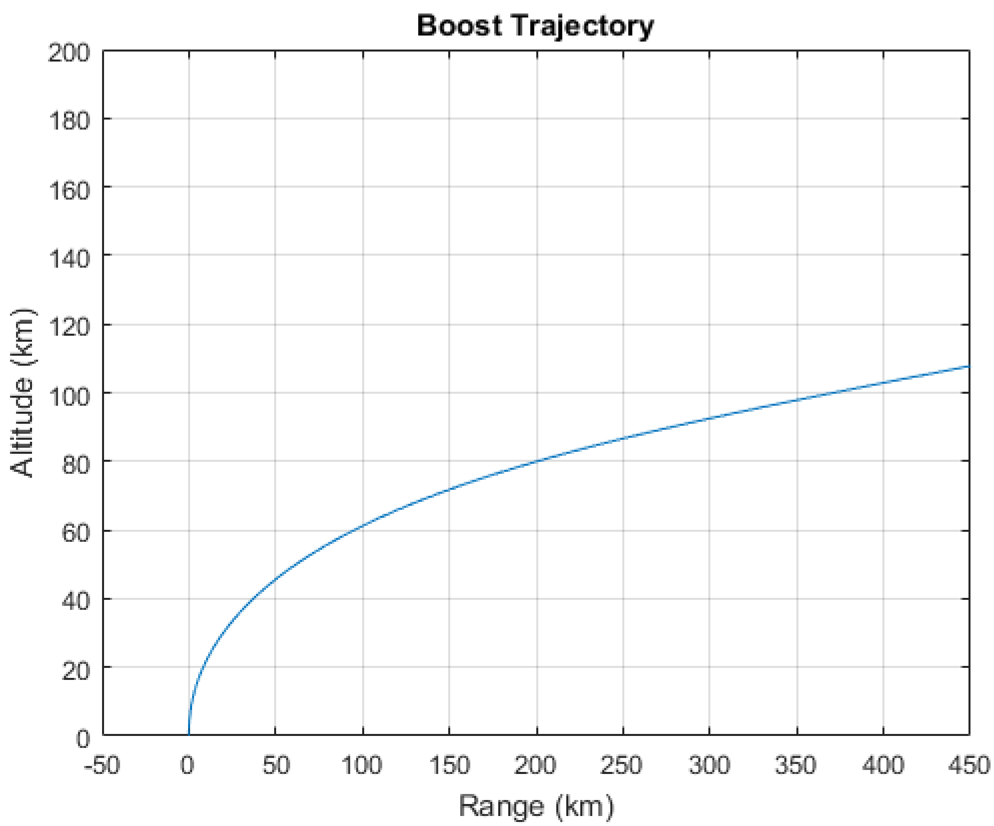
```
clear all; clc; close all;
```

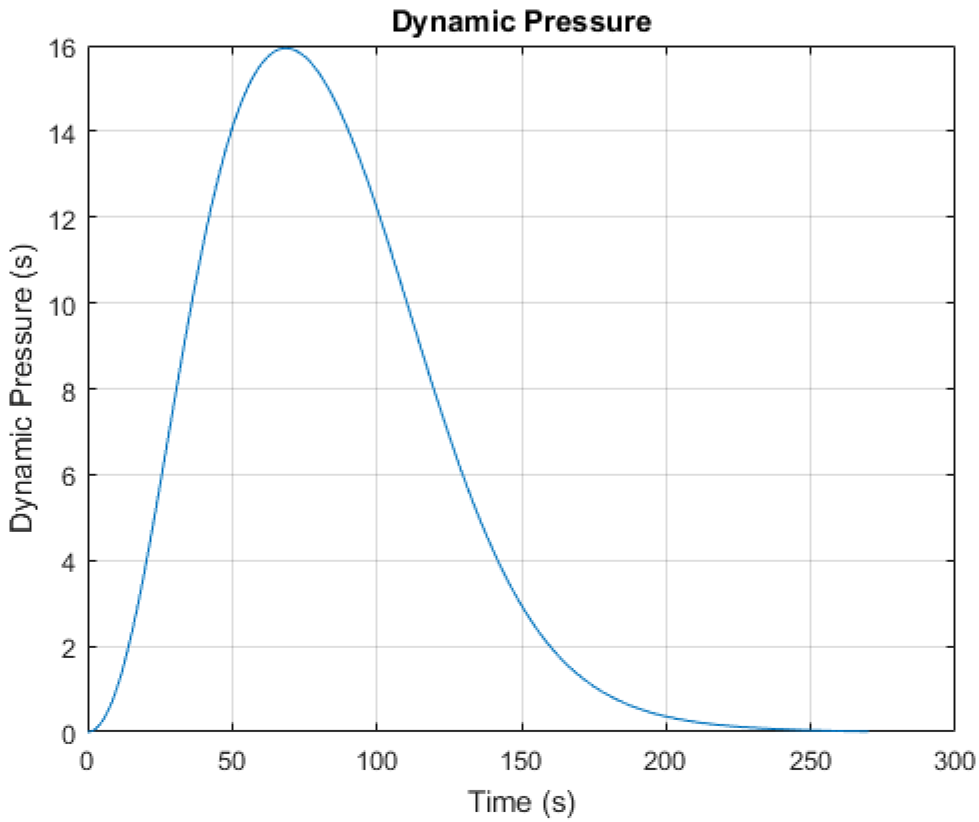
Problem 1

```
mu = 3.9860044189e5;
mo = 68000; %inital masss of vehicle in kg
T = 930; % trust of motor
Isp = 400;
D = 4.75;

dt = 8.1;
tbo = 270;
ho = 130;
i =1;
options = odeset('RelTol',1e-8);
while 1
    [T,Z] = ode45('Launch',[0 dt],[0 0 0 mo],options);
    if max(Z(:,2)) < ho
        dt = dt+0.0001;
    else max(Z(:,2)) > ho;
        dt = dt-0.0001;
    end

    if abs(max(Z(:,2))-ho) < 0.002
        break
    end
    i = i+1;

end
fprintf('Speed at 130 m: %.1f m/s \n',Z(end,1))
fprintf('Time to 130 m: %.3f s \n',dt)
vo = Z(end,1);
ho = Z(end,2);
xo = Z(end,3);
mo = Z(end,4);
yo = 89.85*pi/180;
[T2,Z2] = ode45('Launch2',[dt tbo],[vo ho xo mo yo],options);

v = [Z(:,1)'  Z2(:,1)'];
h = [Z(:,2)'  Z2(:,2)'];
x = [Z(:,3)'  Z2(:,3)'];
m = [Z(:,4)'  Z2(:,4)'];
T = [T'  T2'];
fprintf('Speed at burnout: %.1f m/s \n',Z2(end,1))
fprintf('Altitude at burnout: %.1f m \n',Z2(end,2))
fprintf('Mass expended: %.1f kg \n',68000 - Z2(end,4))
plot(x/1000,h/1000);grid on
axis([-50 450 0 200])
xlabel('Range (km)');ylabel('Altitude (km)')
title('Boost Trajectory')
```

```
rho = 1.225*exp(-h/7500);
dynP = 1/2*rho.*v.^2/1000;
[MaxQ,j] = max(dynP);figure
plot(T,dynP); grid on
