Hw8.3

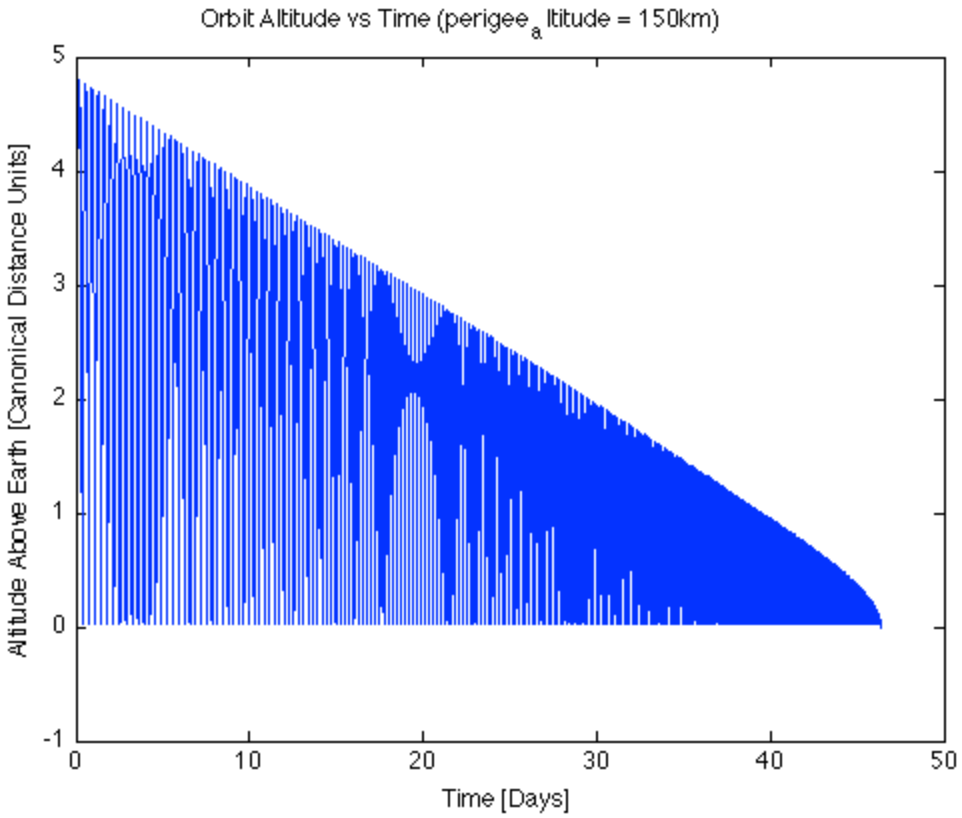
Contents

Part a.)

```
clear all; close all; clc;

DU = 6378.137;  %km
mu_earth = 398600.440; % [km^3/sec^2]

% Since we're not told where in the orbit the satellite starts, I'm just
% going to assume that it starts at perigee.  Also, since we're not given
% an inclination, I'm going to assume equatorial.

ecc = 0.7;
rp = 175 + DU;

a = rp/(1-ecc);
v_norm = sqrt(2*mu_earth/rp - mu_earth/a);

O_r_S__eci = [0 rp 0]';
eci_v_S__eci = [-v_norm 0 0]';

state0 = [O_r_S__eci; eci_v_S__eci];

tau = 2*pi*sqrt(a^3/mu_earth);

t_vec = 0:120:3600*24*50;   %50 days, two minute time steps

options = odeset('Events',@statedot_drag_events,'RelTol', 1e-6, 'AbsTol', 1e-9);
[t_out, state] = ode113(@statedot_drag, t_vec, state0, options);


O_r_S__eci = state(:,1:3);

radius = sqrt(O_r_S__eci(:,1).^2 + O_r_S__eci(:,2).^2 + O_r_S__eci(:,3).^2);
num_steps = length(radius);

figure(1)
plot(t_vec(1:num_steps)/(3600*24), (radius-DU)/DU)
title('Orbit Altitude vs Time (perigee_altitude = 150km)')
xlabel('Time [Days]')
ylabel('Altitude Above Earth [Canonical Distance Units]')
```

```
disp(['Satellite crashes after ' num2str(t_vec(num_steps)/(3600*24)) ' days'])
```

