Problem 2

```
interr = 'latex';
% interr = 'none';
set(groot,'defaulttextinterpreter',interr);
set(groot, 'defaultAxesTickLabelInterpreter',interr);
set(groot, 'defaultLegendInterpreter',interr);
R_E = 6378.1363;
R_J = 71492.0;
R_P = 1162.0;
mu_E = 398600.4415;
mu_J = 126712767.8578;
mu_P = 981.600887707;
mu_S = 132712440017.99;
a_E = 149597898.0;
a_J = 778279959.0;
a_P = 5907150229.0;
AU = 1.496e+8;
```

Given

```
v_E_inf_mag = 12.8;
v_E_mag = sqrt(mu_S/a_E)
```

```
v_E_mag = 29.7847
```

```
v_J_mag = sqrt(mu_S/a_J)
```

```
v_J_mag = 13.0583
```

```
v_P_mag = sqrt(mu_S/a_P)
```

```
v_P_mag = 4.7399
```

Part a)

Transfer Orbit Before Jupiter Encounter (Heliocentric View)

```
rp_T_mag = a_E + 250, r1_mag = rp_T_mag;
```

```
rp_T_mag = 149598148
```

```
vp_T_mag = v_E_inf_mag + v_E_mag
```

```
vp_T_mag = 42.5847
```

```
a_T = -mu_S * (vp_T_mag^2 - 2*mu_S/rp_T_mag)^-1
```

```
a_T = -3.3852e+09
```

```
e_T = 1 - rp_T_mag/a_T
```

```
e_T = 1.0442
```

Earth Parking and Hyperbolic Orbits (Geocentric View)

```
rp_E = R_E + 250
```

```
rp_E = 6.6281e+03
```

```
vp_E_0_mag = sqrt(mu_E/(rp_E))
```

```
vp_E_0_mag = 7.7548
```

```
vp_E_n_mag = sqrt(v_E_inf_mag^2 + 2*mu_E/rp_E)
```

```
vp_E_n_mag = 16.8557
```

```
dv1_mag = vp_E_n_mag - vp_E_0_mag
```

```
dv1_mag = 9.1009
```

Jupiter Encounter Before Assist (Heliocentric View)

```
r_2_mag = a_J
```

```
r_2_mag = 778279959
```

```
ths_2_0 = acos(1/e_T * ((a_T*(1-e_T^2)/r_2_mag)-1))
```

```
ths_2_0 = 2.1912
```

```
ths_2_0_deg = rad2deg(ths_2_0)
```

```
ths_2_0_deg = 125.5477
```

```
ths_1_0 = 0
```

```
ths_1_0 = 0
```

```
H_1_0 = conicanom(ths_1_0,e_T)
```

```
H_1_0 = 0
```

```
H_2_0 = conicanom(ths_2_0,e_T)
```

```
H_2_0 = 0.5879
```

```
TOF_E_J = timeofflight(0,ths_2_0,a_T,e_T,0,mu_S)
```

```
TOF_E_J = 3.3500e+07
```

```
TOF_E_J_day = TOF_E_J/3600/24
```

```
TOF_E_J_day = 387.7281
```

Part b)

```
startJD = 2453754.5000000
```

```
startJD = 2.4538e+06
```

```
endJD = 2454159.5000000
```

```
endJD = 2.4542e+06
```

```
TOF_E_J_actual_day = endJD - startJD
```

```
TOF_E_J_actual_day = 405
```

```
TOF_E_J_actual_sec = TOF_E_J_actual_day * 3600 * 24
```

```
TOF_E_J_actual_sec = 34992000
```