xlabel('Time (s)');ylabel('Dynamic Pressure (s)')
title('Dynamic Pressure')
fprintf('Max Q: %.3f kPa \n',MaxQ)
fprintf('Time of Max Q: %.1f s \n',T(j))
```

```
Speed at 130 m: 32.6 m/s
Time to 130 m: 8.077 s
Speed at burnout: 9446.4 m/s
Altitude at burnout: 115363.7 m
Mass expended: 64010.4 kg
Max Q: 15.936 kPa
Time of Max Q: 68.2 s
```





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```
function [vecDeriv] = Launch(t,z)
%LAUNCH steps up the governing equations of motion for the launch phase
%   solve with ode45
R = 6378*1000;
mo = 68000; %inital masss of vehicle in kg
T = 930*1000; % trust of motor kN
Isp = 400;
d = 4.75;
y = 90;
go = 9.807;
g = go/(1+z(2)/R)^2;
A = pi/4*d^2;
ho = 7.5*1000;
rho = 1.225*exp(-z(2)/ho);
Cd = 0.52;
D = 1/2*rho*z(1)^2*A*Cd;

vecDeriv(1) = T/z(4) - D/z(4) - g*sind(y);
vecDeriv(2) = z(1)*sind(y);
vecDeriv(3) = z(1)*R*cosd(y)/(R+z(2));
vecDeriv(4) = -T/(Isp*go);

vecDeriv = vecDeriv.';
end
```

```
function [vecDeriv] = Launch(t,z)
%LAUNCH steps up the governing equations of motion for the launch phase
%   solve with ode45
R = 6378*1000;
mo = 68000; %inital masss of vehicle in kg
T = 930*1000; % trust of motor N
Isp = 400;
d = 4.75;

go = 9.807;
g = go/(1+z(2)/R)^2;
A = pi/4*d^2;
h = 7.5*1000;
rho = 1.225*exp(-z(2)/h);
Cd = 0.52;
D = 1/2*rho*z(1)^2*A*Cd;

