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 an 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 tf = 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 tf = 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 tf = 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 tf = 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 tf = 114803 sec is:

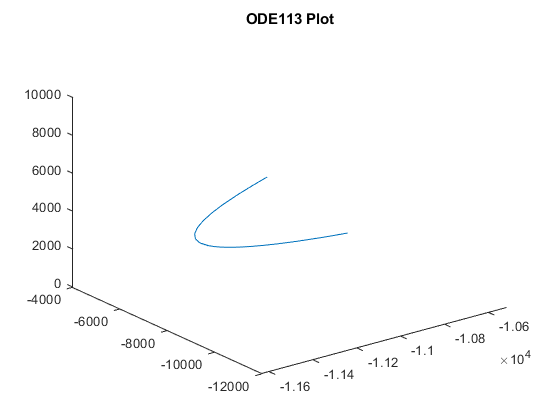
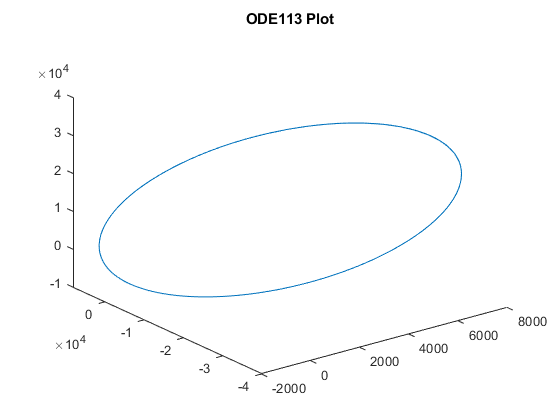
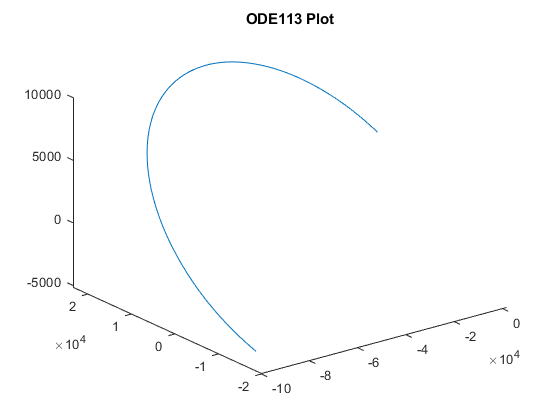
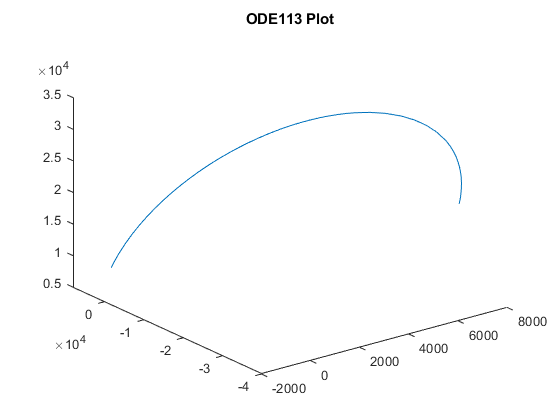
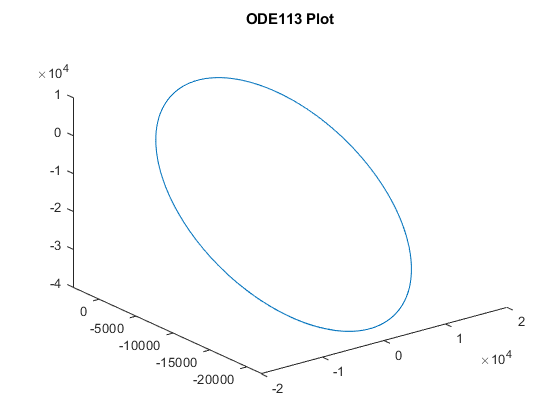
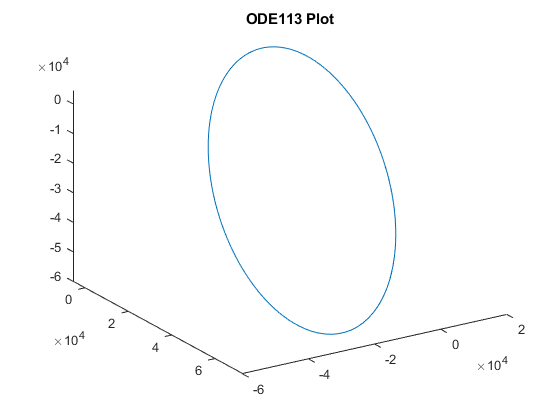
Time X Position Y Position Z Position X Velocity Y Velocity Z Velocity