Part c)

```
H_2_0 = linspace(.4,.7,2^14);

for i = 1:length(H_2_0)
    TOF_test(i) = sqrt(abs(a_T)^3/mu_S) * (e_T*sinh(H_2_0(i)) - H_2_0(i));
end
diff_TOF = abs(TOF_test - TOF_E_J_actual_sec);
ind = find(min(diff_TOF) == diff_TOF)
```

```
ind = 10907
```

```
H_2_0 = H_2_0(ind), ths_2_0 = trueanom(H_2_0,e_T), ths_2_0_deg = rad2deg(ths_2_0)
```

```
H_2_0 = 0.5997
ths_2_0 = 2.2064
ths_2_0_deg = 126.4170
```

```
r_2_0_mag = a_T*(1-e_T^2)/ (1+e_T * cos(ths_2_0))
```

```
r_2_0_mag = 8.0453e+08
```

```
iCr_2_0 = [cos(ths_2_0) -sin(ths_2_0); sin(ths_2_0) cos(ths_2_0)]
```

```
iCr_2_0 = 2×2
   -0.5937   -0.8047
    0.8047   -0.5937
```

```
r_2_0 = iCr_2_0 * [r_2_0_mag 0]'
```

```
r_2_0 = 2×1
10^8 ×
   -4.7761
    6.4742
```

```
p_T = a_T * (1-e_T^2)
```

```
p_T = 3.0581e+08
```

```
v_2_0_mag = sqrt(mu_S*(2/r_2_0_mag - 1/a_T))
```

```
v_2_0_mag = 19.2124
```

```
gamma_2_0 = acos(sqrt(mu_S*p_T)/r_2_0_mag/v_2_0_mag)
```

```
gamma_2_0 = 1.1460
```

```
gamma_2_0_deg = rad2deg(gamma_2_0)
```

```
gamma_2_0_deg = 65.6600
```

```
v_2_0_R = v_2_0_mag * [sin(gamma_2_0); cos(gamma_2_0)]
```

```
v_2_0_R = 2×1
   17.5047
    7.9184
```

```
v_2_0 = iCr_2_0 * v_2_0_R
```

```
v_2_0 = 2×1
  -16.7639
    9.3855
```

```
v_J_mag = sqrt((mu_S + mu_J)/r_2_0_mag)
```

```
v_J_mag = 12.8497
```

```
v_J = iCr_2_0 * [0; v_J_mag]
```

```
v_J = 2×1
  -10.3404
   -7.6283
```

```
v_inf_J_0 = v_2_0 - v_J
```

```
v_inf_J_0 = 2×1
   -6.4235
   17.0139
```

```
v_inf_J_0_mag = norm(v_inf_J_0)
```

```
v_inf_J_0_mag = 18.1861
```

```
v_inf_J_0_R = iCr_2_0.' * v_inf_J_0
```

```
v_inf_J_0_R = 2×1
   17.5047
   -4.9313
```

Part d)