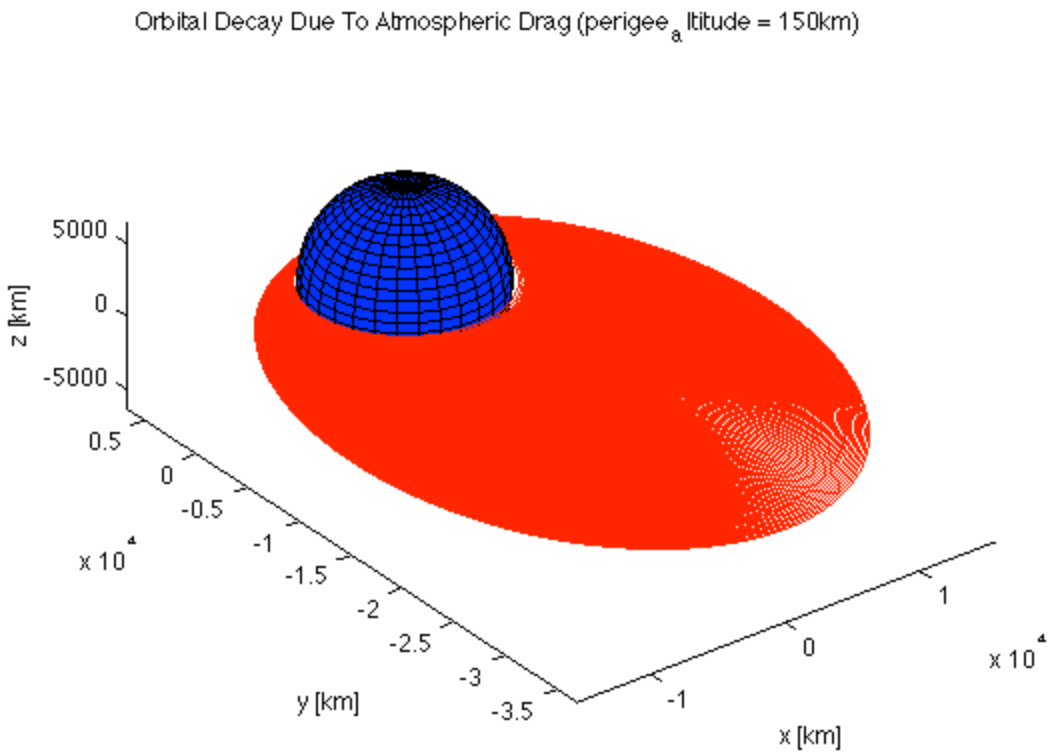
```
You are underground
You are underground
Satellite crashes after 46.3792 days
```



Part b.)

```
[xeplot, yeplot, zeplot] = ellipsoid(0.0, 0.0, 0.0, ...  % earth sphere
                             DU, DU, DU, 30);

% Setup earth plotting data
figure(2)
surface(xeplot, yeplot, zeplot, 'FaceColor', 'blue', 'EdgeColor', 'black');
hold on;

plot3(O_r_S__eci(:,1), ...
      O_r_S__eci(:,2), ...
      O_r_S__eci(:,3), 'red');

view(3)

axis equal;
title('Orbital Decay Due To Atmospheric Drag (perigee_altitude = 150km)')
xlabel('x [km]')
ylabel('y [km]')
```

```
zlabel('z [km]')
```



Part c.)

