Submission Date : 6th February, 2017

AE 322 SPACE FLIGHT MECHANICS

ASSIGNMENT 1

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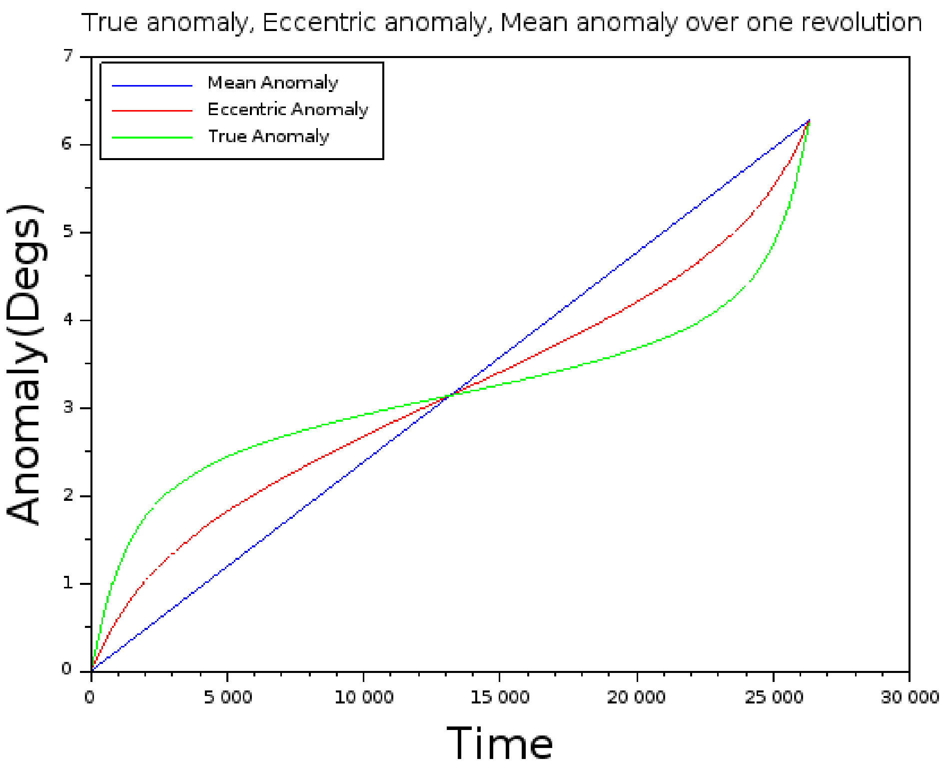
3rd Year Aerospace Engineering

(All the Problems in this Assignment are solved using Scilab)

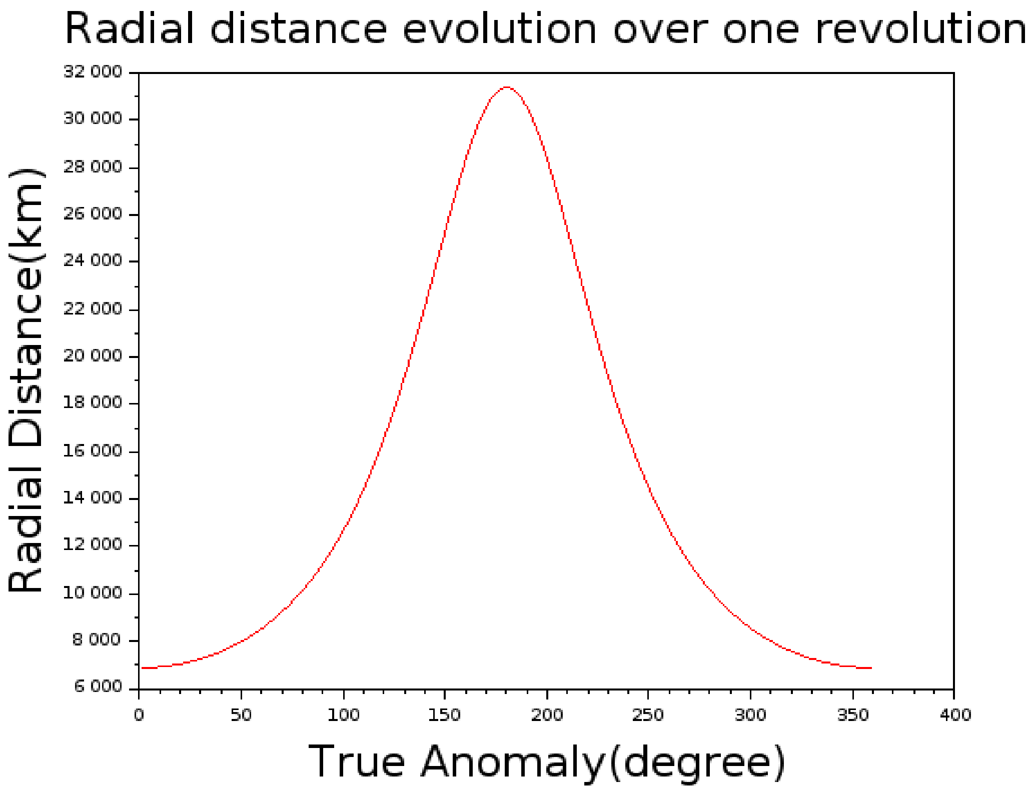
1) A spacecraft goes around Earth in an elliptical orbit with perigee altitude as 500 km and apogee altitude 25000 km. Assume that the spacecraft starts from periapsis.

