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% Juliette Abbonizio and Mo Khaial Lander Legs Calculations
% using the mass and the delta vs calculate the forces

clear all
% masses (kg)
mpr = 23944+7482;
mpr_des = .50*mpr;
mi_des = 2242.4; %includes structural mass
mtot = 40528-(mpr-mpr_des);

%moon gravity (m/s^2)
g = 1.62;

% vertical velocity at touchdown (m/s)
vv = 2;
% time after touchdown (s)
t = 1;
%impulse (N-s)
%I = mtot*v;

%weight
W = mtot*g;

%energy
Ke = 1/2*mtot*vv^2;

% yield strength (sigma) (Pa)
% O = Pcr/A
% O = 276e6;
% P = O.*A;

% vertical acceleration loading
% diameter and thickness for a circular ring
 do = .1:.01:.25;
 dt = .004:.001:.007;
 count = 1;
 count1 = 1;
for i = 1:length(do)
    for j = 1:length(dt)
        di(i,j) = do(i)-dt(j);
        ro(i) = do(i)/2;
        ri(i,j) = di(i,j)/2;
        % length of the legs
        L = 1.8:.1:2.5;

        % use area of an annulus (ring)
        A(i,j) = pi/4*(do(i)^2-di(i,j)^2); % circular ring

        %moment of intertia of a ring (m^4)
        I(i,j) = pi/64*(do(i)^4-di(i,j)^4);

        %E for 7075 aluminum (Pa)
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```
        E = 71.7e9;

        %Density of 7075 aluminum (kg/m^3)
        rho_al = 2810;

        % ultimate safety factor
        SFu = 2;

        %FORCES
        %Pcr = (pi^2*E*I)/(KL)^2
        F = (mtot*(vv/t)*SFu); % estimated landing force
        K = .65; % (fixed-pinned)
        for k = 1:length(L)
            Pcr(i,j) = ((pi^2*E*I(i,j))/(K*L(k))^2); %Buckling N
            Sigma(i,j) = F/A(i,j); %Normal Stress (Pa)

            % Volume of Hollow Cylinder V = pi/4*h*(do^2-di^2)
            V = pi/4*L(k)*(do(i)^2-(do(i)-dt(j))^2);

            % Mass of 1 leg (kg)
            M_leg_al = rho_al*V;

            if Pcr(i,j) > F/2 &&  4*M_leg_al < 200 && 4*M_leg_al > 40
                Pact(count,1) = Pcr(i,j);
                Pact(count,2) = do(i);
                Pact(count,3) = dt(j);
                Pact(count,4) = L(k);
                Pact(count,5) = 4*M_leg_al;
                count = count+1;
            end



        end
    end


end
% [force, outer diameter, thickness, length, weight]
% [4368029, 0.2, 0.007, 2, 48.57] %update CAD
Sy = 503e6;
SF = Sy/4368029
MS = Sy/4368029-1