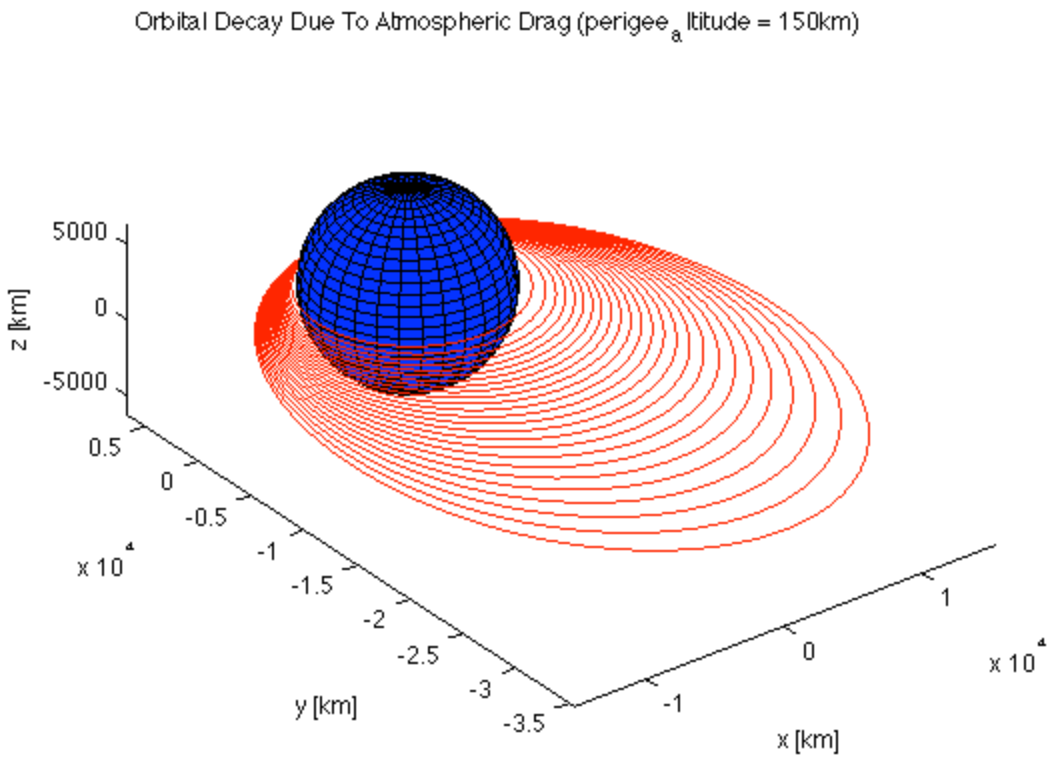
```
% If you imagine the effect of drag as an impulsive effect, you can make
% sense of why perigee stays constant and apogee falls.  Imagine that the
% effects of drag take place at the perigee; the force of the drag is
% perpendicular to the r-vector at this location so it will not change the
% length, that is to say r_perigee remains constant.  Now the effect of
% drag is to remove energy from the system, which manifests itself by
% pulling the apogee in closer and making a more circular orbit because the
% satellite does not have enough energy to travel out to its previous
% apogee.  Drag is, in a sense, a circularizing burn.
```

Part d.)

```
clear all; close all; clc;

DU = 6378.137;  %km
mu_earth = 398600.440; % [km^3/sec^2]


% Since we're not told where in the orbit the satellite starts, I'm just
% going to assume that it starts at perigee.  Also, since we're not given
% an inclination, I'm going to assume equatorial.

ecc = 0.7;
```

```
rp = 150 + DU;

a = rp/(1-ecc);
v_norm = sqrt(2*mu_earth/rp - mu_earth/a);

O_r_S__eci = [0 rp 0]';
eci_v_S__eci = [-v_norm 0 0]';

state0 = [O_r_S__eci; eci_v_S__eci];

tau = 2*pi*sqrt(a^3/mu_earth);

t_vec = 0:120:3600*24*50;   %one period, one minute time steps

options = odeset('Events',@statedot_drag_events,'RelTol', 1e-6, 'AbsTol', 1e-9);
[t_out, state] = ode113(@statedot_drag, t_vec, state0, options);


O_r_S__eci = state(:,1:3);

radius = sqrt(O_r_S__eci(:,1).^2 + O_r_S__eci(:,2).^2 + O_r_S__eci(:,3).^2);
num_steps = length(radius);

[xeplot, yeplot, zeplot] = ellipsoid(0.0, 0.0, 0.0, ...  % earth sphere
                           DU, DU, DU, 30);

% Setup earth plotting data
figure(3)
surface(xeplot, yeplot, zeplot, 'FaceColor', 'blue', 'EdgeColor', 'black');
hold on;

plot3(O_r_S__eci(:,1), ...
      O_r_S__eci(:,2), ...
      O_r_S__eci(:,3), 'red');

view(3)

axis equal;
title('Orbital Decay Due To Atmospheric Drag (perigee_altitude = 150km)')
xlabel('x [km]')
ylabel('y [km]')
zlabel('z [km]')


disp(['Satellite crashes after ' num2str(t_vec(num_steps)/(3600*24)) ' days'])
```

```
You are underground
You are underground
Satellite crashes after 4.1819 days
```

