Venus: We investigate sending spacecraft on various trajectories to Venus!

Use the following data:

$$G = 6.674 \times 10^{-11} m^3/(kgs^2) \quad , \quad m_E = 5.972 \times 10^{24} kg \quad , \quad r_E = 6.371 \times 10^6\ m \quad , \quad d_{S \to E} = 149,600,000\ km$$

Assume that Venus is spherical, with a circular orbit, and

$$m_V = 4.87 \times 10^{24}\ kg \quad , \quad r_V = 6052\ km \quad , \quad d_{S \to V} = 108,200,000\ km$$

The mass of the Sun is $1.989 \times 10^{30}\ kg$

For all answers, assume an inertial coordinate system with origin at the Sun, x-axis pointing at Earth at $t = 0$, y-axis in the direction of Earth's velocity, and all orbits and trajectories lie in the Sun-Earth-Venus plane

---

A spacecraft is to travel to (or near) Venus from Earth. **Unless otherwise instructed, assume that the initial position for the spacecraft in all of the following questions is**

$$(x, y) = (d_{S \to E}, 0)$$

1. Preliminaries

   (a) Calculate g_V and g_S at Earth orbit

   $$g_V = 1.8963 \times 10^{-7} m/(s^2)$$

   $$g_S = 0.0059 m/(s^2)$$

   The gravitational acceleration that Earth experieces at orbit because of Venus is miniscule compared to the Sun, because it is directly related to the mass of the object and the Suns mass is about one million times larger than that of Venuses.

   (b) Calculate g_V, g_S, and g_E at the surface of Venus

   $$g_V = 8.8740 m/(s^2)$$

   $$g_S = 0.0113 m/(s^2)$$

   $$g_E = 2.3254 \times 10^{-7} m/(s^2)$$

   The gravitational acceleration that Venuses surface experieces because of Venus is large compared to the Earth, and especially large compared to the sun. In this case the gravitational acceleration depends more on the distance between the celestial objects, they are inversely related, and the Sun is the farthest from Venuses surface, while the Earth is the second farthest from Venuses surface, and Venuses surface is extremely close to Venus.

   (c) Calculate the specific work (i.e., work per unit mass of a spacecraft) done by the Sun as the spacecraft travels from Earth radius to Venus radius

   $$W_S = 3.3952 \times 10^8 J/kg$$

   The specific work done by the Sun as the spacecraft travels from Earth radius to Venus radius is calculated by calculating the specific work done done by the sun on the Earth and the specific work done by the Sun on Venus and subtracting the former by the latter.

   (d) Calculate ω_V around the Sun, and v_V along its orbital path

   $$\omega_V = 3.2372 \times 10^{-7} (s^{-1})$$

   $$v_V = 3.5027 \times 10^4 m/s$$

   The angular velocity is calculated by using the gravitational contant times the mass of the sun over the distace from the sun to venus cubed. The velocity is then calculated by multiplying the distance from Sun to Venus by the angular velocity.

(e) Calculate escape velocity from Venus, ignoring atmospheric drag

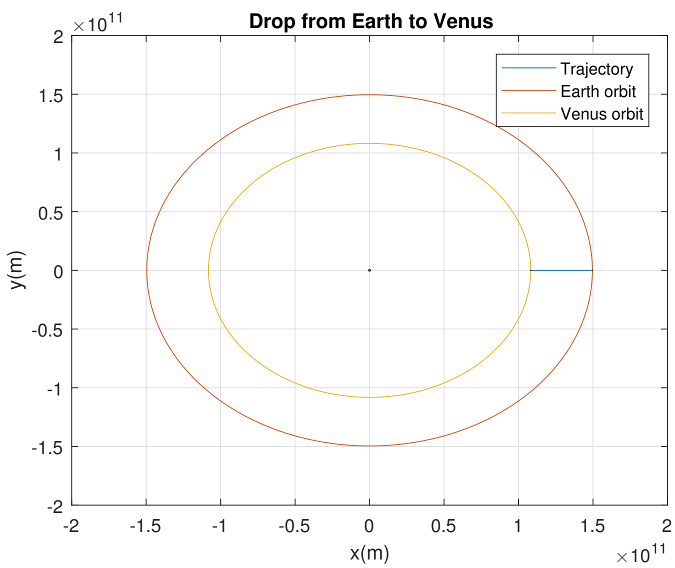
$$v_{esc} = 1.0364 \times 10^4 m/s$$

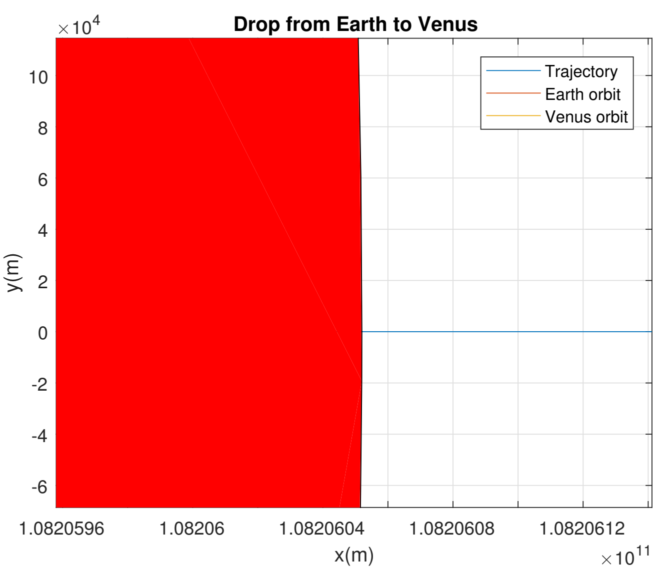
The escape velocity is calculated by multiplying 2 by the gravitational constant by the mass of venus divided by the radius of venus and then square root that calculation.