SF =

  115.1549


MS =

  114.1549
```

horiztonal acceleration loading

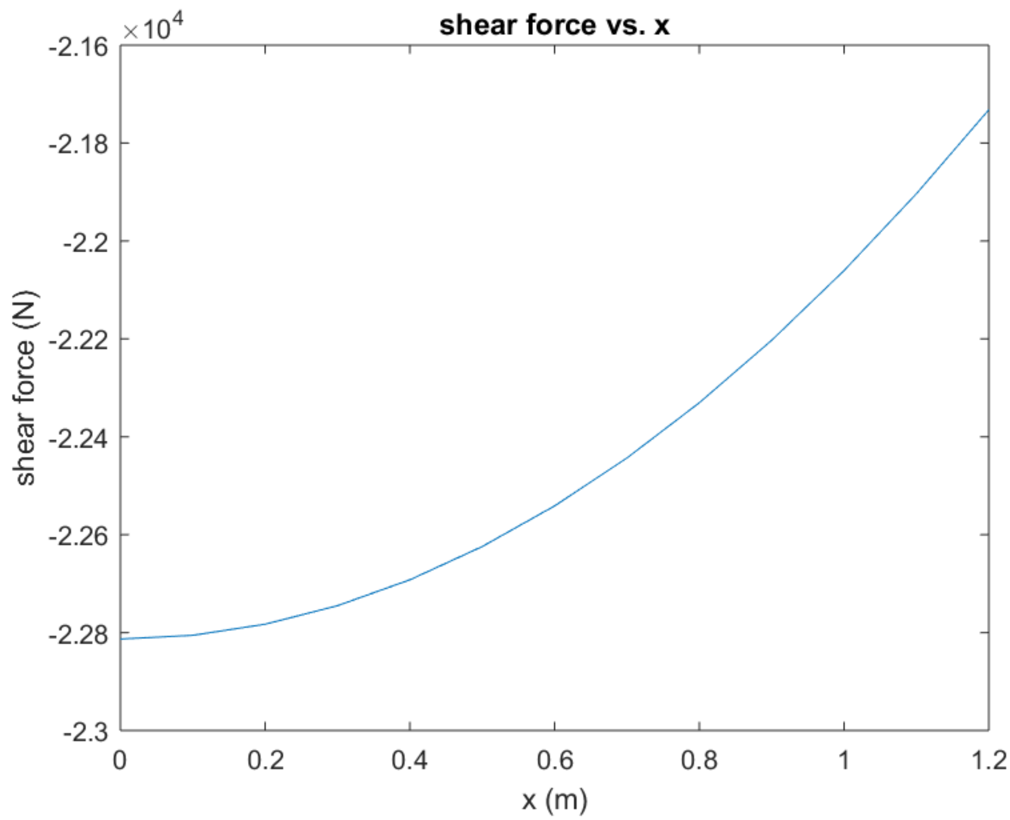
masses (kg)

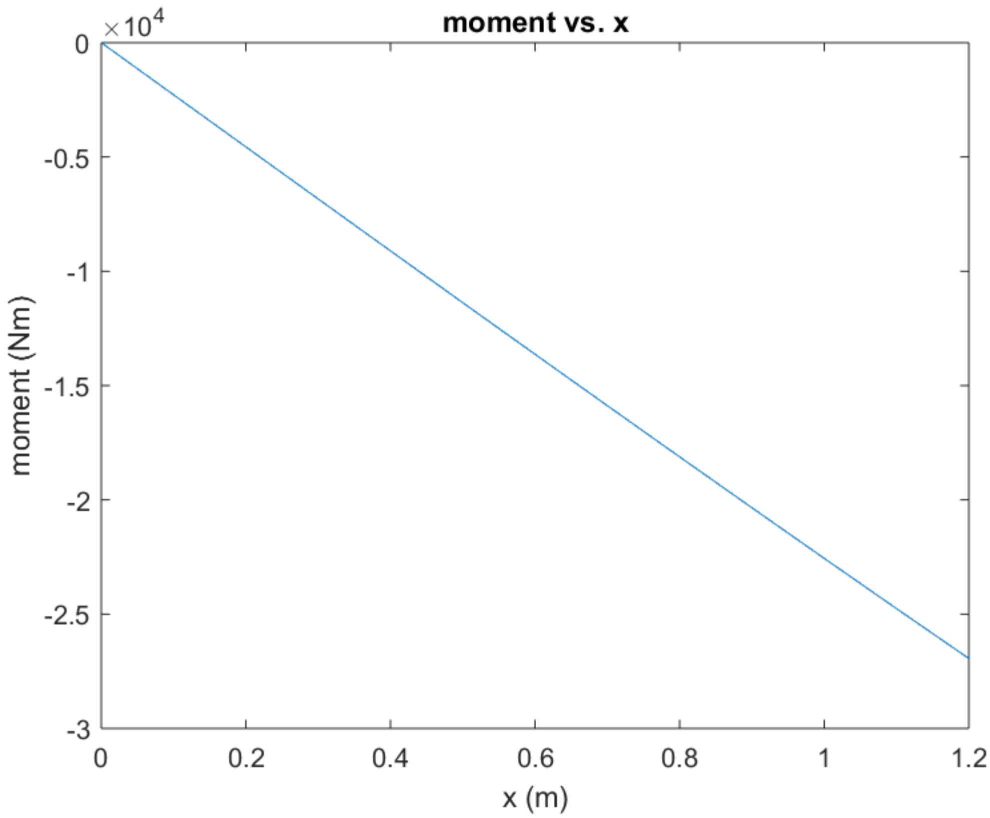
```
mpr = 23944+7482;
mpr_des = .50*mpr;
mi_des = 2242.4; %includes structural mass
mtot = 40528-(mpr-mpr_des);

vh = 1; %horizontal velocity (m/s)
t = 1; %time to touchdown (s)
P = 99260/2; % vertical force
W = (.8*P)/2; %horizontal force (N) using friction (.8) coefficient of
 friction
x = 0:.1:1.2; %distance from the end of the beam to wherever we want
 to analyze
a = 0; % W occurs at the tip
l = 2;
E = 71.7e9;
do = .2;
dt = .007;
di = do-dt;
ro = do/2;
ri = di/2;
I = pi/64*(do^4-di^4);
A = pi/4*(do^2-di^2);