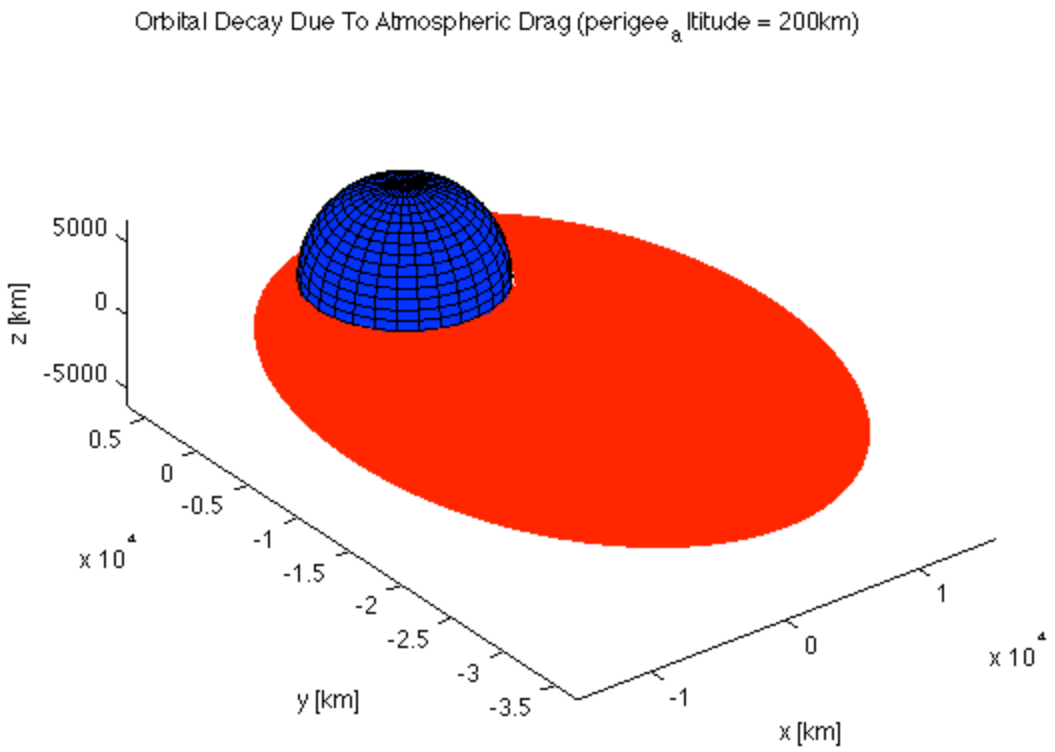


Part e.)

```
clear all; close all; clc;

DU = 6378.137;  %km
mu_earth = 398600.440; % [km^3/sec^2]


% Since we're not told where in the orbit the satellite starts, I'm just
% going to assume that it starts at perigee.  Also, since we're not given
% an inclination, I'm going to assume equatorial.

ecc = 0.7;
rp = 200 + DU;

a = rp/(1-ecc);
v_norm = sqrt(2*mu_earth/rp - mu_earth/a);

O_r_S__eci = [0 rp 0]';
eci_v_S__eci = [-v_norm 0 0]';

state0 = [O_r_S__eci; eci_v_S__eci];

tau = 2*pi*sqrt(a^3/mu_earth);

t_vec = 0:5*60:3600*24*365;   %one year, every five minutes

options = odeset('Events',@statedot_drag_events,'RelTol', 1e-6, 'AbsTol', 1e-9);
```

```
[t_out, state] = ode113(@statedot_drag, t_vec, state0, options);


O_r_S__eci = state(:,1:3);

radius = sqrt(O_r_S__eci(:,1).^2 + O_r_S__eci(:,2).^2 + O_r_S__eci(:,3).^2);
num_steps = length(radius);

[xeplot, yeplot, zeplot] = ellipsoid(0.0, 0.0, 0.0, ...  % earth sphere
                           DU, DU, DU, 30);

% Setup earth plotting data
figure(4)
surface(xeplot, yeplot, zeplot, 'FaceColor', 'blue', 'EdgeColor', 'black');
hold on;

plot3(O_r_S__eci(:,1), ...
      O_r_S__eci(:,2), ...
      O_r_S__eci(:,3), 'red');

view(3)

axis equal;
title('Orbital Decay Due To Atmospheric Drag (perigee_altitude = 200km)')
xlabel('x [km]')
ylabel('y [km]')
zlabel('z [km]')


disp(['Satellite crashes after ' num2str(t_vec(num_steps)/(3600*24)) ' days'])
```

```
You are underground
You are underground
Satellite crashes after 293.9479 days
```