2. If the spacecraft's initial inertial $v_0 = 0$, i.e., if we could 'drop' the spacecraft from Earth orbit toward the Sun without any initial velocity,

(a) Plot the trajectory from Earth orbit to Venus orbit, ignoring the effect of Venus' mass (assume Venus is far away, around its orbit)

The drop from Earth to Venus doesn't change along the y axis but it does along the x-axis, its a straight line from Earth to Venus as seen in the zoom in.





(b) Calculate the velocity (vector) of the spacecraft when it reaches Venus' orbit

$\hat{v} = -2.6057 \times 10^4 \hat{\imath} + 0\hat{\jmath}$ m/s

The velocity vector is obtained from the using ode45 a function that calculates the velocities and position with respect to time in this case for the drop from Earth to Venus.

(c) Calculate the time required to travel from Earth orbit to Venus orbit

$$t = 3.5558 \times 10^6 s$$

The time is obtained from the using the plot from Earth to Venus to see when the spacecraft reaches Venuses orbit.

(d) Still ignoring Venus' gravity effect on the spacecraft trajectory, calculate the position of Venus in its orbit at $t = 0$ if the spacecraft is to collide with Venus. For convenience, assume that the collision will occur at Venus' surface on the line from the Sun to the initial position of the spacecraft.

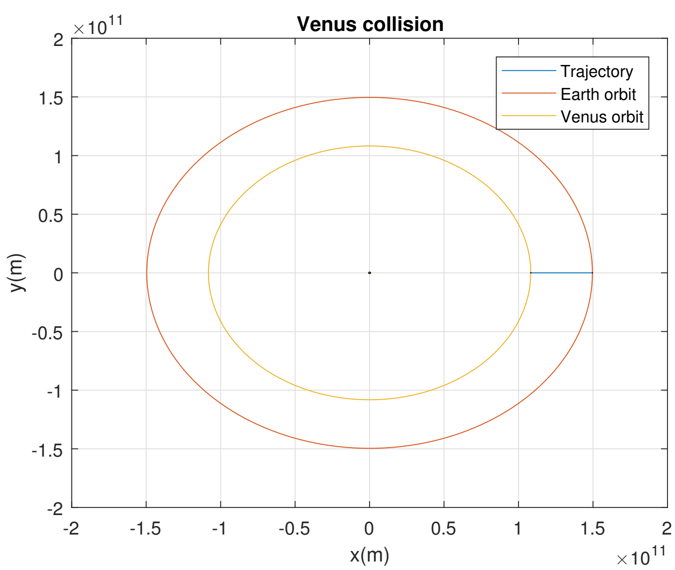
$\hat{p} = 4.4091 \times 10^{10} \hat{\imath} - 9.8809 \times 10^{10} \hat{\jmath} m/s$

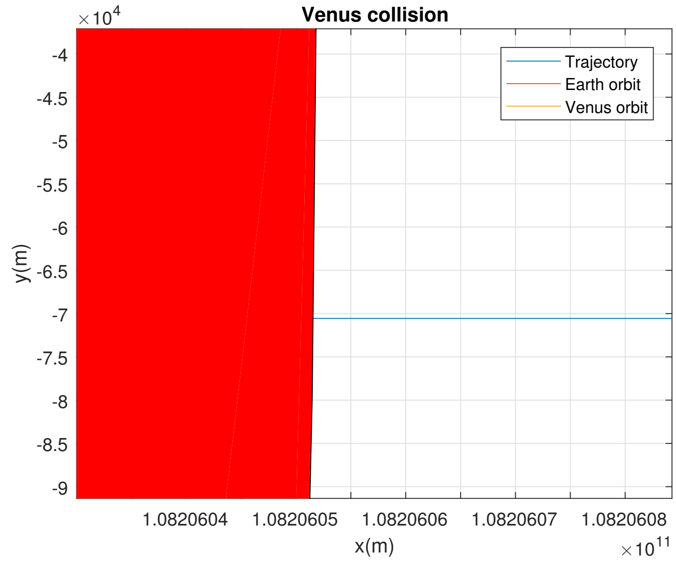
The position vector is obtained from calculating the angle at that point by subtracting the result of the multiplication of the angular velocity and the time to reach Venus orbit from 0. The x position is obtained by multiplying the distance from sun to venus by cosine theta and the y position is obtained by multiplying the distance from sun to venus by sin theta.

3. Use your solution from 2(d) as the initial condition for Venus, and $v_0 = 0$ for the spacecraft, but do NOT ignore the gravity effects of Venus

(a) Plot the trajectory of the spacecraft from $t = 0$ to collision on Venus' surface

When you account the gravity effects of Venus, this time the y-axis does change, its hard to see in the regular plot, but you can see the change in y in the zoom in, the y postion gets lower as time goes on as does the x position.





(b) What is the velocity (vector) at the instant of collision?