a) Time Vs true anomaly, Eccentric anomaly, Mean anomaly over one revolution.

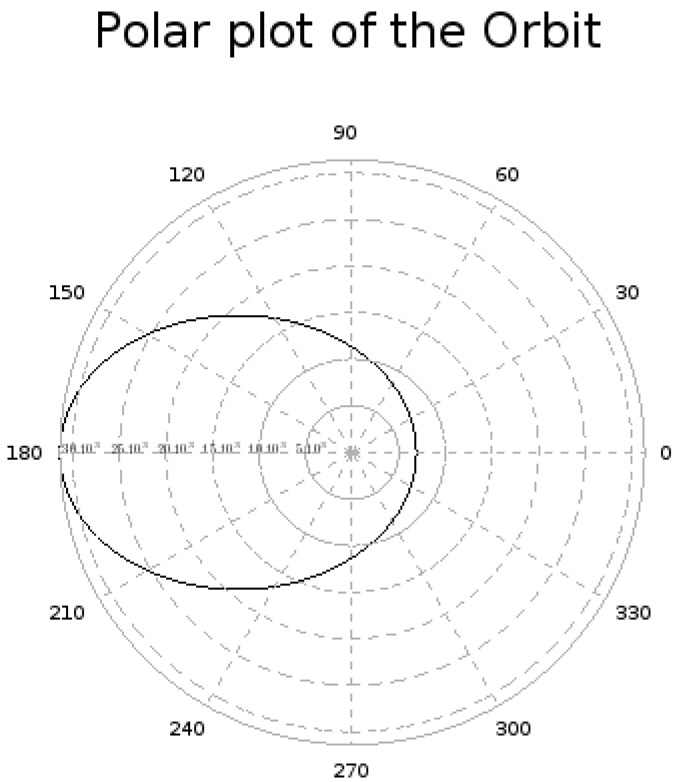


- The 3 Anomalies are equal at the starting, midway and end point
- Mean Anomaly increase linearly with time