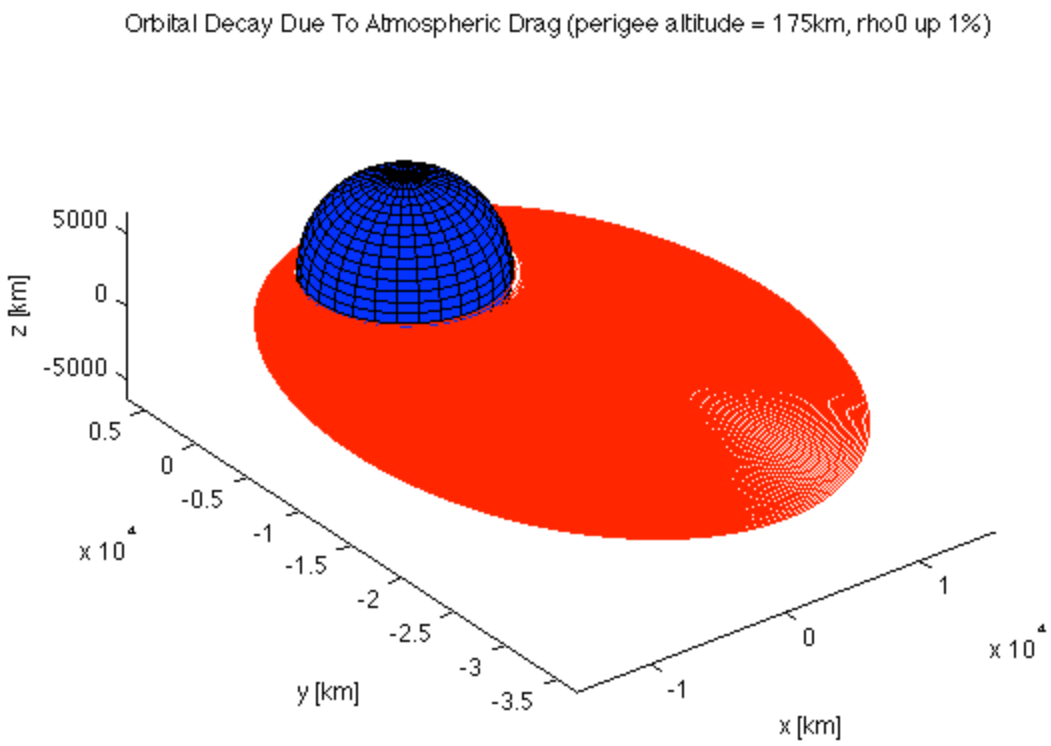


f.)

```
clear all; close all; clc;

DU = 6378.137;  %km
mu_earth = 398600.440; % [km^3/sec^2]


% Since we're not told where in the orbit the satellite starts, I'm just
% going to assume that it starts at perigee.  Also, since we're not given
% an inclination, I'm going to assume equatorial.

ecc = 0.7;
rp = 175 + DU;

a = rp/(1-ecc);
v_norm = sqrt(2*mu_earth/rp - mu_earth/a);

O_r_S__eci = [0 rp 0]';
eci_v_S__eci = [-v_norm 0 0]';

state0 = [O_r_S__eci; eci_v_S__eci];

tau = 2*pi*sqrt(a^3/mu_earth);

t_vec = 0:2*60:3600*24*50;   %50 days, every five minutes

options = odeset('Events',@statedot_drag_events,'RelTol', 1e-6, 'AbsTol', 1e-9);
```

```
[t_out, state] = ode113(@statedot_drag_dense, t_vec, state0, options);


O_r_S__eci = state(:,1:3);

radius = sqrt(O_r_S__eci(:,1).^2 + O_r_S__eci(:,2).^2 + O_r_S__eci(:,3).^2);
num_steps = length(radius);

[xeplot, yeplot, zeplot] = ellipsoid(0.0, 0.0, 0.0, ...  % earth sphere
                           DU, DU, DU, 30);

% Setup earth plotting data
figure(5)
surface(xeplot, yeplot, zeplot, 'FaceColor', 'blue', 'EdgeColor', 'black');
hold on;

plot3(O_r_S__eci(:,1), ...
      O_r_S__eci(:,2), ...
      O_r_S__eci(:,3), 'red');

view(3)

axis equal;
title('Orbital Decay Due To Atmospheric Drag (perigee altitude = 175km, rho0 up 1%)'
xlabel('x [km]')
ylabel('y [km]')
zlabel('z [km]')


disp(['Satellite crashes after ' num2str(t_vec(num_steps)/(3600*24)) ' days'])

% This decreased the de-orbit time by about a day.
```

```
You are underground
You are underground
You are underground
Satellite crashes after 45.3542 days
```