1.148e+05 -152.2 7659.3 8708 -0.95798 1.519 -7.0144

6) The position and velocity at tf = 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



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 anamoly

%Output: nu, true anamoly

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 anamoly

%Input: k, number of periapsis crossings

%

%Output: E, eccentric anamoly

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

A picture containing diagram

Description automatically generated

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 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

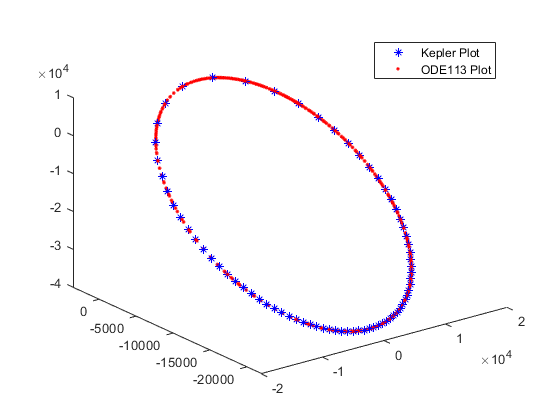
Results:

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



|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Time | X Position | Y Position | Z Position | X Velocity | Y Velocity | Z 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

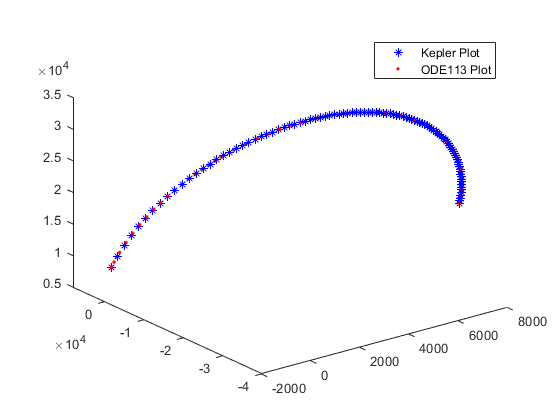
Results:

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

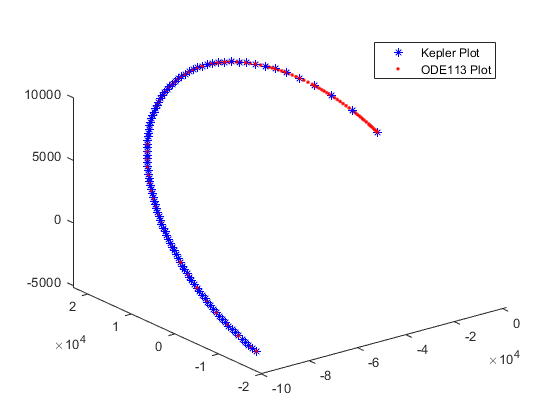
Results:

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



|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Time | X Position | Y Position | Z Position | X Velocity | Y Velocity | Z 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

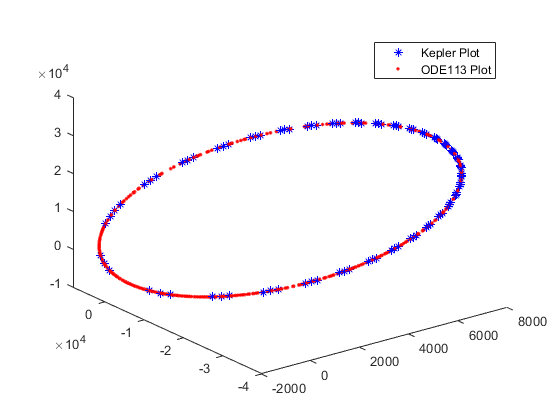
Results:

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



|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Time | X Position | Y Position | Z Position | X Velocity | Y Velocity | Z 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

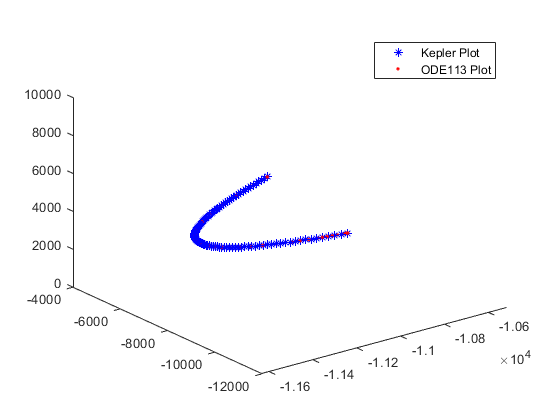
Results:

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 |