i)

```
rp_J = 200*R_J
```

```
rp_J = 14298400
```

```
a_hyp_J = -mu_J/v_inf_J_0_mag^2
```

```
a_hyp_J = -3.8313e+05
```

```
e_hyp_J = 1 - rp_J/a_hyp_J
```

```
e_hyp_J = 38.3203
```

```
delta = 2*(asin(1/e_hyp_J)),delta_deg = rad2deg(delta)
```

```
delta = 0.0522
delta_deg = 2.9907
```

```
ths_inf = acos(-1/e_hyp_J), ths_inf_deg = rad2deg(ths_inf)
```

```
ths_inf = 1.5969
ths_inf_deg = 91.4954
```

```
eta = asin(v_2_0_mag/v_inf_J_0_mag * sin(gamma_2_0)),eta_deg = rad2deg(eta)
```

```
eta = 1.2962
eta_deg = 74.2669
```

```
zeta = asin(v_J_mag/v_inf_J_0_mag * sin(gamma_2_0)),zeta_deg = rad2deg(zeta)
```

```
zeta = 0.6994
zeta_deg = 40.0731
```

```
% eta = pi - (pi-zeta) - gamma_2_0
v_inf_J_n_mag = v_inf_J_0_mag
```

```
v_inf_J_n_mag = 18.1861
```

```
v_2_n_mag = sqrt(v_J_mag^2 + v_inf_J_n_mag^2 - 2*v_J_mag*v_inf_J_n_mag*cos(eta+delta))
```

```
v_2_n_mag = 19.8182
```

```
gamma_2_n = asin(v_inf_J_n_mag/v_2_n_mag * sin(eta+delta)), gamma_2_n_deg = rad2deg(gam
```

```
gamma_2_n = 1.1085
gamma_2_n_deg = 63.5142
```

```
r_2_n = r_2_0
```

```
r_2_n = 2×1
10^8 ×
   -4.7761
    6.4742
```

```
r_2_n_mag = norm(r_2_n)
```

```
r_2_n_mag = 8.0453e+08
```

```
v_2_n_R = v_2_n_mag * [sin(gamma_2_n); cos(gamma_2_n)]
```

```
v_2_n_R = 2×1
   17.7382
    8.8384
```

```
ths_2_n = atan((r_2_n_mag * v_2_n_mag^2 / mu_S)*sin(gamma_2_n)*cos(gamma_2_n)...
    /((r_2_n_mag * v_2_n_mag^2 / mu_S)*cos(gamma_2_n)^2-1))+pi
```

```
ths_2_n = 2.0766
```

```
ths_2_n_deg = rad2deg(ths_2_n)
```

```
ths_2_n_deg = 118.9821
```

```
v_2_n = iCr_2_0 * v_2_n_R
```

```
v_2_n = 2×1
  -17.6428
    9.0272
```

```
dv_eq = v_2_n - v_2_0
```

```
dv_eq = 2×1
   -0.8789
   -0.3583
```

```
dv_eq_mag = norm(dv_eq)
```

```
dv_eq_mag = 0.9492
```

```
dgamma = gamma_2_n - gamma_2_0 ,dgamma_deg = rad2deg(dgamma)
```

```
dgamma = -0.0375
dgamma_deg = -2.1457
```

```
beta = asin(v_2_n_mag/dv_eq_mag * sin(dgamma)); beta = [beta pi-beta]; beta(2) = -(2*pi
```

```
beta = 1×2
   -0.8975   -2.2441
```

```
beta_deg = rad2deg(beta)
```

```
beta_deg = 1×2
  -51.4222 -128.5778
```

```
a_T_n = -mu_S * (v_2_n_mag^2 - 2*mu_S/r_2_n_mag)^-1
```

```
a_T_n = -2.1117e+09
```

```
h_2_n = cross([r_2_n;0],[v_2_n;0]), h_2_n_mag = norm(h_2_n)
```

```
h_2_n = 3×1
10^9 ×
         0
         0
    7.1108
h_2_n_mag = 7.1108e+09
```

```
p_T_n = h_2_n_mag^2/mu_S
```

```
p_T_n = 3.8100e+08
```

```
e_T_n = sqrt(1-p_T_n/a_T_n)
```

```
e_T_n = 1.0865
```

```
H_2_n = conicanom(ths_2_n,e_T_n), H_2_n_deg = rad2deg(H_2_n)
```

```
H_2_n = 0.7206
H_2_n_deg = 41.2883
```

```
N_2_n = e_T_n * sinh(H_2_n) - H_2_n, N_2_n_deg = rad2deg(N_2_n)
```

```
N_2_n = 0.1319
N_2_n_deg = 7.5548
```

```
ra = a_T_n*(1+e_T_n)/a_E
```

```
ra = -29.4520
```

Plotting

```
plotorbit(a_E,0,0,2*pi,0) % earth
hold on
plotorbit(a_J,0,0,2*pi,0) % jupiter
plotorbit(a_P,0,0,2*pi,0) % pluto
plot(0,0,'r*','MarkerSize',2)
plotorbit(a_T,e_T,0,ths_2_0,0)
maxlim = [-a_P a_P]*1.25;
xlim(maxlim), ylim(maxlim)
dw = ths_2_n-ths_2_0;
plotorbit(a_T_n,e_T_n,ths_2_n,acos(-1/e_T_n),dw)
```