% beams under axial compression and transverse loading
% MAKE GRAPHS WITH DIFFERENT A VALUES ASSUMING MAX BENDING WHEN a = 0
% table 8.8 1a

%constants
k = sqrt(P/(E*I));
F1 = cos(k*x);
F2 = sin(k*x);
F3 = 1-cos(k*x);
F4 = k*x-sin(k*x);

%constants
C1 = cos(k*l);
C2 = sin(k*l);
C3 = 1-cos(k*l);
C4 = k*l-sin(k*l);
Ca1 = cos(k*(l-a));
Ca2 = sin(k*(l-a));
Ca3 = 1-cos(k*(l-a));
Ca4 = k*(l-a)-sin(k*(l-a));
Ca5 = k^2/2*(l-a)^2-Ca3;
Ca6 = k^3/6*(l-a)^3-Ca4;

Ra = 0;
Siga = (W/P)*(Ca3/C1);
Ma = 0;
```

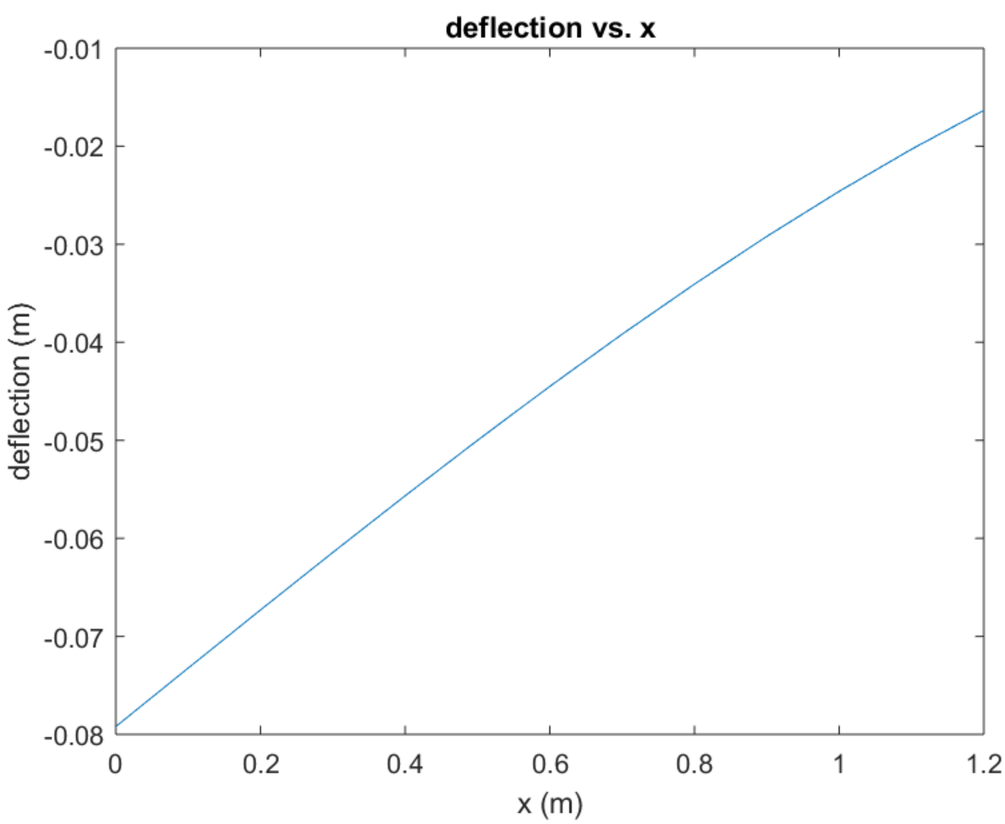
```
ya = (-W/(k*P))*((C2*Ca3-C1*Ca4)/C1);
yb = 0;
Rb = W;
Sigb = 0;
Mb = -(W/k)*((C2*Ca3+C1*Ca2)/C1);
for i = 1:length(x)
    if (i/10) < a
        Fa1(i) = 0*cos(k*(x(i)-a));
        Fa2(i) = sin(k*(x(i)-a));
        Fa3(i) = 0*(1-cos(k*(x(i)-a)));
        Fa4(i) = k*(x(i)-a)-sin(k*(x(i)-a));
        Fa5(i) = ((k^2)/2)*((x(i)-a)^2)-Fa3(i);
        Fa6(i) = ((k^3)/6)*((x(i)-a)^3)-Fa4(i);
    else
        Fa1(i) = cos(k*(x(i)-a));
        Fa2(i) = sin(k*(x(i)-a));
        Fa3(i) = 1-cos(k*(x(i)-a));
        Fa4(i) = k*(x(i)-a)-sin(k*(x(i)-a));
        Fa5(i) = ((k^2)/2)*((x(i)-a)^2)-Fa3(i);
        Fa6(i) = ((k^3)/6)*((x(i)-a)^3)-Fa4(i);
    end
end
V = (Ra.*F1)-(Ma.*k.*F2)-(Siga.*P.*F1)-(W.*Fa1); %transverse shear
M = (Ma.*F1)+((Ra./k).*F2)-(((Siga.*P)./k).*F2)-((W./
k).*Fa2); %bending moment
dy = ya+((Siga./k).*F2)+((Ma./P).*F3)+((Ra./(k.*P)).*F4)-((W./
(k.*P)).*Fa4); %deflection