vecDeriv(1) = T/z(4) - D/z(4) - g*sin(z(5));
vecDeriv(2) = z(1)*sin(z(5));
vecDeriv(3) = z(1)*R*cos(z(5))/(R+z(2));
vecDeriv(4) = -T/(Isp*go);
vecDeriv(5) = -cos(z(5))*(g - (z(1)^2/(R+z(2))))/z(1);

vecDeriv = vecDeriv.';
end
```

```
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```

Problem 2

```
mu = 3.9860044189e5;
go = 9.807;
vbo = 6.7*1000;
mpl = 10;
e1 = 0.30;
Isp1 = 340;
e2 = 0.25;
Isp2 = 250;
c1 = Isp1*go;
c2 = Isp2*go;

lamda_guess = 7.716197e-3;
lamda = fzero('lagrange',lamda_guess);

n1 = (c1*lamda-1)/(c1*lamda*e1);
n2 = (c2*lamda-1)/(c2*lamda*e2);
check_1 = lamda*c1*(e1*n1 - 1)^2 + 2*e1*n1 - 1;
check_2 = lamda*c2*(e2*n2 - 1)^2 + 2*e2*n2 - 1;

m2 = mpl*(n2-1)/(1-n2*e2);
m1 = (m2+mpl)*(n1-1)/(1-n1*e1);

me1 = e1*m1;
me2 = e2*m2;
mp1 = m1-me1;
mp2 = m2-me2;
mo = m1+m2+mpl;

fprintf('Optimum mass for stage 1: %.1f kg \n', m1)
fprintf('Optimum mass for stage 2: %.1f kg \n', m2)
fprintf('Total mass: %.1f kg \n', mo)
fprintf('Propellant mass for stage 1: %.1f kg \n', mp1)
fprintf('Propellant mass for stage 2: %.1f kg \n', mp2)
```

```
Optimum mass for stage 1: 3769.5 kg
Optimum mass for stage 2: 179.5 kg
Total mass: 3959.1 kg
Propellant mass for stage 1: 2638.7 kg
Propellant mass for stage 2: 134.7 kg
```

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```
function func = lagrange(lamda)
%FZERO Summary of this function goes here
%   Detailed explanation goes here
go = 9.807;
 vbo = 6.7*1000;
 e1 = 0.30;
Isp1 = 340;
e2 = 0.25;
Isp2 = 250;
c1 = Isp1*go;
c2 = Isp2*go;

func = c1*log(c1*lamda-1) - c1*log(c1*lamda*e1) + c2*log(c2*lamda-1) - c2*log(c2*lamda*e2) - vbo;

end
```

```
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```

Problem 3

```
Pt = 2.04e06;
Tt = 2266;
Prec = .1013e06;
R = 365;
k = 1.3;
n_eff = 0.97;
g = 9.80665;
ratio = Prec/Pt;
M = [0:0.00001:20];

for i = 1:length(M)
    P_ratio(i) = (1+0.5*(k-1)*M(i)^2)^(k/(k-1));
    P_ratio(i) = P_ratio(i)^-1;
    T_ratio(i) = (1+0.5*(k-1)*M(i)^2);
    T_ratio(i) = T_ratio(i)^-1;
end

[~,j] = find(ratio==P_ratio);
Me = M(j);

if isempty(Me) == 1
    [~,j] = min(abs(ratio-P_ratio));
    Me = M(j);
end

Te = T_ratio(j)*Tt;
sonic_ext = sqrt(k*R*Te);
Ve = Me*sonic_ext;

Cf = (2*k^2/(k-1)*(2/(k+1))^((k+1)/(k-1))*(1-(ratio)^((k-1)/k)))^0.5;
Isp = n_eff*Ve*Cf/g;
fprintf('Exit Mach: %.3f  \n', Me)
fprintf('Nozzle Exit Velocity: %.1f m/s \n', Ve)
fprintf('Thrust Coefficent: %.3f \n', Cf)
fprintf('Specific Impulse: %.1f s \n', Isp)
```

```
Exit Mach: 2.581
Nozzle Exit Velocity: 1892.9 m/s
Thrust Coefficent: 1.389
Specific Impulse: 260.0 s
```

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```
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```

Problem 4

```
i = [0.7082 -0.2082 .6165];
j = [-0.1090 -0.6091 -0.7348];
k = [0.9073 0.0825 -0.4124];

W = [-2 1.5 4.6];

Q = [i;j;k];

phi = atan(Q(3,1)/-Q(3,2));
if phi<0
    phi = phi + pi;
end
theta = acos(Q(3,3));
psi = atan(Q(1,3)/Q(2,3));
if psi<0
    psi = psi + pi;
end
w = Q*W';
wp = (w(1)*sin(psi) + w(2)*cos(psi))/sin(theta);
wn = w(1)*cos(psi) - w(2)*sin(psi);
ws = -(w(1)*sin(psi) + w(2)*cos(psi))/tan(theta) + w(3);

fprintf('Phi: %.3f deg \n', phi*180/pi)
fprintf('Theta: %.3f deg \n', theta*180/pi)
fprintf('Psi: %.3f deg \n', psi*180/pi)

fprintf('Precession Rate: %.3f rad/s \n', wp)
fprintf('Nutation Rate: %.3f rad/s \n', wn)
fprintf('Spin Rate: %.3f rad/s \n', ws)
```

```
Phi: 95.196 deg
Theta: 114.356 deg
Psi: 140.003 deg
Precession Rate: 4.209 rad/s
Nutation Rate: 1.771 rad/s
Spin Rate: -1.852 rad/s
```