Part ii)

```
rp_J = 32*R_J
```

```
rp_J = 2287744
```

```
a_hyp_J = -mu_J/v_inf_J_0_mag^2
```

```
a_hyp_J = -3.8313e+05
```

```
e_hyp_J = 1 - rp_J/a_hyp_J
```

```
e_hyp_J = 6.9712
```

```
delta = 2*asin(1/e_hyp_J),delta_deg = rad2deg(delta)
```

```
delta = 0.2879
delta_deg = 16.4947
```

```
ths_inf = acos(-1/e_hyp_J), ths_inf_deg = rad2deg(ths_inf)
```

```
ths_inf = 1.7147
ths_inf_deg = 98.2473
```

```
eta = asin(v_2_0_mag/v_inf_J_0_mag * sin(gamma_2_0)),eta_deg = rad2deg(eta)
```

```
eta = 1.2962
eta_deg = 74.2669
```

```
zeta = asin(v_J_mag/v_inf_J_0_mag * sin(gamma_2_0)),zeta_deg = rad2deg(zeta)
```

```
zeta = 0.6994
zeta_deg = 40.0731
```

```
% eta = pi - (pi-zeta) - gamma_2_0
v_inf_J_n_mag = v_inf_J_0_mag
```

```
v_inf_J_n_mag = 18.1861
```

```
v_2_n_mag = sqrt(v_J_mag^2 + v_inf_J_n_mag^2 - 2*v_J_mag*v_inf_J_n_mag*cos(eta+delta))
```

```
v_2_n_mag = 22.4067
```

```
gamma_2_n = asin(v_inf_J_n_mag/v_2_n_mag * sin(eta+delta)), gamma_2_n_deg = rad2deg(gam
```

```
gamma_2_n = 0.9468
gamma_2_n_deg = 54.2490
```

```
r_2_n = r_2_0
```

```
r_2_n = 2×1
10^8 ×
   -4.7761
    6.4742
```

```
r_2_n_mag = norm(r_2_n)
```

```
r_2_n_mag = 8.0453e+08
```

```
v_2_n_R = v_2_n_mag * [sin(gamma_2_n); cos(gamma_2_n)]
```

```
v_2_n_R = 2×1
   18.1845
   13.0914
```

```
ths_2_n = atan((r_2_n_mag * v_2_n_mag^2 / mu_S)*sin(gamma_2_n)*cos(gamma_2_n)...
    /((r_2_n_mag * v_2_n_mag^2 / mu_S)*cos(gamma_2_n)^2-1))
```

```
ths_2_n = 1.5438
```

```
ths_2_n_deg = rad2deg(ths_2_n)
```

```
ths_2_n_deg = 88.4533
```

```
v_2_n = iCr_2_0 * v_2_n_R
```

```
v_2_n = 2×1
  -21.3302
    6.8615
```

```
dv_eq = v_2_n - v_2_0
```

```
dv_eq = 2×1
   -4.5663
   -2.5240
```

```
dv_eq_mag = norm(dv_eq)
```

```
dv_eq_mag = 5.2175
```

```
dgamma = gamma_2_n - gamma_2_0 ,dgamma_deg = rad2deg(dgamma)
```

```
dgamma = -0.1992
dgamma_deg = -11.4109
```

```
beta = asin(v_2_n_mag/dv_eq_mag * sin(dgamma)); beta = [beta pi-beta]; beta(2) = -(2*pi
```

```
beta = 1×2
   -1.0153   -2.1263
```

```
beta_deg = rad2deg(beta)
```

```
beta_deg = 1×2
  -58.1742 -121.8258
```

```
a_T_n = -mu_S * (v_2_n_mag^2 - 2*mu_S/r_2_n_mag)^-1
```

```
a_T_n = -7.7093e+08
```

```
h_2_n = cross([r_2_n;0],[v_2_n;0]), h_2_n_mag = norm(h_2_n)
```

```
h_2_n = 3×1
10^10 ×
         0
         0
    1.0532
h_2_n_mag = 1.0532e+10
```

```
p_T_n = h_2_n_mag^2/mu_S
```

```
p_T_n = 8.3588e+08
```

```
e_T_n = sqrt(1-p_T_n/a_T_n)
```

```
e_T_n = 1.4437
```

```
H_2_n = conicanom(ths_2_n,e_T_n), H_2_n_deg = rad2deg(H_2_n)
```

```
H_2_n = 0.8827
H_2_n_deg = 50.5740
```

```
N_2_n = e_T_n * sinh(H_2_n) - H_2_n, N_2_n_deg = rad2deg(N_2_n)
```

```
N_2_n = 0.5637
N_2_n_deg = 32.2967
```

