# Problem 3

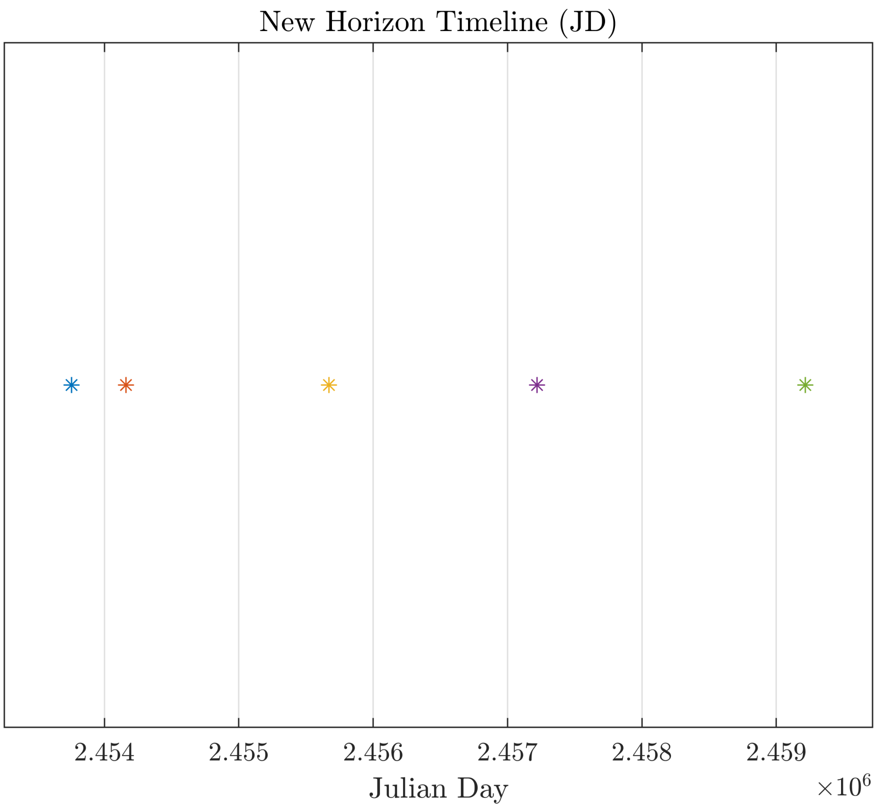
```
interr = 'latex';
% interr = 'none';
set(groot,'defaulttextinterpreter',interr);
set(groot, 'defaultAxesTickLabelInterpreter',interr);
set(groot, 'defaultLegendInterpreter',interr);
```

## Preliminary Calculations and Constants:

```
Rm = 1738.2; % Lunar radius, km
mu = 4902.8005821478; % Lunar mu, km^3/s^2
```

## Part a)

```
launch = 2453755.0000000;
Jupiter = 2454160.0000000;
Uranus = 2455670.0000000;
Pluto = 2457219.0000000;
UltimaThule = 2459216.0000000;
plot(launch,0,'*'),hold on,plot(Jupiter,0,'*'),plot(Uranus,0,'*'),plot(Pluto,0,'*'),plo
grid on
xlabel('Julian Day')
% ylim([-.002 .002])
xlim([launch-500, UltimaThule+500])
title('New Horizon Timeline (JD)')
axis equal
set(gca,'ytick',[])
```




## Part b)

```
mu = 132712440017.99;
a1 = 149597898;
a2 = 5907150229;
[aT, eT, TOF_total, ...
    v1_0, gamma_1_N, v1_N, dv1, alpha1, beta1, ...
    v2_0, gamma_2_N, v2_N, dv2, alpha2, beta2, ...
    dv_mag_total] = coplanartransfer(a1,a2,0,pi,mu)
```

```
aT = 3.0284e+09
eT = 0.9506
TOF_total = 1.4372e+09
v1_0 = 2×1
         0
   29.7847
gamma_1_N = 2.9802e-08
v1_N = 2×1
    0.0000
   41.5985
dv1 = 2×1
    0.0000
   11.8138
alpha1 = 1.0494e-07
beta1 = 3.1416
v2_0 = 2×1
         0
    1.0535
gamma_2_N = 2.1073e-08
v2_N = 2×1
```

```
         0
    4.7399
dv2 = 2×1
         0
    3.6864
alpha2 = 2.7096e-08
beta2 = 3.1416
dv_mag_total = 15.5002
```

```
1/2 * (a1 + a2)
```

```
ans = 3.0284e+09
```

```
norm(dv1),norm(dv2)
```

```
ans = 11.8138
ans = 3.6864
```

```
TOF_jdyear = TOF_total/86400/365.25
```

```
TOF_jdyear = 45.5412
```

```
TOF_newhorz = (Pluto - launch)/365.25
```

```
TOF_newhorz = 9.4839
```