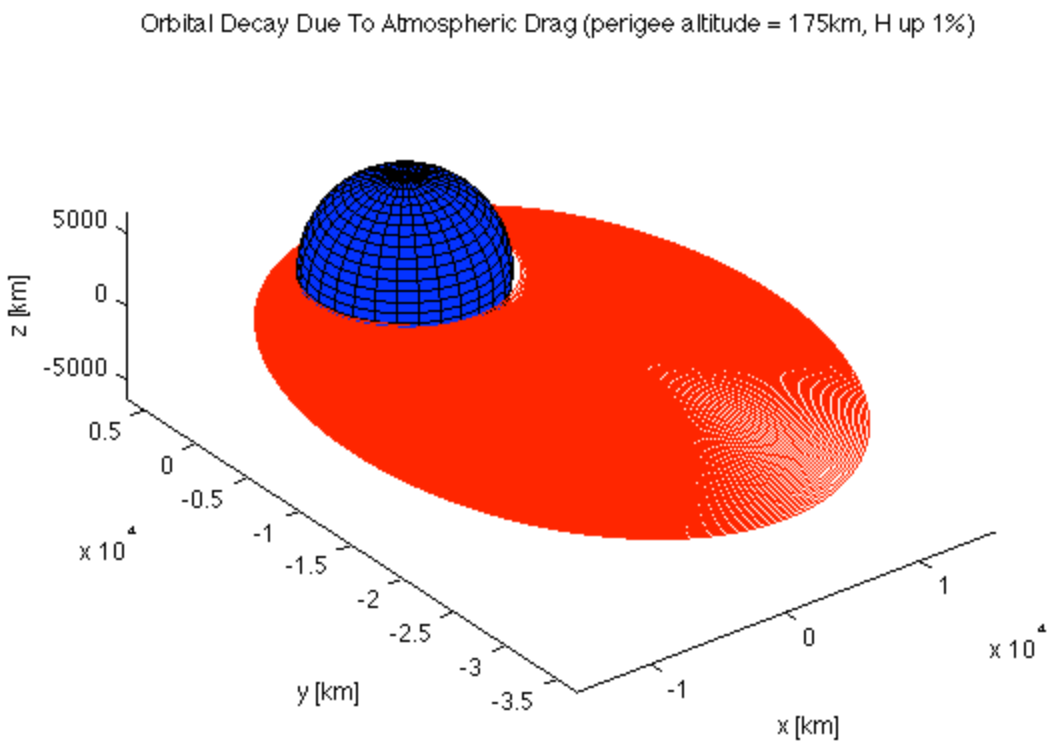


Part g.)

```
clear all; close all; clc;

DU = 6378.137;  %km
mu_earth = 398600.440; % [km^3/sec^2]


% Since we're not told where in the orbit the satellite starts, I'm just
% going to assume that it starts at perigee.  Also, since we're not given
% an inclination, I'm going to assume equatorial.

ecc = 0.7;
rp = 175 + DU;

a = rp/(1-ecc);
v_norm = sqrt(2*mu_earth/rp - mu_earth/a);

O_r_S__eci = [0 rp 0]';
eci_v_S__eci = [-v_norm 0 0]';

state0 = [O_r_S__eci; eci_v_S__eci];

tau = 2*pi*sqrt(a^3/mu_earth);

t_vec = 0:2*60:3600*24*50;   %50 days, every five minutes

options = odeset('Events',@statedot_drag_events,'RelTol', 1e-6, 'AbsTol', 1e-9);
```

```
[t_out, state] = ode113(@statedot_drag_H, t_vec, state0, options);


O_r_S__eci = state(:,1:3);

radius = sqrt(O_r_S__eci(:,1).^2 + O_r_S__eci(:,2).^2 + O_r_S__eci(:,3).^2);
num_steps = length(radius);

[xeplot, yeplot, zeplot] = ellipsoid(0.0, 0.0, 0.0, ...  % earth sphere
                           DU, DU, DU, 30);

% Setup earth plotting data
figure(6)
surface(xeplot, yeplot, zeplot, 'FaceColor', 'blue', 'EdgeColor', 'black');
hold on;

plot3(O_r_S__eci(:,1), ...
      O_r_S__eci(:,2), ...
      O_r_S__eci(:,3), 'red');

view(3)

axis equal;
title('Orbital Decay Due To Atmospheric Drag (perigee altitude = 175km, H up 1%)')
xlabel('x [km]')
ylabel('y [km]')
zlabel('z [km]')


disp(['Satellite crashes after ' num2str(t_vec(num_steps)/(3600*24)) ' days'])

% Wow!  Changing H by 1% shaved a week off the de-orbit time!  Given how
% sensitive the de-orbit calculation is to uncertainties in atmospheric
% conditions, I can now appreciate how difficult it is to predict an event
% like this.
```