$\hat{v} = -2.6056 \times 10^4 \hat{\imath} - 0.0412\hat{\jmath}$ m/s

The velocity vector is obtained from the using ode45 a function that calculates the velocities and position with respect to time in this case for the drop from Earth to Venus accounting for Venus gravity effects this time.

(c) When does the collision occur?

$$t = 3.55572 \times 10^6 s$$

The time is obtained from the using the plot from Earth to Venus collision to see when the spacecraft collides with Venus.

(d) Where (along the Venus orbit path) does the collision occur?

$\hat{p} = 1.0821 \times 10^{11}\hat{\imath} - 7.0553 \times 10^4\hat{\jmath}$ m

The position vector is obtained from the using the plot from Earth to Venus collision to see where the spacecraft collides with Venus.

4. These questions explore an elliptical transfer orbit (Hohmann) from Earth to Venus, where the orbit focus is the Sun, Earth is aphelion, and Venus is perihelion. Well define $t = 0$ when the spacecraft is beginning its trajectory from aphelion at $(d_{S\rightarrow E}, 0)$

(a) For the elliptical orbit described, find the initial velocity vector

$\hat{v} = 0\hat{\imath} + 2.7292 \times 10^4\hat{\jmath}$ m/s

The initial velocity vector is calculated by using the Vis Viva equation.

(b) Find ΔV for a Cape Canaveral launch into this elliptical orbit

$$\Delta V = 1.3754 \times 10^8 m/s$$

ΔV for Cape Canaveral is calculated by first calculating the velocity of geosychronous orbit and using the law of cosines with the velocity of geosynchronous orbit, the initial velocity and Earths inclination.

(c) Find the spacecrafts velocity vector at perihelion, ignoring Venus gravity

$$v = 3.7734 \times 10^4 m/s$$

The spacecrafts velocity vector at perihelion is calculated using the Vis Viva equation.

(d) Find (x, y, t) when the spacecraft arrives at Venus orbit

$$x = -1.0819 \times 10^{11} m$$

$$y = -6.4743 \times 10^6 m$$

$$t = 1.2619 \times 10^7 s$$

The time is calculated by using the orbital period equation for the orbit using the semimajor axis. The (x, y) is then calculated by plotting the hohman transfer with the time using ode45 and obtaining the results from the plot.

(e) Find $(x, y, 0)$ for Venus so that the spacecraft will meet it at perihelion

$$x = 6.3520 \times 10^{10} m$$

$$y = -8.7593 \times 10^{10} m$$

(x, y) were calculated by first finding theta. Calculating the angle at that point by subtracting the result of the multiplication of the angular velocity and the time to reach perihelion from pi. The x position is obtained by multiplying the distance from sun to venus by cosine theta and the y position is obtained by multiplying the distance from sun to venus by sin theta.

(f) Find ΔV between the spacecraft and Venus when the spacecraft arrives

$$\Delta V = 2.7078 \times 10^3 m/s$$

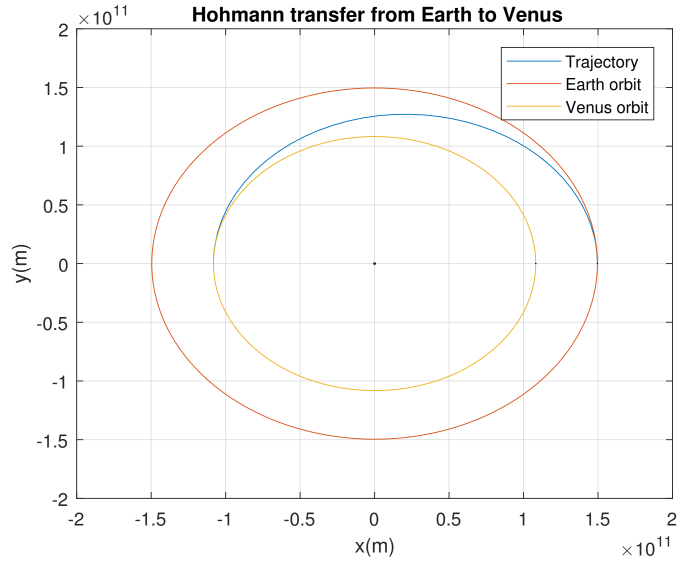
ΔV is calculted by subtracting the tangential velocity of venus from the velocity at perihelion.

(g) Find the radius of the circular orbit around Venus corresponding to ΔV from (f)

$$r = 1.2004 \times 10^{11} m$$

The radius is calculated by adding the radius of venus to the gravitational constant times the mass of venus over ΔV.

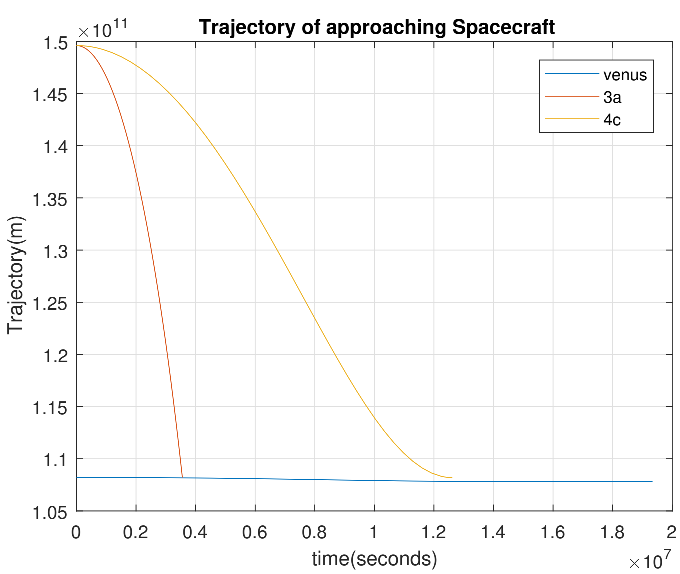
This is the hohman transfer plot.