## Part c)

```
phase = pi - TOF_total * sqrt(mu/a2^3), phase_deg = rad2deg(phase)
```

```
phase = 1.9884
phase_deg = 113.9276
```

```
ts = 2*pi / (sqrt(mu/a1^3)-sqrt(mu/a2^3)), ts_day = ts/3600/24, ts_year = ts_day/365.25
```

```
ts = 3.1686e+07
ts_day = 366.7350
ts_year = 1.0041
```

## Part d)

```
e_pluto = 0.24885238;
rp_pluto = a2 * (1 - e_pluto)
```

```
rp_pluto = 4.4371e+09
```

```
[aTn, eTn, TOF_totaln, ...
    v1_0n, gamma_1_Nn, v1_Nn, dv1n, alpha1n, beta1n, ...
    v2_0n, gamma_2_Nn, v2_Nn, dv2n, alpha2n, beta2n, ...
    dv_mag_totaln] = coplanartransfer(a1,rp_pluto,0,pi,mu)
```

```
aTn = 2.2934e+09
eTn = 0.9348
TOF_totaln = 9.4712e+08
v1_0n = 2×1
         0
   29.7847
```

```
gamma_1_Nn = 2.1073e-08
v1_Nn = 2×1
    0.0000
   41.4293
dv1n = 2×1
    0.0000
   11.6446
alpha1n = 7.4975e-08
beta1n = 3.1416
v2_0n = 2×1
         0
    1.3968
gamma_2_Nn = 4.2147e-08
v2_Nn = 2×1
         0
    5.4690
dv2n = 2×1
         0
    4.0722
alpha2n = 5.6604e-08
beta2n = 3.1416
dv_mag_totaln = 15.7168
```

```
norm(dv1n)
```

```
ans = 11.6446
```

```
TOF_year = TOF_totaln/86400/365.25
```

```
TOF_year = 30.0124
```

```
TOF_jdyear - TOF_year
```

```
ans = 15.5288
```

## Function 1: Transfer Characteristics (Circle to Circle)

Can change to work with any starting and ending orbits, once that works, bi-elliptic/multiburn transfer can be done through recursion or multiple function calls

Transfer starting at periapsis of transfer orbit to transfer angle on orbit

a1 and a2 in km

ths1 and ths2 are initial and final true anomalies on transfer orbit

```
function [aT, eT, TOF_total, ...
    v1_0, gamma_1_N, v1_N, dv1, alpha1, beta1, ...
    v2_0, gamma_2_N, v2_N, dv2, alpha2, beta2, ...
    dv_mag_total] = coplanartransfer(a1,a2,ths1,ths2,mu)
```

Transfer Orbit Characteristics:

```
eT = (a2 - a1)/(a2 + a1 * cos(ths1));
aT = a2/(1+eT);
E1 = eccenAnom(ths1,eT);
E2 = eccenAnom(ths2,eT);
TOF1 = sqrt(aT^3/mu) * (E1 - eT*sin(E1));
```

```
TOF2 = sqrt(aT^3/mu) * (E2 - eT*sin(E2));
TOF_total = TOF2-TOF1;
```

1st Thrust Point Conditions (Pre-Maneuver: Initial Orbit): (change this to be able to accomodate other starting orbit)

```
r1_mag = a1; v1_mag_0 = sqrt(mu*(2/r1_mag-1/a1));
v1_0 = [0 v1_mag_0]';
```

1st Thrust Point Conditions (Post-Maneuver: Transfer Orbit):

```
v1_mag_N = sqrt(mu*(2/r1_mag - 1/aT));
gamma_1_N = findFPA(aT,eT,r1_mag,mu,ths1);
v1_N = v1_mag_N * [sin(gamma_1_N),cos(gamma_1_N)]';
dv1 = v1_N - v1_0; dv1_mag = norm(dv1);
[alpha1,beta1] = alphabeta(v1_mag_0,norm(v1_N),dv1_mag,gamma_1_N);
```

2nd Thrust Point Conditions (Pre-Maneuver: Transfer Orbit):

```
r2_mag = a2;
v2_mag_0 = sqrt(mu*(2/r2_mag - 1/aT)); v2_0 = [0 v2_mag_0]';
```

2nd Thrust Point Conditions (Post-Maneuver: Final Orbit): (change this to be able to accomodate other final orbit)

```
v2_mag_N = sqrt(mu*(2/r2_mag - 1/a2)); v2_N = [0 v2_mag_N]';
gamma_2_N = findFPA(aT,eT,r2_mag,mu,ths2);
dv2 = v2_N - v2_0; dv2_mag = norm(dv2);
dv_mag_total = dv1_mag + dv2_mag;
[alpha2,beta2] = alphabeta(v2_mag_0,norm(v2_N),dv2_mag,gamma_2_N);
end
```