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```
clear all; clc; close all;
```

Problem 5

```
m = 500;
w = [0.08 -0.06 -0.03];

dx = 1;
dy = 0.5;
dz = 3;

Ixx = 1/12*m*(dz^2+dy^2);
Iyy = 1/12*m*(dz^2+dx^2);
Izz = 1/12*m*(dx^2+dy^2);
I = [Ixx 0 0; 0 Iyy 0; 0 0 Izz];
Hg = I*w';

vecDeriv = cross(w,Hg);
wdot = -vecDeriv/I;

fprintf('Angular Acceleration in X: %.3s rad/s \n', wdot(1))
fprintf('Angular Acceleration in Y: %.3s rad/s \n', wdot(2))
fprintf('Angular Acceleration in Z: %.3s rad/s \n', wdot(3))
```

```
Angular Acceleration in X: 1.703e-03 rad/s
Angular Acceleration in Y: 1.920e-03 rad/s
Angular Acceleration in Z: 2.880e-03 rad/s
```

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```
clear all; clc; close all;
```

Problem 6

```
phidot = 1.5*2*pi/3600;
R = 3;
L = 30;
theta = 30*pi/180;
m = 1;
Ixx = m*(1/12*L^2 + 1/4*R^2);
Iyy = Ixx;
Izz = 1/2*m*R^2;
psidot = (Iyy-Izz)/(Izz)*phidot*cos(theta);

fprintf('Spin Rate: %.1f rev/hr \n', psidot/(2*pi)*3600)
```

```
Spin Rate: 21.0 rev/hr
```

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```
clear all; clc; close all;
```

Problem 6

```
m = 145;
psidot = 240*2*pi/60;
B = 9.5*pi/180;
D = 1200;
c = 0.6;

kz = 0.76;
kx = 0.42;
ky = kx;

Iz = kz^2*m;
Ix = kx^2*m;
Iy = Ix;

%forced precession
lhs = c*D*sin(B); %solve quadratic eq for roots of B
p = [(Iz-Ix)*sin(B)*cos(B) Iz*psidot*sin(B) -c*D*sin(B)];
phidot = roots(p);
fprintf('Spin Rate 1: %.1f rad/s \n', phidot(1))
fprintf('Spin Rate 2: %.1f rad/s \n', phidot(2))
fprintf('Spin Rate 1: %.1f rpm \n', phidot(1)*60/(2*pi))
fprintf('Spin Rate 2: %.1f rpm \n', phidot(2)*60/(2*pi))
```

```
Spin Rate 1: -37.0 rad/s
Spin Rate 2: 0.3 rad/s
Spin Rate 1: -353.6 rpm
Spin Rate 2: 3.2 rpm
```

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```
clear all; clc; close all;
```

Problem 8

```
m = 240;
wo = 1.5;
m_ast = 0.03;
vo = [-576 -432 960];
ro = [0.3 0.375 0];
kx = 0.3; ky = 0.40; kz = ky;
Ix = kx^2*m;
Iy = ky^2*m;
Iz = Iy;
wrb = [wo 0 0];
I = [Ix 0 0; 0 Iy 0; 0 0 Iz;];
Hg = I*wrb';

Hg2 = Hg + m_ast*cross(ro,vo)';
wx = Hg2(1)/Ix;
wy = Hg2(2)/Iy;
wz = Hg2(3)/Iz;
w = [wx wy wz];
K = Hg2/norm(Hg2);
theta = [acos(K(1)) acos(K(2)) acos(K(3))];
y = acos(wx/norm(w));
psidot = norm(w)/sin(pi - theta(1))*sin(theta(1)-y);
phidot = norm(w)/sin(pi - theta(1))*sin(y);


fprintf('Angular Velocity after impact: [%.3f %.3f %.3f] rad/s \n', w)
fprintf('Spin rate: %.2f rad/s \n', psidot)
fprintf('Precession rate: %.2f rad/s \n', phidot)
```

```
Angular Velocity after impact: [2.000 -0.225 0.067] rad/s
Spin rate: 0.87 rad/s
Precession rate: 1.15 rad/s
```

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