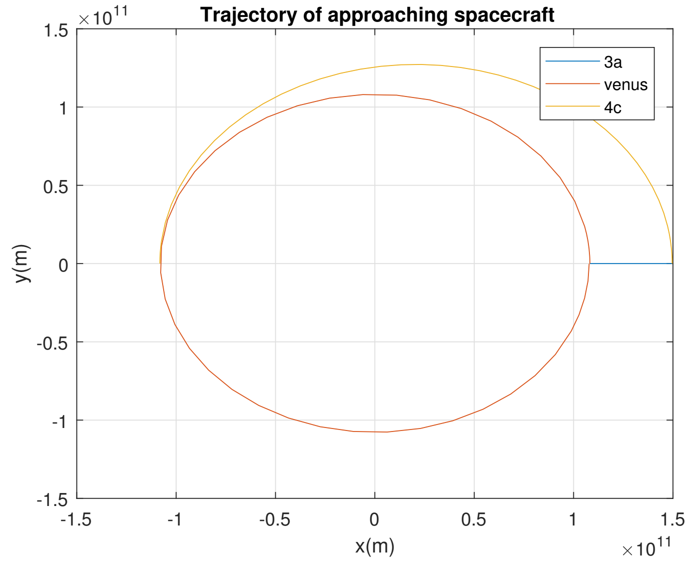


5. Lets see if we can get into a Venus orbit.... repeat the following for (3a) and (4c)

   (a) Plot the trajectories of the approaching spacecraft in a Cartesian coordinate system centered at, and moving with, Venus ; you can ignore rotation (i.e., plot the relative velocity of the spacecraft, with respect to Venus)

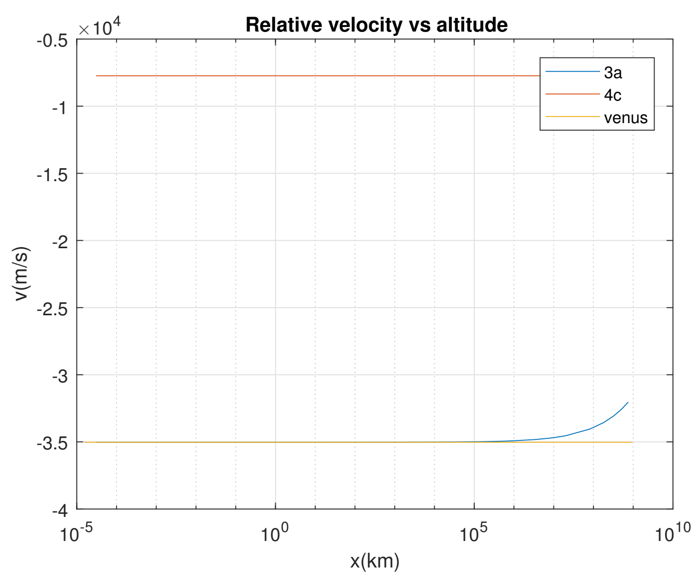
   On the top there is a plot of the trajectory vs time for problem 3a,4c and Venus. Below that there is a plot of the trajectory for problem 3a,4c and Venus.





(b) Plot the absolute value of the relative velocity vs altitude, and plot the velocity of the circular orbit about Venus vs altitude on the same plot, using a semilog plot for altitude, equally spaced from 200 to 1,000,000 km

Below is a plot of the relative velocity of 3a and 4c versus altitude and of the velocity of the circular orbit about Venus versus altitude.



(c) Find the altitude (if any) at which the velocity of the spacecraft matches the circular orbit velocity

For 3a there is no altitude at which the velocity of the spacecraft matches the circular orbit velocity. The opposite is true for 4c until about 1000000 km.

6. Now lets try a flyby gravity assist maneuver, based on the sphere-of-influence approach

(a) Calculate the radius of the sphere of influence of Venus, based on

$$r_{SOI} \approx d_{S\to V}\left(\frac{m_V}{m_S}\right)^{2/5}$$

$$r_{SOI} = 6.1629 \times 10^8 m$$

(b) Assume that the spacecraft reaches the SOI of Venus after an elliptical orbit in the SOI of the Sun, with a velocity equal to the perihelion velocity of the elliptical Hohmann transfer orbit from Earth to Venus (use Q6 results)

$$v = 3.7734 \times 10^4 m/s$$

(c) Find v_∞ , defined as the difference between the velocity in (b) and the orbital velocity of Venus. This is now treated as the velocity at that instant in a hyperbolic orbit of Venus, ignoring the Sun and all other bodies

$$v_\infty = 2.7078 \times 10^3 m/s$$

(d) Our fly-by is an hyperbolic orbit with periapsis r_p at altitude 300 km above the surface. Calculate v_{esc} for this altitude, and the velocity at periapsis of the hyperbolic fly-by orbit, v_p, defined by

$$v_p^2 = v_\infty^2 + v_{esc}^2$$

$$v_{esc} = 1.0116 \times 10^4 m/s$$

$$v_p = 1.0472 \times 10^4 m/s$$

(e) Calculate the eccentricity and semi-major axis a (note: a is negative for hyperbolic orbits) of our fly-by (μ here corresponds to Venus):