## Function 2: Eccentric Anomaly

```
function E = eccenAnom(ths,e)
    E = 2*atan(sqrt((1-e)/(1+e))*tan(ths/2));
end
```

## Function 3: Find FPA

```
function FPA = findFPA(a,e,r,mu,ths)
vmag = sqrt(mu*(2/r-1/a));
p = a*(1-e^2);
h = sqrt(mu*p);
FPA = acos(h/r/vmag);
if wrapTo2Pi(ths) <= 180
    FPA = abs(FPA);
else
    FPA = -abs(FPA);
end
end
```

## Function 4: Alpha and Beta

```
function [alpha, beta] = alphabeta(v0,vN,dv,dgamma)
angles = asin(vN/dv * sin(dgamma));
```

```
angles = [angles pi-angles];

if v0 > vN
    alpha = max(angles);
    beta = min(angles);
elseif v0 < vN
    alpha = min(angles);
    beta = max(angles);
elseif dv == 0
    alpha = 0;
    beta = pi;
end

if dgamma < 0
    alpha = -abs(alpha);
else
    alpha = abs(alpha);
end
end
```

### Function 5: Plotting Initial and Final Orbits

```
function plotinitfin(ai,ei,af,ef)
    ths_plot = linspace(0,2*pi,2^12)';
    ri = (ai*(1-ei^2))./(1+ei*cos(ths_plot));
    rf = (af*(1-ef^2))./(1+ef*cos(ths_plot));
    ri = ri .* [cos(ths_plot),sin(ths_plot)];
    rf = rf .* [cos(ths_plot),sin(ths_plot)];
    plot(ri(:,1),ri(:,2)), hold on, plot(rf(:,1),rf(:,2))
    grid on
    axis equal
    maxlim = max([ai af]); maxlim = [-maxlim maxlim]*1.5;
    xlim(maxlim), ylim(maxlim)
    plot(0,0,'go','MarkerSize', 10)
end
```

### Function 6: Plotting Transfer Orbit

```
function plottransfer(aT,eT,ths1,ths2)
ths_plot = linspace(ths1,ths2,2^12);
r_T_plot = aT * (1-eT^2)./(1+eT*cos(ths_plot));
rx_T = r_T_plot.*cos(ths_plot-ths1); ry_T = r_T_plot.*sin(ths_plot-ths1);
plot(rx_T,ry_T)
plot(r_T_plot(end).*cos(ths2-ths1),r_T_plot(end).*sin(ths2-ths1),'*')
end
```

### Function 7: Velocity Vectors

```
function plotvel(a,e,ths,v,color,dvoption,angle)
rmag = a*(1-e^2)/(1+e*cos(ths));
size = 3e3;
iCr = [cos(ths-angle) -sin(ths-angle); sin(ths-angle) cos(ths-angle)];
v = iCr*v;
if dvoption(1) == 1
```

```
    v0 = dvoption(2:3);
    v0 = iCr * v0;
    quiver(rmag*cos(ths-angle)+v0(1)*size,rmag*sin(ths-angle)+v0(2)*size,v(1),v(2),size
else
    quiver(rmag*cos(ths-angle),rmag*sin(ths-angle),v(1),v(2),size,color)
end
end
```

### Function 8: Position Vectors

```
function plotpos(a,e,ths,color,angle)
rmag = a*(1-e^2)/(1+e*cos(ths)); r = [rmag 0]';
iCr = [cos(ths-angle) -sin(ths-angle); sin(ths-angle) cos(ths-angle)];
r = iCr * r;
quiver(r(1),r(2),color,'Autoscale','off')
plotunit(r,ths-angle,color)
end
```

### Function 9: Unit Vectors

```
function plotunit(pos,th,color)
x = pos(1); y = pos(2); size = 7e3;
iCr = [cos(th) -sin(th); sin(th) cos(th)];
hat1 = iCr * [1 0]' * size;
hat2 = iCr * [0 1]' * size;
quiver(x,y,hat1(1),hat1(2),'r--')% x1
quiver(x,y,hat2(1),hat2(2),'r--')% x2
end
```

## Function 3: Find Direction Cosine Matrix

```
function iCr = findDCM(om,inc,th)
    col1 = [cos(om)*cos(th) - sin(om)*cos(inc)*sin(th);
        sin(om)*cos(th)+cos(om)*cos(inc)*sin(th);
        sin(inc)*sin(th)];
%     col2 = [-cos(om)*sin(th)-sin(om)*cos(inc)*cos(th);
%         -sin(om)*sin(th)+cos(om)*cos(inc)*cos(th);
%         sin(inc)*cos(th)];
    col3 = [sin(om)*sin(inc);
        -cos(om)*sin(inc);
        cos(inc)];

    col2 = cross(col3,col1);
    iCr = [col1 col2 col3];
end
```