Problem 3

```
interr = 'latex';
% interr = 'none';
set(groot,'defaulttextinterpreter',interr);
set(groot, 'defaultAxesTickLabelInterpreter',interr);
set(groot, 'defaultLegendInterpreter',interr);
R_E = 6378.1363;
R_M = 1738.2;
mu_E = 398600.4415;
mu_M = 4902.8005821478;
a_M = 384400.00;
```

Part a)

Hohmann Transfer Characterisitcs

```
rp_T_mag = 250 + R_E, ra_T_mag = a_M
```

```
rp_T_mag = 6.6281e+03
ra_T_mag = 384400
```

```
a_T = (rp_T_mag + ra_T_mag)/2
```

```
a_T = 1.9551e+05
```

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

```
e_T = 0.9661
```

```
v1_n_mag = sqrt(mu_E*(2/rp_T_mag - 1/a_T))
```

```
v1_n_mag = 10.8737
```

```
v1_n = [v1_n_mag 0]'
```

```
v1_n = 2×1
   10.8737
         0
```

```
v2_0_mag = sqrt(mu_E*(2/ra_T_mag - 1/a_T))
```

```
v2_0_mag = 0.1875
```

```
v2_0 = [-v2_0_mag 0]'
```

```
v2_0 = 2×1
   -0.1875
         0
```

```
energy = -mu_E/2/a_T
```

```
energy = -1.0194
```

```
n_T = sqrt(mu_E/a_T^3)
```

```
n_T = 7.3030e-06
```

```
period = 2*pi/n_T
```

```
period = 8.6036e+05
```

```
period_hr = period/3600
```

```
period_hr = 238.9877
```

```
period_day = period_hr/24
```

```
period_day = 9.9578
```

```
phase = pi - sqrt(mu_E/ra_T_mag^3)*period/2
```

```
phase = 2.0020
```

```
phase_deg = rad2deg(phase)
```

```
phase_deg = 114.7073
```

```
TOF = period/2
```

```
TOF = 4.3018e+05
```

```
TOF_day = period_day/2
```

```
TOF_day = 4.9789
```

Moon Orbit about Earth

```
v_M_mag = sqrt((mu_E+mu_M)/a_M)
```

```
v_M_mag = 1.0245
```

```
v_M = [-v_M_mag, 0]'
```

```
v_M = 2×1
   -1.0245
         0
```

Departure Parking Orbit

```
r1_mag = 250 + R_E
```

```
r1_mag = 6.6281e+03
```

```
v1_0_mag = sqrt(mu_E/r1_mag)
```

```
v1_0_mag = 7.7548
```

```
v1_0 = v1_0_mag * [1 0]'
```

```
v1_0 = 2×1
    7.7548
         0
```

```
dv1 = v1_n-v1_0, dv1_mag = norm(dv1)
```

```
dv1 = 2×1
    3.1188
         0
dv1_mag = 3.1188
```

Arrival Parking orbit

```
rp_M = 195 + R_M
```

```
rp_M = 1.9332e+03
```

Arrival Hyperbolic Orbit

```
v_inf_M = v2_0 - v_M
```

```
v_inf_M = 2×1
    0.8371
         0
```

```
v_inf_M_mag = norm(v_inf_M)
```

```
v_inf_M_mag = 0.8371
```

```
v2_n_mag = sqrt(mu_M/rp_M)
```

```
v2_n_mag = 1.5925
```

```
dv2_mag = sqrt(v_inf_M_mag^2 + 2*mu_M/rp_M) - v2_n_mag
```