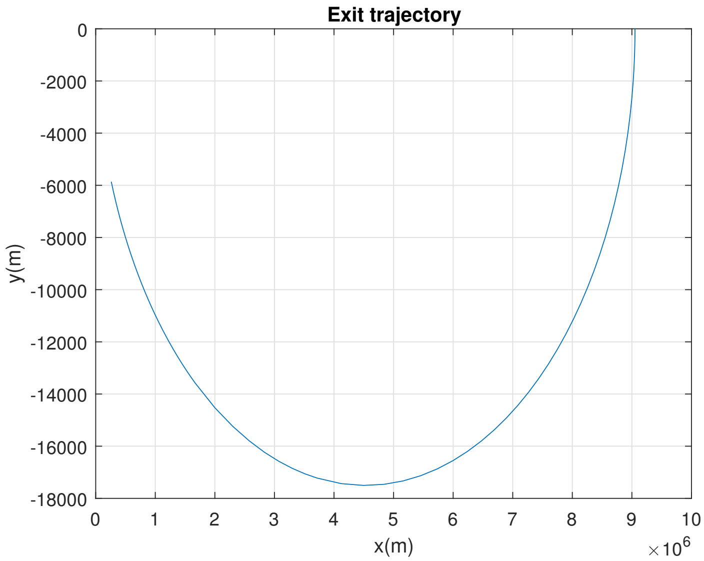
$$e = 1 + \frac{r_p v_\infty^2}{\mu} \quad , \quad r_p = a(1-e)$$

$$e = 1.1433$$

$$a = -4.4329 \times 10^7 m$$

(f) Using ODE45 and the hyperbolic initial conditions at our fly-by periapsis about Venus, calculate and plot the exit trajectory (note: this is the mirror image of the entrance trajectory)

Below is a plot of the exit trajectory..



(g) Find the total angular change of this flyby trajectory in heliocentric coordinates, noting again that the trajectory in (f) is only half of the fly-by

$$\Delta\theta = 90\circ$$

$\Delta\theta$ is calculated by first taking the arctan of the heliocentric y velocity over the heliocentric x velocity. The heliocentric x velocity is the inertial exit x velocity taken from the plot of the exit trajectory, and the heliocentric y velocity is calculated by adding the tangential velocity to the inertial exit y velocity on the plot. Then the angle calculated is subtracted from 90 degrees to get the angle change.

(h) Now use the (inertial) exit velocity and angle as a point in a heliocentric orbit. Ignore all other planets. Have we achieved escape velocity of the solar system? If not, what is the apohelion of the new heliocentric elliptical orbit?