b) Time Vs Radial distance evolution over one revolution



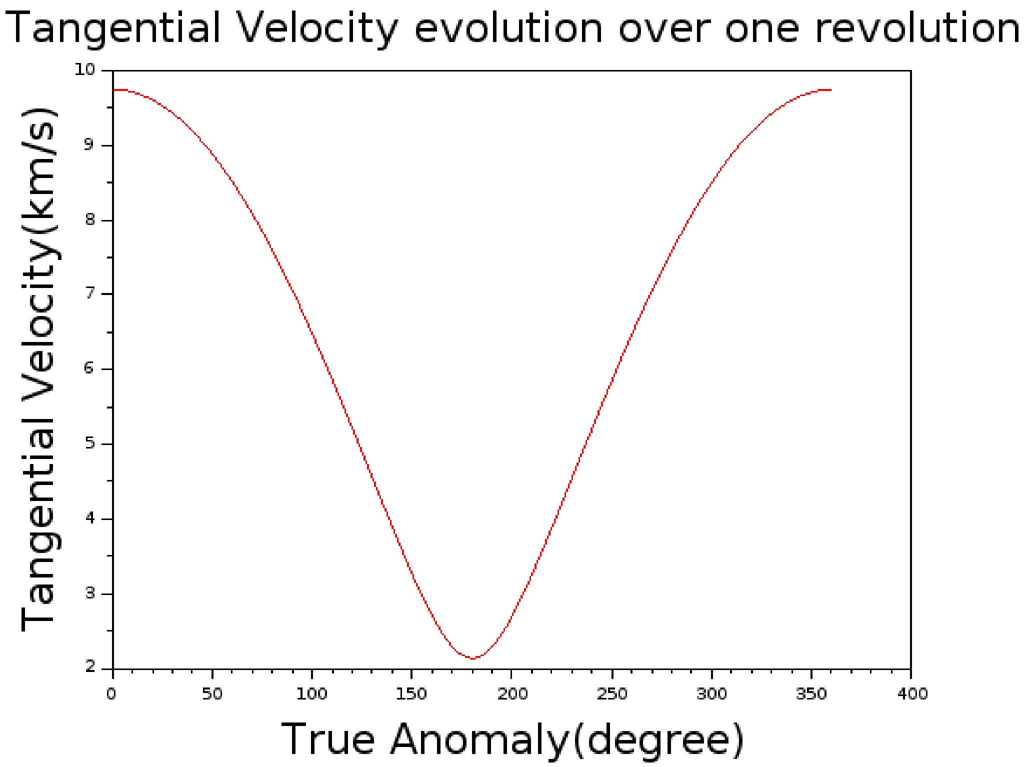
The plot has a maxima somewhere at the centre. This point is apogee of the elliptic orbit. The largest distance ois equal to the apoapsis of its orbit.



From polar plot we can see the radial distance plot is an ellipse with earth's centre as one of the focus of the ellipse.

Fom the radius distance evolution and the Polar plot we can tell that the minimum distance is at the perigee and the maximum distance is at the apogee.

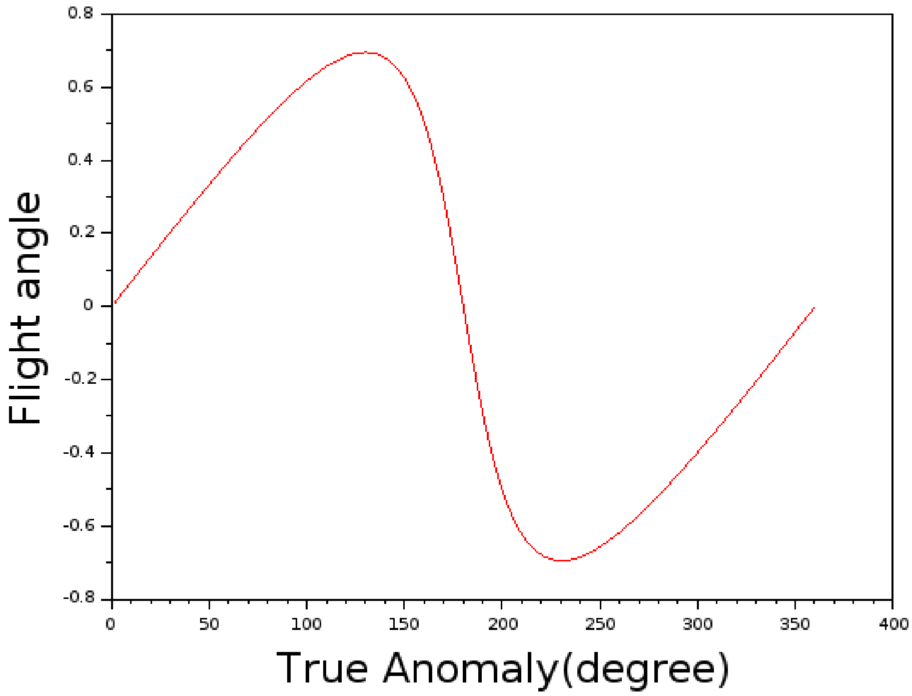
c) Time Vs Velocity evolution over one revolution



The plot has a minima at the centre.
The smallest velocity of the body will be at the apoapsis of its orbit, due to conservation of angular momentum.