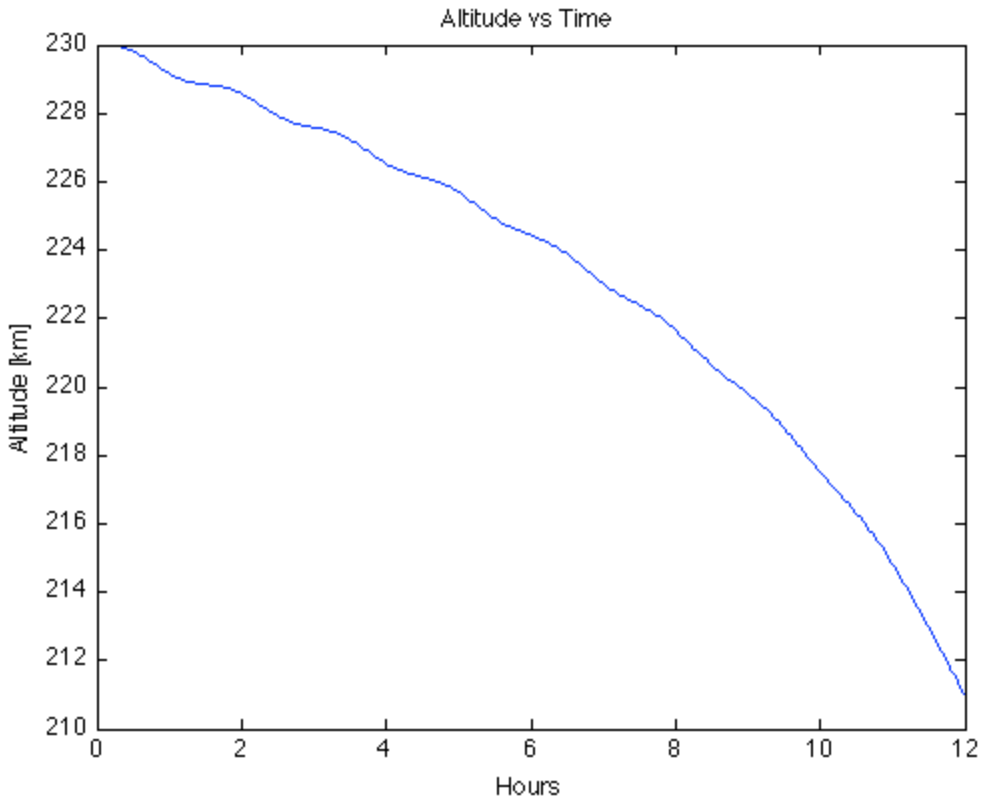
```
You are underground
You are underground
Satellite crashes after 38.7569 days
```