$$v_{esc} = 3.1419 \times 10^7 m/s$$

The velocity is calculated by squaring the inertial exit x and y velocity, summing them and taking the square root. It did achieve escape velocity.

```
Appendix
function dzdt=hw11(t,z) %m-file for derivatives
ms=1.989*10^30 ;
mus=(6.674*10^(-11))*ms;

D=(z(1)^2+z(3)^2)^(3/2);
dzdt=[z(2); -mus*z(1)/D; z(4); -mus*z(3)/D];

function dzdt2=hw11p2(t2,z2) %m-file for derivatives
mv=4.87*10^24;      %kg mass of venus
ms=1.989*10^30 ;     %kg mass of the sun
mus=(6.674*10^(-11))*ms;
dse=149600000*1000; %meters distance from sun to earth
```

```
dsv=108200000000;    % meters distance from sun to venus
tv2c=3555800;
wv1d=(mus/(dsv^3))^.5;
thetazero=0-(wv1d*tv2c);
rvx2d=dsv*cos(thetazero);
rvy2d=dsv*sin(thetazero);
muv=(6.674*10^(-11))*mv;    % mass of venus *G
Ds=(z2(1)^2+z2(3)^2)^(3/2);   %(x^2+y^2)^1.5

Dvx=rvx2d-z2(1);                 %x1-x
Dvy=rvy2d-z2(3);
D5=(Dvx^2+Dvy^2)^(3/2);         %((x1-x)+y^2)^.15
dzdt2=[z2(2); (muv*Dvx/D5)-(mus*z2(1)/Ds); z2(4); (muv*Dvy)/D5-(mus*z2(3))/Ds];%integral
end


function dzdt3=hw11p3(t3,z3) %m-file for derivatives
mv=4.87*10^24;      %kg mass of venus
dse=149600000*1000; %meters distance from sun to earth
dsv=108200000000;    % meters distance from sun to venus
ms=1.989*10^30 ;     %kg mass of the sun
mus=(6.674*10^(-11))*ms;    %mass of sun times G
muv=(6.674*10^(-11))*mv;    % mass of venus *G
D3=(z3(1)^2+z3(3)^2)^(3/2);   %(x^2+y^2)^1.5
         %((x1-x)+y^2)^.15
dzdt3=[z3(2); (mus*z3(1)/D3); z3(4); (-mus*z3(3))/D3];%integral
end

function dzdt4=hw11p4(t4,z4) %m-file for derivatives
mv=4.87*10^24;      %kg mass of venus
ms=1.989*10^30 ;     %kg mass of the sun
mus=(6.674*10^(-11))*ms;
dse=149600000*1000; %meters distance from sun to earth
dsv=108200000000;    % meters distance from sun to venus
tv2c=3555800;
wv1d=(mus/(dsv^3))^.5;
thetazero=0-(wv1d*tv2c);
rvx2d=dsv*cos(thetazero);
rvy2d=dsv*sin(thetazero);
muv=(6.674*10^(-11))*mv;    % mass of venus *G
Ds=(z4(1)^2+z4(3)^2)^(3/2);   %(x^2+y^2)^1.5

Dvx=rvx2d-z4(1);                 %x1-x
Dvy=rvy2d-z4(3);
D5=(Dvx^2+Dvy^2)^(3/2);         %((x1-x)+y^2)^.15
dzdt4=[z4(2); (muv*Dvx/D5)-(mus*z4(1)/Ds); z4(4); (muv*Dvy)/D5-(mus*z4(3))/Ds];%integral
end

function dzdt=hw11p6(t6,z6) %m-file for derivatives
mv=4.87*10^24;      %kg
ms=1.989*10^30 ;
mus=(6.674*10^(-11))*ms;
muv=(6.674*10^(-11))*mv;
D3=(z6(1)^2+z6(3)^2)^(3/2);
dzdt=[z6(2); (-mus*z6(1))/D3; z6(4); (-mus*z6(3))/D3];
end
```

```
close all;
clear all;
clc;
%Project 2 Andy Perez
G=6.674*10^-11;   %m^3/(kgs^2)
me=5.972*10^24;   % kg
re=6.371*10^6 ;    % m
dse=149600000*1000;  %m
mv=4.87*10^24;      %kg
rv=6052*1000 ;       %m
dsv=108200000*1000 ;  %m
ms=1.989*10^30 ;     %kg
rs=659.7*10^6;
whattoendvenusat=dsv+2*rv;
%1
dev=dse-dsv;
gv1a=G*mv/(dev^2)
gs1a=G*ms/(dse^2)
gv1b=G*mv/(rv^2)
gs1b=G*ms/(dsv^2)
ge1b=G*me/(dev^2)
Wse=(dse*G*ms)/(dse^2);
Wsv=(dsv*G*ms)/(dsv^2);
Ws1c=Wsv-Wse
wv1d=(G*ms/(dsv^3))^.5
vv1d=dsv*wv1d
vvesc1e=((2*G*mv)/rv)^.5
%2
theta=0:pi/90:2*pi;
x2=dse*cos(theta);
y2=dse*sin(theta);
x2v=dsv*cos(theta);
y2v=dsv*sin(theta);
%function dzdt=hw11(t,z) %m-file for derivatives
%mus=6.674/10^(11)*ms
%z=[dse;0;0;0];
%D=(z(1)^2+z(3)^2)^(3/2)
%dzdt=[z(2); -mus*z(1)/D; z(4); -mus*z(3)/D];
[t,z] = ode45(@hw11,[0 3555800],[dse;0;0;0]); %Actual integration
 %2a
figure
plot(z(:,1),z(:,3));
hold on;
plot(x2,y2)
plot(x2v,y2v)
 ylim([-2*10^11 2*10^11])
 xlim([-2*10^11 2*10^11])
 %axis equal

 grid on;
 %Plot the orbit
```

```
 ang=[0:0.01:2*pi];X=(dse)+6370000*cos(ang);Y=6370000*sin(ang); %Define