The Kinetic Energy is maximum at the Perigee point and Potential Enegy is Maximun at the Apogee point

d)Time Vs. Flight path angle over one revolution



The flight path angle is first positive then it becomes negative.

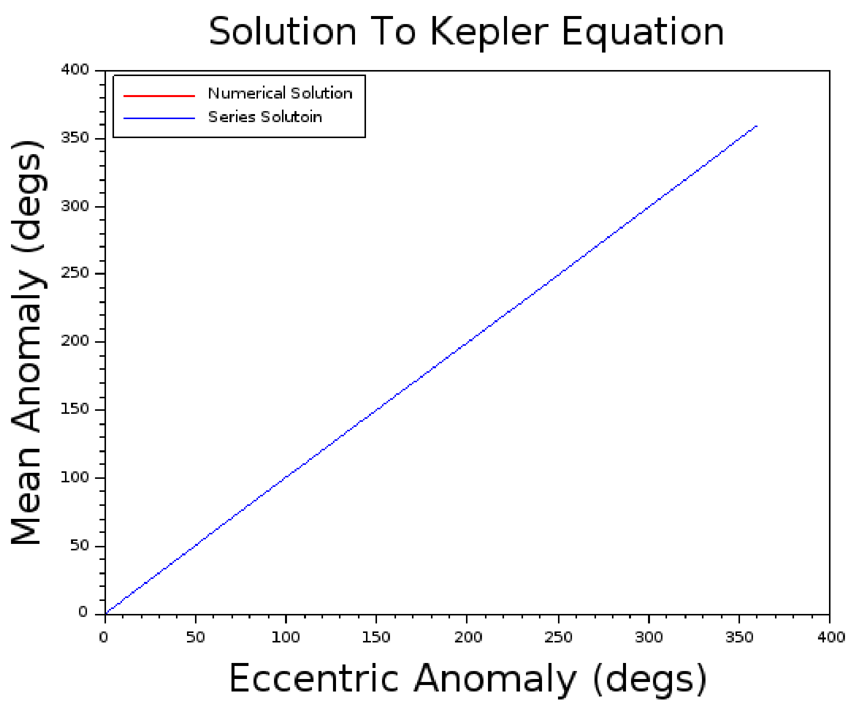
The value becomes zero at 3 points.