Q = 2/3*(ro^3-ri^3);
Tau = (V*Q)/(I*dt);
Sig = (M*ro)/I;
Sy = 503e6;

SF = Sy/abs(min(Sig))
MS = Sy/abs(min(Sig))-1

figure(1)
plot(x,V)
title('shear force vs. x')
xlabel('x (m)')
ylabel('shear force (N)')

figure(2)
plot(x,M)
title('moment vs. x')
xlabel('x (m)')
ylabel('moment (Nm)')

figure(3)
plot(x,dy)
title('deflection vs. x')
xlabel('x (m)')
ylabel('deflection (m)')
```

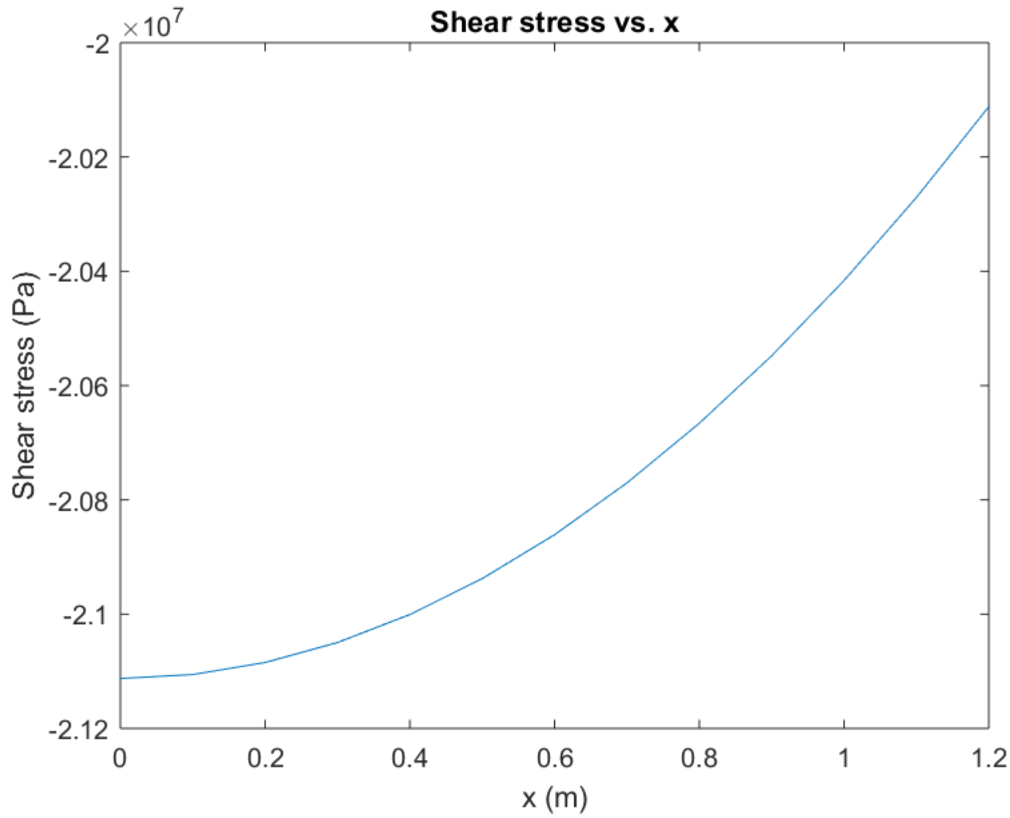
```
figure(4)
plot(x,Tau)
title('Shear stress vs. x')
xlabel('x (m)')
ylabel('Shear stress (Pa)')

