10873.5	9150.517	0.427219	-2.45622	4.726729
3383.636	-11519.7	-10918	9236.359	0.440777	-2.4434	4.715913
3401.818	-11511.6	-10962.3	9322.005	0.454184	-2.43067	4.70511
3420	-11503.2	-11006.4	9407.454	0.467441	-2.41801	4.694321