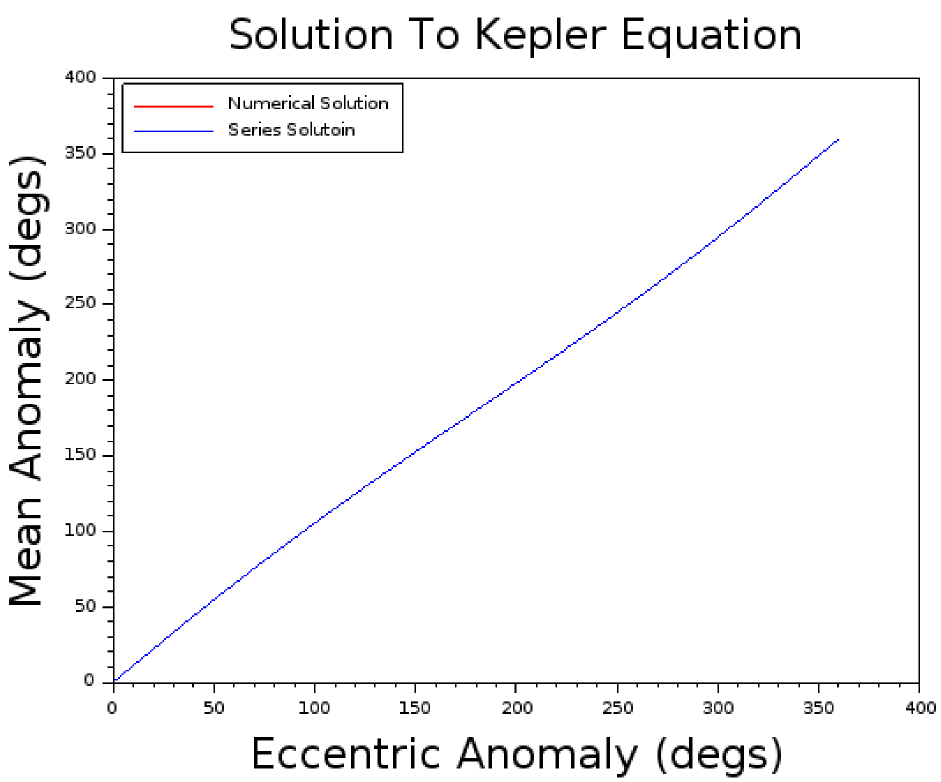
2) Solving the Kepler Equation

The Kepler Equation was solved using Newton Rhapson Method.

The Mean Anomaly and Eccentric Anomaly vary almost linearly for small eccentricity . The series solution also mathches the numerical solution. After e=0.6 the solutions dont match and the relationship is no longer linear