figure(5)
plot(x,Sig)
title('Bending stress vs. x')
xlabel('x (m)')
ylabel('Bending stress (Pa)')
```

```
SF =

    1.9476


MS =

    0.9476
```

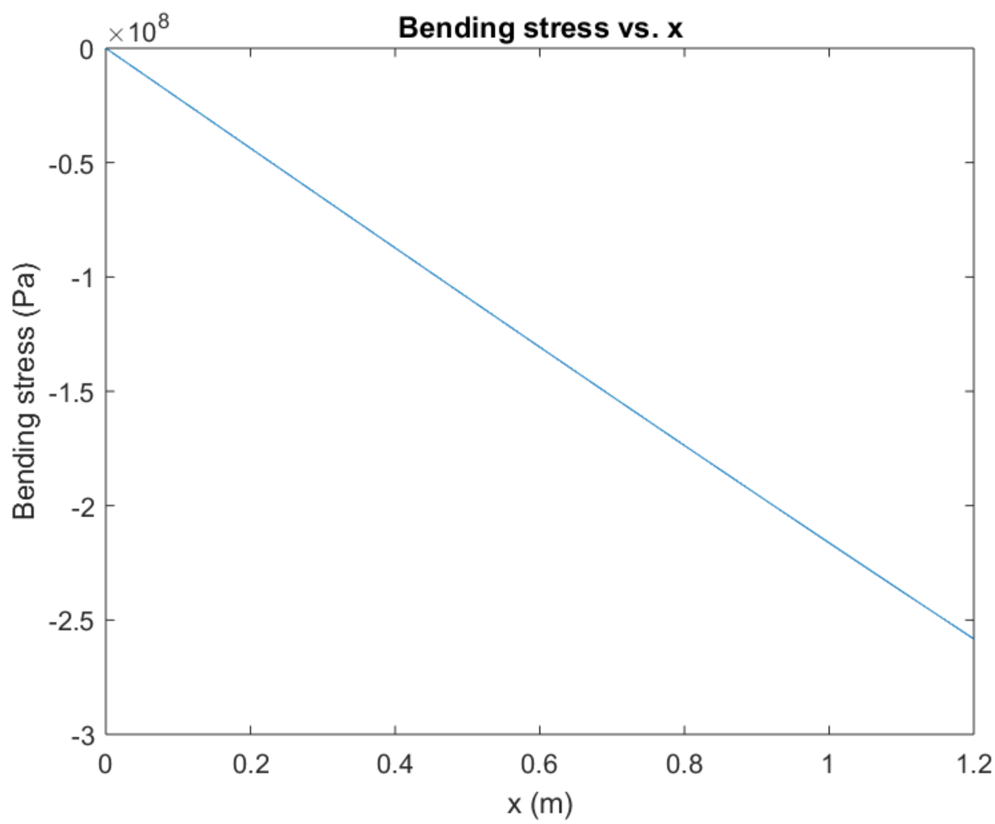



moment vs. x
×10^4
0
-0.5
-1
-1.5
-2
-2.5
-3
moment (Nm)
0
0.2
0.4
0.6
0.8
1
1.2
x (m)


deflection vs. x
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
-0.07
-0.08
deflection (m)
0
0.2
0.4
0.6
0.8
1
1.2
x (m)



Shear stress vs. x
×10^7
-2
-2.02
-2.04
-2.06
-2.08
-2.1
-2.12
Shear stress (Pa)
0
0.2
0.4
0.6
0.8
1
1.2
x (m)



Bending stress vs. x
×10^8
0
-0.5
-1
-1.5
-2
-2.5
-3
Bending stress (Pa)
0
0.2
0.4
0.6
0.8
1
1.2
x (m)

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