 the Earth
 fill(X,Y,'g') %Plot the Earth
 ang=[0:0.01:2*pi];Xv=(10.82*10^10)+rv*cos(ang);Yv=rv*sin(ang);
 fill(Xv,Yv,'r') %Plot the Venus
 ang=[0:0.01:2*pi];Xs=rs*cos(ang);Ys=rs*sin(ang);
 fill(Xs,Ys,'y') %Plot the Sun
 title('Drop from Earth to Venus')
 legend('Trajectory','Earth orbit','Venus orbit')

 xlabel('x(m)')
 ylabel('y(m)')
%end
%2b
vvx2b=z(81,2)
vvy2b=z(81,4)
vv2b=abs(vvx2b);
%2c
tv2c=3555800
%take from graph
%2d
thetazero=0-(wv1d*tv2c);
rvx2d=dsv*cos(thetazero)
rvy2d=dsv*sin(thetazero)
%theta0=theta-wv*t
%theta=0
%rv=dsvcos(theta0)+dsvsin(theta0)
%3a
[t2,z2] = ode45(@hw11p2,[0 tv2c-80],[dse;0;0;0]);

%plot(z2(1),z2(3))

 figure
 plot(z2(:,1),z2(:,3));
%[t3,z3] = ode45(@hw11p3,[0 tv2c],[rvx2d;0;rvy2d;0]); %Actual
 integration
%4.3*10^6
hold on;
%ylim([-10*10^10 1*10^10])
 ang=[0:0.01:2*pi];X=(dse)+6370000*cos(ang);Y=6370000*sin(ang); %Define
 the Earth

 plot(x2,y2)
plot(x2v,y2v)
 fill(X,Y,'g') %Plot the Earth
 ang=[0:0.01:2*pi];Xv=(10.82*10^10)+rv*cos(ang);Yv=rv*sin(ang);
 fill(Xv,Yv,'r') %Plot the Venus
 ang=[0:0.01:2*pi];Xs=rs*cos(ang);Ys=rs*sin(ang);
 fill(Xs,Ys,'y') %Plot the Sun
 ang=[0:0.01:2*pi];X=(dse)+6370000*cos(ang);Y=6370000*sin(ang); %Define
 the Earth
 fill(X,Y,'g') %Plot the Earth
 %axis equal ;
 grid on;
```

```
%Plot the orbit
title('Venus collision')
 legend('Trajectory','Earth orbit','Venus orbit')
xlabel('x(m)')
 ylabel('y(m)')
 ylim([-2*10^11 2*10^11])
 xlim([-2*10^11 2*10^11])
%3b
vx3b=z2(81,2)
vy3b=z2(81,4)
%3c
tv3c=tv2c-80
%3d
x3d=z2(81,1)
y3d=z2(81,3)
%4

%use vb equation in lecture 12
%vi=(re*2*pi*cosd(28.6))/(24*3600)
%b use a and +vcapecanaveral
%vcapecanaveral =dse2pi/1 year-(re2pi/1day*cos(28.6))
%4c=(Gm/r1)^.5*(2R2/(R1+r2)^.5
%4a and 4c 0 in the i direction
%for 4b use page 14 lecture 12 theta is 23 degrees
%4d period of an elliptical orbit divide by 2
%4e pi=theta
%theta0=theta-wv*t
%theta=0
%rv=dsvcos(theta0)+dsvsin(theta0)
%4f 4c-vv vvi sthe tangential velocity of venus
%for 3 just find from graph
% 4g R+g*mv/deltav from part f
%5 for 4c use venus gravity
a=(dse+dsv)/2;
b=(dse*dsv)^.5;
e=(1-(b^2/a^2))^.5;
vp=(G*ms/a)*((1-e)/(1+e));
fo4=(2/re)-(1/dse);
fo42=(2/rv)-(2/dse);
vha=(G*ms*fo4)^.5;
bigR=dse/dsv;
v4a=((G*ms)/dse)^.5*(2/(1+bigR))^.5% this is correct
vcc =((dse*2*pi)/(365*24*3600))-(((re*2*pi)/(24*3600))*cosd(28.6));
deltav4b=v4a^2+vcc^2-(2*v4a*vcc*cosd(23.5))
vpha4c=((G*ms)/dsv)^.5*((2*dse)/(dsv+dse))^.5



%4d
%a4d=(-G*ms)/dse^2

t4d=pi*(a^3/(G*ms))^.5
%t4d=2*pi*(a^3/(G*ms))^.5 period
%4e
```

```
theta4e=pi-wv1d*t4d;
rvx4e=dsv*cos(theta4e)
rvy4e=dsv*sin(theta4e)

%4f
deltav4f=vpha4c-vv1d
%4g
R4g=rv+((G*mv)/deltav4f)
%wv4g=(G*mv/(rv^3))^.5
%v4g=v4f*wv4g
%4
figure
[t4,z4] = ode45(@hw11p4,[0 t4d],[dse;0;0;v4a]);
rvx4d=z4(125,1)
rvy4d=z4(125,3)

%tv2c*3.56
plot(z4(:,1),z4(:,3));
hold on;
plot(x2,y2)
plot(x2v,y2v)
grid on;
ang=[0:0.01:2*pi];X=(dse)+6370000*cos(ang);Y=6370000*sin(ang); %Define
 the Earth
 fill(X,Y,'g') %Plot the Earth
 ang=[0:0.01:2*pi];Xv=(10.82*10^10)+rv*cos(ang);Yv=rv*sin(ang);
 fill(Xv,Yv,'r') %Plot the Venus
 ang=[0:0.01:2*pi];Xs=rs*cos(ang);Ys=rs*sin(ang);
 fill(Xs,Ys,'y') %Plot the Sun
 title('Hohmann transfer from Earth to Venus')
 legend('Trajectory','Earth orbit','Venus orbit')
xlabel('x(m)')
 ylabel('y(m)')
ylim([-2*10^11 2*10^11])
 xlim([-2*10^11 2*10^11])

 %5a
[t5,z5] = ode45(@venus,[0 (225*24*3600)-100000],[dsv;0;0;vv1d]);
%5a
r3a5=zeros(81,1);
r4c5=zeros(125,1);
rvenustraj5=zeros(125,1);
for ii=1:1:125