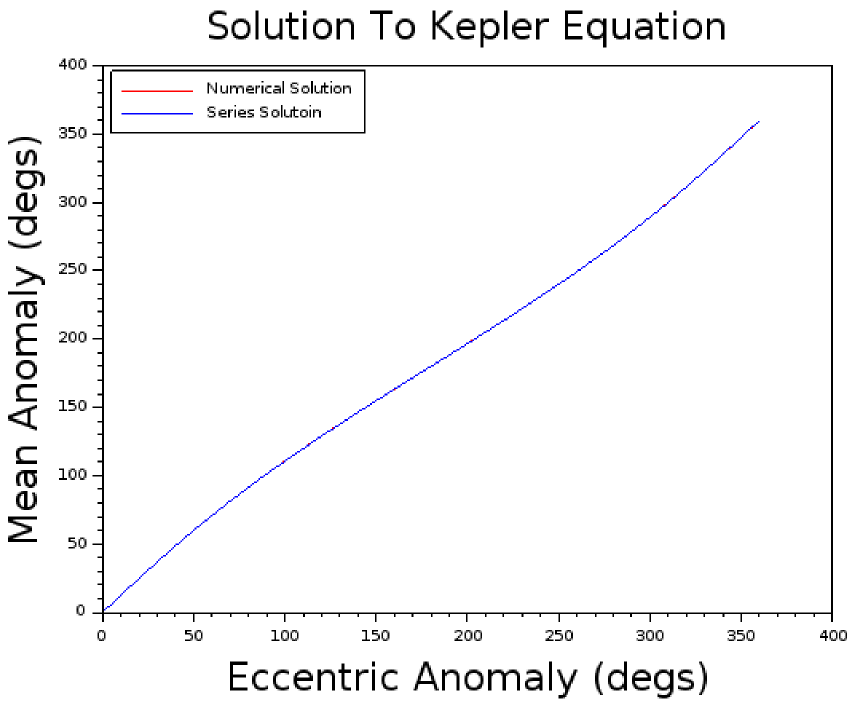
e= 0.01





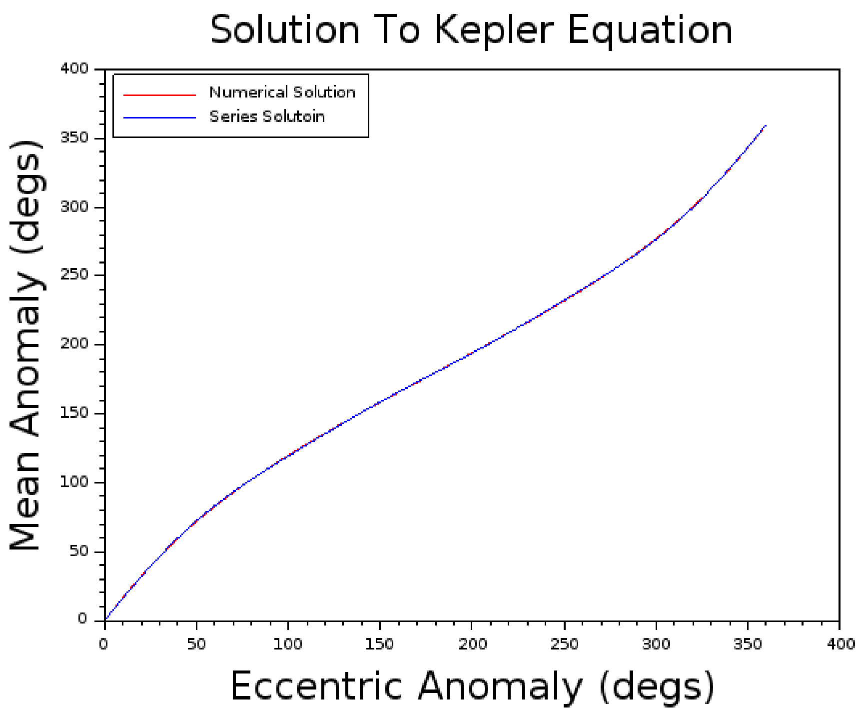
e= 0.1

e= 0.2



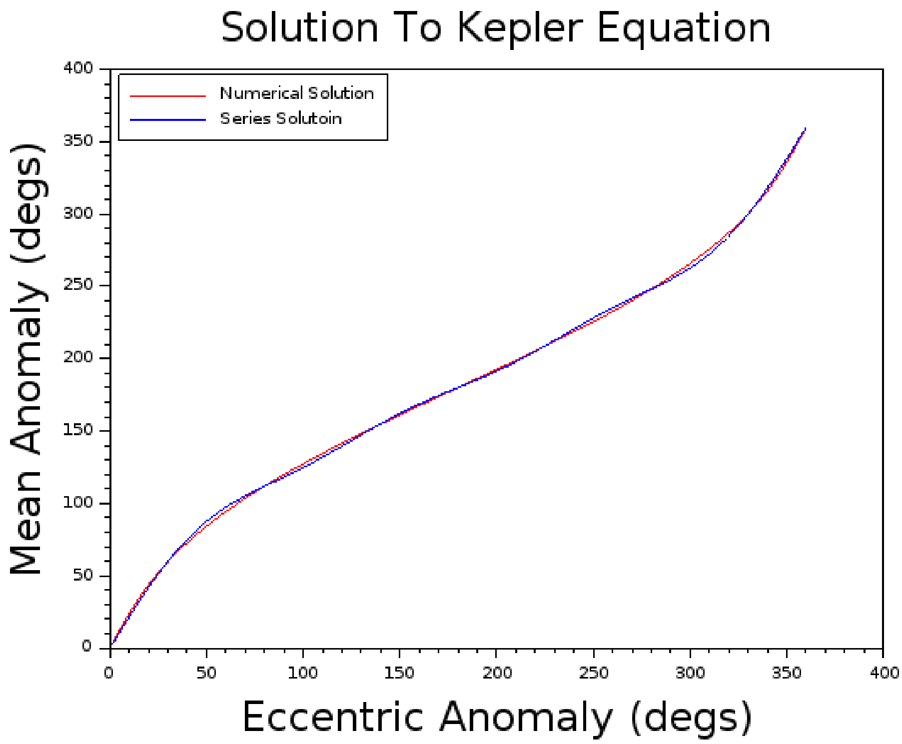
Solution To Kepler Equation
Numerical Solution
Series Solutoin
Mean Anomaly (degs)
Eccentric Anomaly (degs)
0
50
100
150
200
250
300
350
400