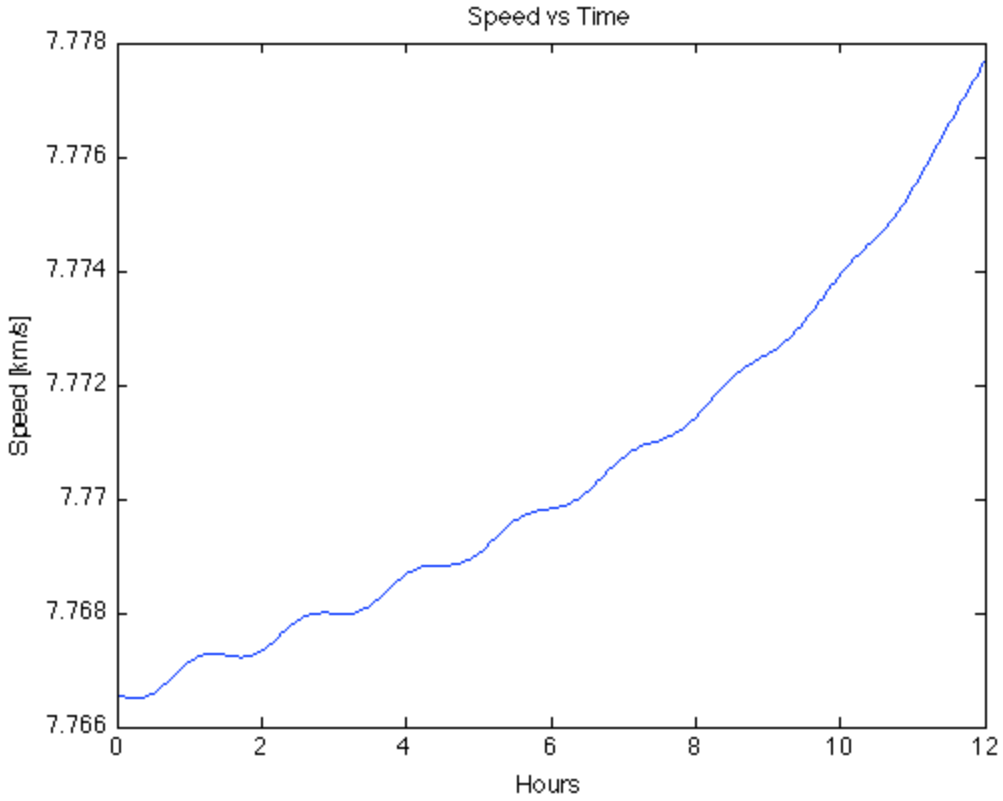


Part h.)

```
clear all; close all; clc;

DU = 6378.137;  %km
mu_earth = 398600.440; % [km^3/sec^2]


% Since we're not told where in the orbit the satellite starts, I'm just
% going to assume that it starts at perigee.  Also, since we're not given
% an inclination, I'm going to assume equatorial.

ecc = 0.0;
rp = 230 + DU;

a = rp/(1-ecc);
v_norm = sqrt(2*mu_earth/rp - mu_earth/a);

O_r_S__eci = [0 rp 0]';
eci_v_S__eci = [-v_norm 0 0]';

state0 = [O_r_S__eci; eci_v_S__eci];

tau = 2*pi*sqrt(a^3/mu_earth);

t_vec = 0:2*60:3600*12;   %12 hours, every 2 minutes

options = odeset('Events',@statedot_drag_events,'RelTol', 1e-6, 'AbsTol', 1e-9);
```

```
[t_out, state] = ode113(@statedot_drag, t_vec, state0, options);


O_r_S__eci = state(:,1:3);
eci_v_S__eci = state(:,4:6);

radius = sqrt(O_r_S__eci(:,1).^2 + O_r_S__eci(:,2).^2 + O_r_S__eci(:,3).^2);
speed = sqrt(eci_v_S__eci(:,1).^2 + eci_v_S__eci(:,2).^2 + eci_v_S__eci(:,3).^2);
num_steps = length(radius);

figure(7)
plot(t_vec/(3600),radius-DU)
title('Altitude vs Time')
xlabel('Hours')
ylabel('Altitude [km]')

figure(8)
plot(t_vec/(3600),speed)
title('Speed vs Time')
xlabel('Hours')
ylabel('Speed [km/s]')

en_kin = 0.5*speed.^2;
en_pot = - mu_earth./radius;
en_mech = en_kin + en_pot;

figure(9)
plot(t_vec/(3600),en_kin,t_vec/(3600),en_pot,t_vec/(3600),en_mech)
legend('specific kinetic','specific potential','specific mechanical')
ylabel('Specific Energy [km/s^2]')
xlabel('Time [hours]')

% This illustrates the drag paradox because the effect of drag is actually
% to increase the velocity of the satellite.
```


Altitude vs Time
Altitude [km]
230
228
226
224
222
220
218
216
214
212
210
0
2
4
6
8
10
12
Hours


Speed vs Time
Speed [km/s]
7.778
7.776
7.774
7.772
7.77
7.768
7.766
0
2
4
6
8
10
12
Hours