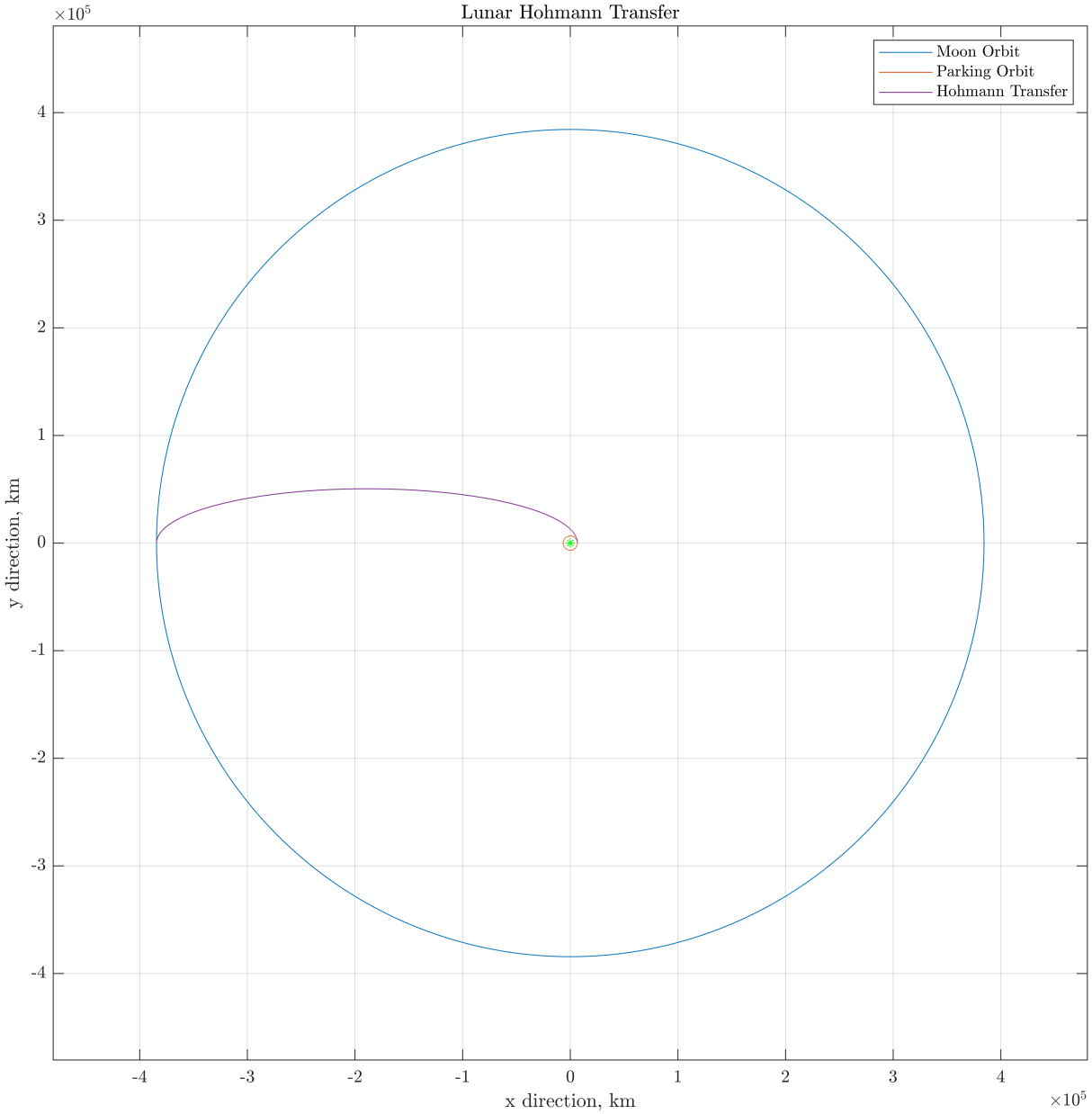
```
dv2_mag = 0.8102
```

Total

```
dvtotal_mag = dv1_mag + dv2_mag
```

```
dvtotal_mag = 3.9290
```

```
plotorbit(a_M,0,0,2*pi,0)
hold on
plotorbit(rp_T_mag,0,0,2*pi,0)
plot(0,0,'g*','MarkerSize',5)
plotorbit(a_T,e_T,0,pi,0)
maxlim = [-a_M a_M]*1.25;
xlim(maxlim), ylim(maxlim)
title('Lunar Hohmann Transfer')
xlabel('x direction, km')
ylabel('y direction, km')
legend('Moon Orbit','Parking Orbit','','Hohmann Transfer')
hold off
set(gcf,'position',[0,0,1000,1000])
```




```
plotorbit(a_M,0,0,2*pi,0)
hold on
plotorbit(rp_T_mag,0,0,2*pi,0)
plot(0,0,'g*','MarkerSize',5)
plotorbit(a_T,e_T,0,pi,0)
dw = 0;
```

Part b)

```
a_h = -mu_M/v_inf_M_mag^2
```

```
a_h = -6.9974e+03
```

```
e_h = 1 - rp_M/a_h
```

```
e_h = 1.2763
```

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

```
delta = 1.8007
delta_deg = 103.1700
```

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

```
ths_inf = 2.4711
ths_inf_deg = 141.5850
```

```
v2_n_mag = sqrt(v_M_mag^2 + v_inf_M_mag^2 - 2*v_M_mag*v_inf_M_mag*cos(delta))
```

```
v2_n_mag = 1.4633
```

```
gamma_2_n = asin(v_inf_M_mag/v2_n_mag * sin(delta)), gamma_2_n_deg = rad2deg(gamma_2_n)
```

```
gamma_2_n = 0.5908
gamma_2_n_deg = 33.8485
```

```
v2_n_R = v2_n_mag*[sin(gamma_2_n);cos(gamma_2_n)]
```

```
v2_n_R = 2×1
    0.8150
    1.2153
```

```
v_2_0_R = [0 v2_0_mag]'
```

```
v_2_0_R = 2×1
         0
    0.1875
```

```
dveq = v2_n_R - v_2_0_R
```

```
dveq = 2×1
    0.8150
    1.0278
```

```
norm(dveq)
```

```
ans = 1.3117
```

```
ths_2_n = atan((ra_T_mag * v2_n_mag^2 / mu_E)*sin(gamma_2_n)*cos(gamma_2_n)...
    /((ra_T_mag * v2_n_mag^2 / mu_E)*cos(gamma_2_n)^2-1))
```

```
ths_2_n = 1.1528
```