e= 0.4

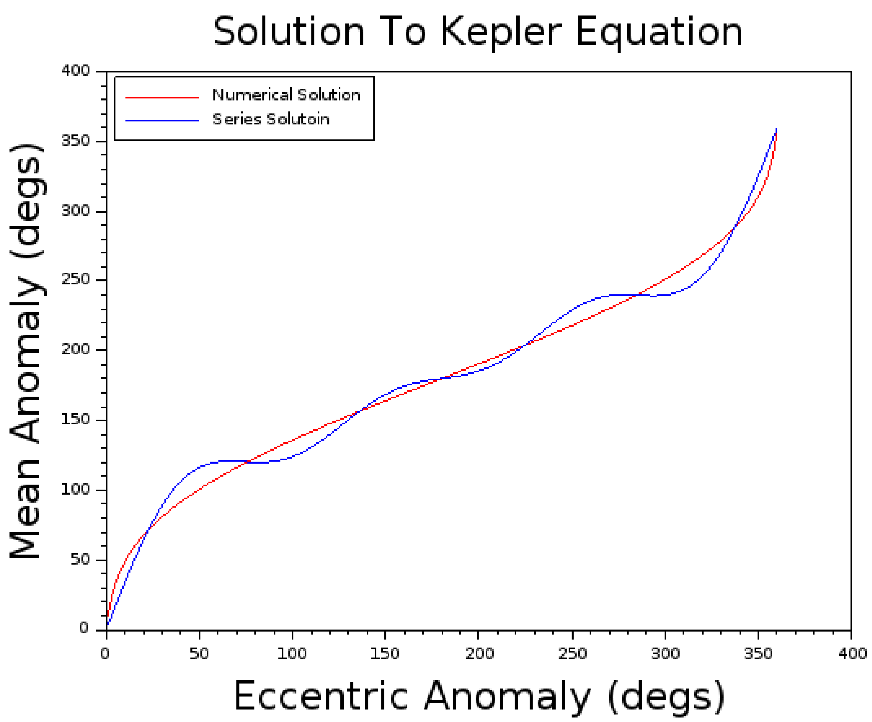


Solution To Kepler Equation
Numerical Solution
Series Solutoin
Mean Anomaly (degs)
Eccentric Anomaly (degs)
0
50
100
150
200
250
300
350
400

e= 0.6


Solution To Kepler Equation
Numerical Solution
Series Solutoin
Mean Anomaly (degs)
Eccentric Anomaly (degs)
0
50
100
150
200
250
300
350
400