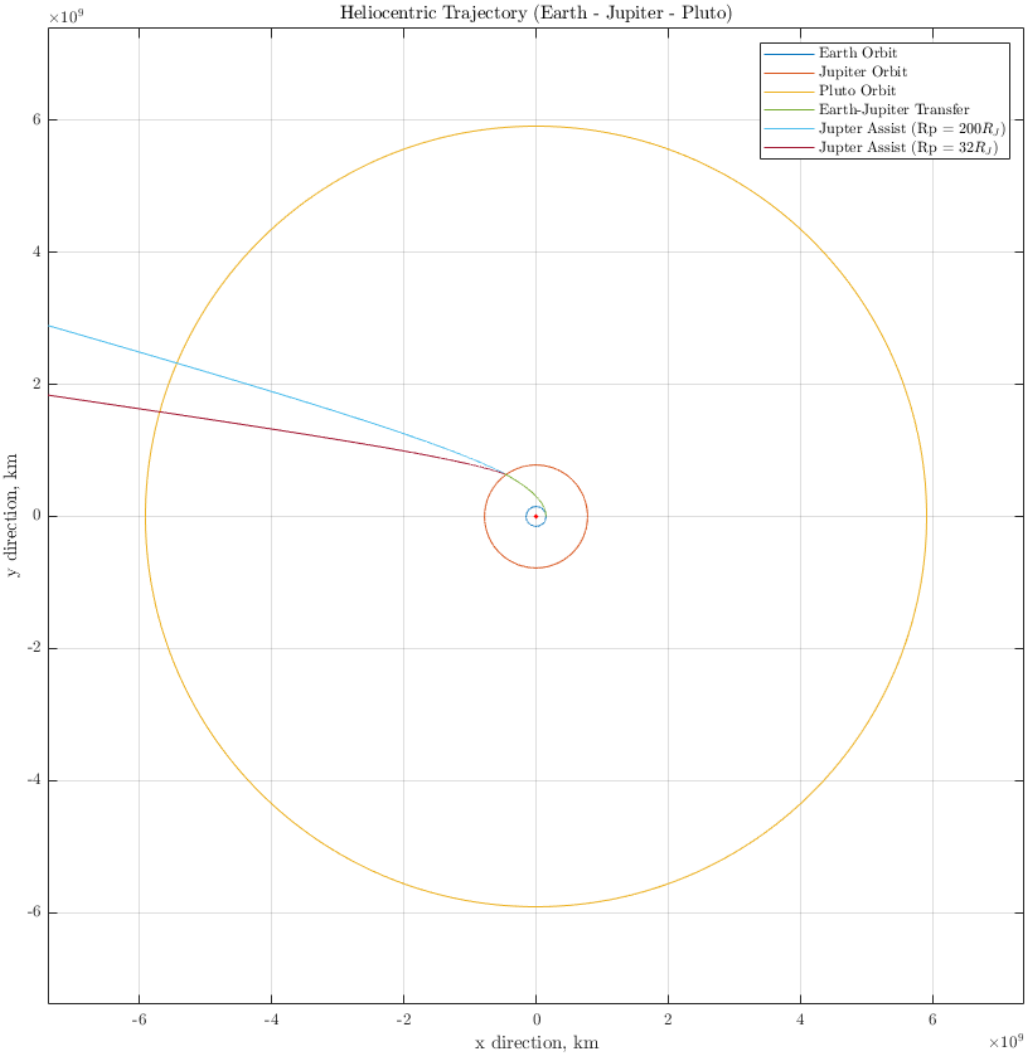
```
ra = a_T_n*(1+e_T_n)/a_E
```

```
ra = -12.5932
```

Plotting

```
dw = ths_2_n - ths_2_0;
plotorbit(a_T_n,e_T_n,ths_2_n,acos(-1/e_T_n),dw)
maxlim = [-a_P a_P]*1.25;
xlim(maxlim), ylim(maxlim)
title('Heliocentric Trajectory (Earth - Jupiter - Pluto)')
xlabel('x direction, km')
ylabel('y direction, km')
```

```
legend('Earth Orbit','Jupiter Orbit','Pluto Orbit','','Earth-Jupiter Transfer','Jupter
hold off
set(gcf,'position',[0,0,1000,1000])
```



Function 1: Plotting Orbit

```
function plotorbit(ai,ei,ths1,ths2,rotate)
ths_plot = linspace(ths1,ths2,2^12)';
ri = (ai*(1-ei^2))./(1+ei*cos(ths_plot));
ri = ri .* [cos(ths_plot-rotate),sin(ths_plot-rotate)];
plot(ri(:,1),ri(:,2))
grid on
axis equal
end
```