    rvenustraj=((z5(ii,1))^2+(z5(ii,3))^2)^.5;
    rvenustraj5(ii,1)=rvenustraj;
    r4c=((z4(ii,1))^2+(z4(ii,3))^2)^.5;
    r4c5(ii,1)=r4c;
end
for ii=1:1:81
    r3a=((z2(ii,1))^2+(z2(ii,3))^2)^.5;
    r3a5(ii,1)=r3a;
end
 figure
 plot(t5,rvenustraj5,t2,r3a5)
```

```
 grid on;
 hold on;
 plot(t4,r4c5)
 legend('venus','3a','4c')
 title('Trajectory of approaching Spacecraft')
 ylabel('Trajectory(m)')
 xlabel('time(seconds)')
%figure

%plot(z2(:,1),z2(:,3))
%5b
realv5b3a=zeros(81,1);
realv5b4c=zeros(125,1);
for threea=1:81
    v5b3a=((z2(threea,2))^2+(z2(threea,4))^2)^.5;
realv5b3a(threea)=v5b3a;
end
for fourc=1:125
    v5b4c=((z4(fourc,2))^2+(z4(fourc,4))^2)^.5;
    realv5b4c(fourc)=v5b4c;
end

figure
plot(z2(:,1),z2(:,3),z5(:,1),z5(:,3),z4(:,1),z4(:,3))

grid on;
relv5b3a=realv5b3a-vv1d;
relv5b4c=realv5b4c-vv1d;
x5b3a=zeros(81,1);
title('Trajectory of approaching spacecraft')
xlabel('x(m)')
 ylabel('y(m)')
 legend('3a','venus','4c')
for threea=1:81
 if  z2(threea,1)<(dse-10^9)
     break
 else
x5b3a(threea)=abs(((z2(threea,1)-dse)));
end
end
x5b4c=zeros(125,1);
for fourc=1:125
 if  z4(fourc,1)<(dse-10^9)
     break
 else
x5b4c(fourc)=abs(((z4(fourc,1)-dse)));
end
end
x5bvenus=zeros(125,1);
for b5venus=1:125
 if  z5(b5venus,1)<(dsv-10^9)
     break
 else
x5bvenus(b5venus)=abs(((z5(b5venus,1)-dsv)));
```

```
end
end
anglev5=zeros(125,1);
vvenus5=zeros(125,1);
for iii=1:1:125
    anglev=atan(z5(iii,4)/z5(iii,2));
    anglev5(iii,1)=anglev;
    if anglev<0
        vvenus5(iii,1)=-vv1d;
    else
        vvenus5(iii,1)=vv1d;
    end
end


x5b3aa=x5b3a(1:46);
x5b4cc=x5b4c(1:83);
figure
semilogx(x5b3aa,relv5b3a(1:46))
hold on;
semilogx(x5b4cc,relv5b4c(1:83))
semilogx(x5bvenus,vvenus5)
legend('3a','4c','venus')
title('Relative velocity vs altitude')
xlabel('x(km)')
 ylabel('v(m/s)')
grid on;





%6f
%-vp=vy
%rv+3000000=x
%vx=0
%y=0
%6a
%vyhelio=vy+vv
%vxhelio=vx
%taninverse(vyhelio/vxhelio)
%90-taninverse(theta);
%pyhelio=py
%pxhelio=px+dsv

rsoi6a=dsv*(mv/ms)^.4
v6b=vpha4c
vinf6c=vpha4c-vv1d
vvesc6d=((2*G*mv)/(rv+300000))^.5
vp6d=(vinf6c^2+vvesc6d^2)^.5
e6e=1+(((rv+300000)*vinf6c^2)/(G*mv))
a6e=(rv+300000)/(1-e6e)
%6f
vy6f=-vp6d;
```

```
x6f=rv+3000000;
vx6f=0;
y6f=0;
[t6,z6] = ode45(@hw11p6,[0 2.62],[x6f;0;0;vy6f]);
figure
plot(z6(:,1),z6(:,3));
grid on;
title('Exit trajectory')
xlabel('x(m)')
 ylabel('y(m)')


pyhelio=z6(121,3);
pxhelio=z5(121,3)+dsv;
angs6g=atand(pyhelio/pxhelio);
angle6g=90-angs6g

vyhelio=z6(121,4)+vv1d;
vxhelio=z6(121,2);
angs6h=atand(vyhelio/vxhelio);
angle6h=90-angs6h
v6h=(vxhelio^2+vyhelio^2)^.5


gv1a =

   1.8963e-07


gs1a =

    0.0059


gv1b =

    8.8740


gs1b =

    0.0113


ge1b =

   2.3254e-07


Ws1c =

   3.3952e+08
```

```
wv1d =

   3.2372e-07


vv1d =

   3.5027e+04


vvesc1e =

   1.0364e+04


vvx2b =

  -2.6057e+04


vvy2b =

     0


tv2c =

     3555800


rvx2d =

   4.4091e+10


rvy2d =

  -9.8809e+10


vx3b =

  -2.6056e+04


vy3b =

   -0.0412


tv3c =

     3555720
```

```
x3d =

   1.0821e+11


y3d =

  -7.0553e+04


v4a =

   2.7292e+04


deltav4b =

   1.3754e+08


vpha4c =

   3.7734e+04


t4d =

   1.2619e+07


rvx4e =

   6.3520e+10


rvy4e =

  -8.7593e+10


deltav4f =

   2.7078e+03


R4g =

   1.2004e+11


rvx4d =

  -1.0819e+11
```

```
rvy4d =

  -6.4743e+06

rsoi6a =

   6.1629e+08

v6b =

   3.7734e+04

vinf6c =

   2.7078e+03

vvesc6d =

   1.0116e+04

vp6d =

   1.0472e+04

e6e =

    1.1433

a6e =

  -4.4329e+07

angle6g =

   90.0000

angle6h =

   90.6875

v6h =
```

3.1419e+07