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

```
ths_2_n_deg = 66.0518
```

```
iCr2 = [cos(pi), -sin(pi); sin(pi) cos(pi)]
```

```
iCr2 = 2×2
   -1.0000   -0.0000
    0.0000   -1.0000
```

```
a_post = -mu_E*(v2_n_mag^2 - 2*mu_E/ra_T_mag)^-1
```

```
a_post = -5.9257e+06
```

```
e_post = sqrt((ra_T_mag * v2_n_mag^2/mu_E -1)^2*cos(gamma_2_n)^2+sin(gamma_2_n)^2)
```

```
e_post = 1.0452
```

```
rp_post = a_post*(1-e_post)
```

```
rp_post = 2.6769e+05
```

```
energy_post = -mu_E/2/a_post
```

```
energy_post = 0.0336
```

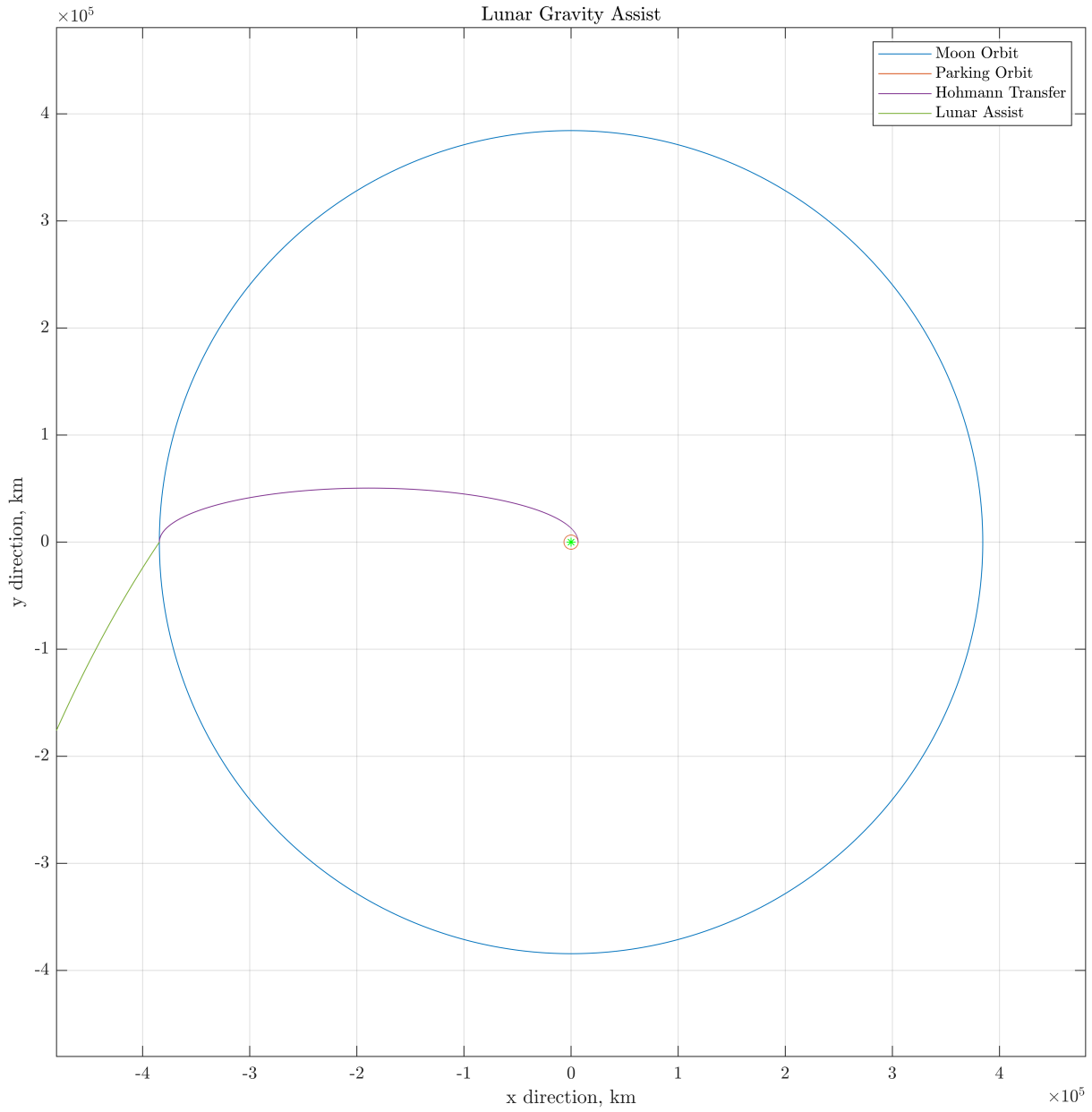
```
dw = ths_2_n - pi
```

```
dw = -1.9888
```

```
dw_deg = rad2deg(dw)
```

```
dw_deg = -113.9482
```

```
plotorbit(a_post,e_post,ths_2_n,acos(-1/e_post),dw)
title('Lunar Gravity Assist')
xlabel('x direction, km')
ylabel('y direction, km')
legend('Moon Orbit','Parking Orbit','','Hohmann Transfer','Lunar Assist')
maxlim = [-a_M a_M]*1.25;
xlim(maxlim), ylim(maxlim)
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
```