e= 0.9


Solution To Kepler Equation
Numerical Solution
Series Solutoin
Mean Anomaly (degs)
Eccentric Anomaly (degs)
0
50
100
150
200
250
300
350
400

```
//
// SPACE FLIGHT MECHANICS
// Assignment 1
//============================================================
==========//
// Created : 4-02-2017
//
// Ref: Notes
// Author: Partha Surve (SC14B036, Aerospace Engineering 3rd Year, IIST)
// parthasurve1@gmail.com
//
clc
clear
clf
//-----------------------------------------------//
//  Constants  //
H_p = 500 //Perigee Altitude
H_a = 25000 //Apogee Altitude
R_e = 6378 //Radius of earth
R_p = H_p + R_e // Perigee radius
R_a = H_a + R_e //Apogee Radius
a = (R_p + R_a)/2 //Semi-Major Axis
G_earth = 398600 //gravitational constant of Earth (mu)
e=(R_a-R_p)/(R_a+R_p)//eccentricity of the orbit
pi = 3.14
p=2*pi*(a^1.5)/(G_earth^0.5);//time period
n=(G_earth/(a^3))^0.5;
tolerance = 1.e-2
//------------------------------------------------//
//Mean Anomaly Vs Time

t= 1:1:p
M=n.*t

//Evaluating Eccentric anomaly based on Mean Anomaly using Newton Rhapson
Residue = 1
for t = 1:1:p
E(t)=M(t)
while abs(Residue) > tolerance

E(t) = E(t)- (E(t) - e.*sin(E(t)) - M(t))/(1 - e.*cos(E(t)))
Residue = E(t)-e.*sin(E(t))-M(t)

end
Residue=1

//Evaluating True Anomaly from Eccentric Anomaly
v(t)=atan(((1-e*e)^.5)*sin(E(t))/(1-e*cos(E(t))),(cos(E(t))-e)/(1-e*cos(E(t))));
        if(v(t)<=0)
             v(t)=v(t)+2*pi;
        end
end
//plotting the anomalies vs time
t= 1:1:p
figure(1)
plot(t,M,'b')
plot(t,E,'r')
plot(t,v,'g')
xlabel('Time ', "fontsize", 5)
ylabel('Anomaly(Degs)', "fontsize", 5)
```

```
title('True anomaly, Eccentric anomaly, Mean anomaly over one revolution', "fontsize", 3)
hl=legend(['Mean Anomaly';'Eccentric Anomaly';'True Anomaly'],2);
//-----------------------------------------------//

//plotting radial distance

r=zeros(360,1) //radial distance


for V = 1:1:360 // V is true anomaly
r(V)=(a*(1-e^2)./(1+e.*cos(V*pi/180))); //Evaluating Radial Distance
end

V=  0:0.01:2*%pi;

figure(2)
polarplot(V,(a*(1-e^2)./(1+e.*cos(V)))); // Orbit of the Space craft
title('Polar plot of the Orbit ', "fontsize", 5)

//PLotting the Variation of radial distance with the true anomaly

  V = 1:1:360
  figure(3)
  plot(V,r,'r')
xlabel('True Anomaly(degree)', "fontsize", 5)
ylabel('Radial Distance(km)', "fontsize", 5)
title('Radial distance evolution over one revolution', "fontsize", 5)

//-----------------------------------------------------------//
// tangential Velocity
V_t = zeros(360,1)
for V = 1:1:360 // V is true anomaly
V_t(V) = sqrt(G_earth*(2*(1+e.*cos(V*pi/180))./(a*(1-e*e)) - 1/a))

end
  V = 1:1:360

  figure(4)
  plot(V,V_t,'r')

  xlabel('True Anomaly(degree)', "fontsize", 5)
ylabel('Tangential Velocity(km/s)', "fontsize", 5)
title('Tangential Velocity evolution over one revolution', "fontsize", 5)

//-----------------------------------------------------------//
//Flight Angle
E = zeros(360,1)
flight_angle = zeros(360,1)
for V = 1:1:360
    A = sin(V*pi/180).*sqrt(1 - e^2)./(1 + e * cos(V*pi/180));
    B = (e + cos(V*pi/180))./(1 + e .* cos(V*pi/180));
    E(V) = atan(A/B);
    flight_angle(V) = atan((e.*sin(V*pi/180))/(1+e.*cos(V*pi/180)))
end
V = 1:1:360

  figure(5)
  plot(V,flight_angle,'r')
  xlabel('True Anomaly(degree)', "fontsize", 5)
ylabel('Flight angle', "fontsize", 5)
title('', "fontsize", 5)
```

//==
==//

CODE 2 Kepler Equation Solution

```
clear;
clc
clf

pi = 2*3.14
M=2.9288 //mean anomaly angle
e = 0.9 //eccentricity
tolerance = 1.e-6 //error tolerance

//Select a starting value for E:

//Iterate using the Newton Rhapson Method

Residue = 1
E= ones(360,1)
E1= ones(360,1)
for M = 1:1:360

while abs(Residue) > tolerance

E(M) = E(M)- (E(M) - e.*sin(E(M)) - (M*pi/360))/(1 - e.*cos(E(M)))
Residue = E(M)-e.*sin(E(M))-M*pi/360

end
//----------------------//
//Series Solution
//Ref : Curtis
E1(M)= M*pi/360 + e*sin(M*pi/360) + ((e^2)/2)*sin(2*M*pi/360) +
((e^3)/8)*(3*sin(3*M*pi/360)-sin(M*pi/360))
//------------------------//
E(M)=E(M)*360/pi;
E1(M)=E1(M)*360/pi;
Residue =1

end
M=[1:1:360]
            plot(M,E,"r");
            plot(M,E1,"b");
            title('Solution To Kepler Equation', "fontsize", 5);
xlabel("Eccentric Anomaly (degs)", "fontsize", 5);
ylabel("Mean Anomaly (degs)","fontsize", 5);
hl=legend(['Numerical Solution';'Series Solutoin'],2);
```