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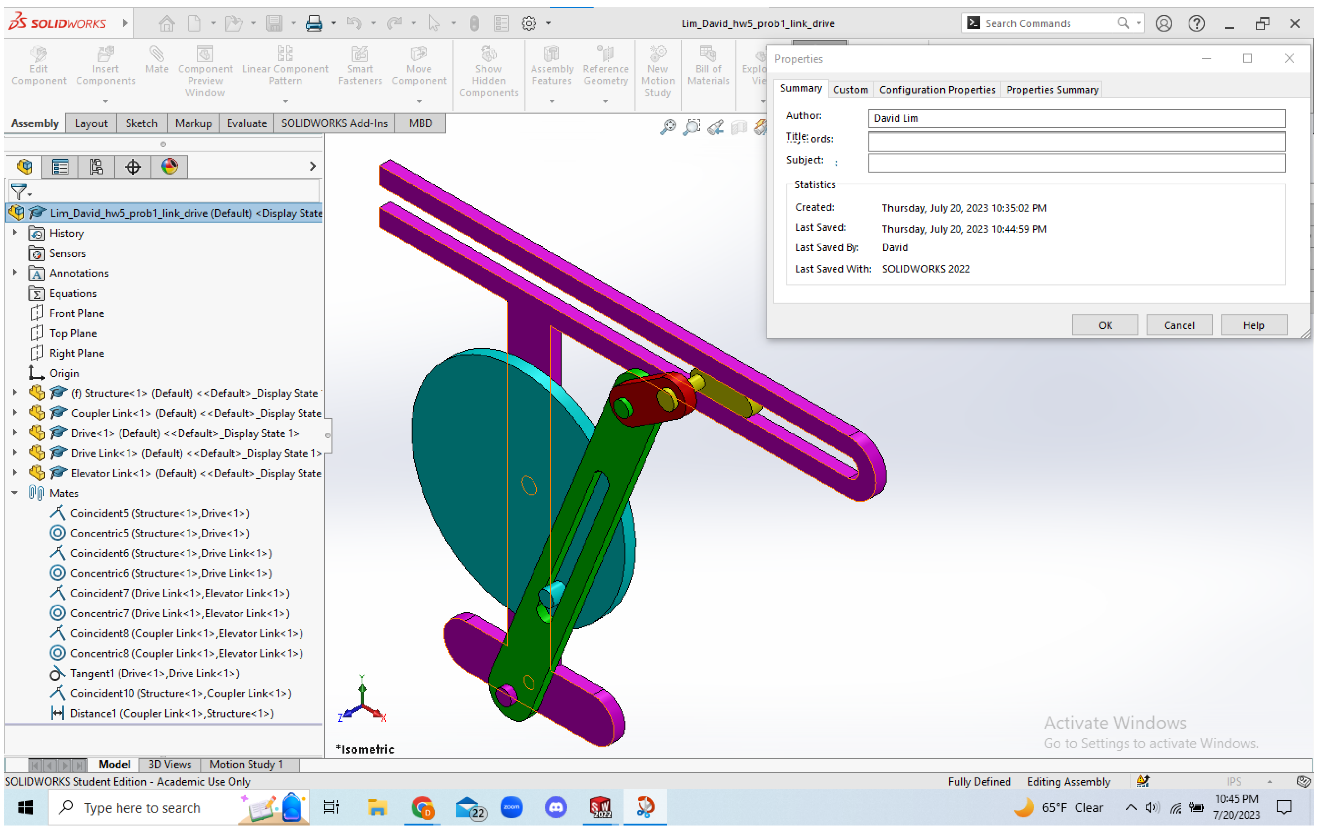
MAE 150

07/19/23

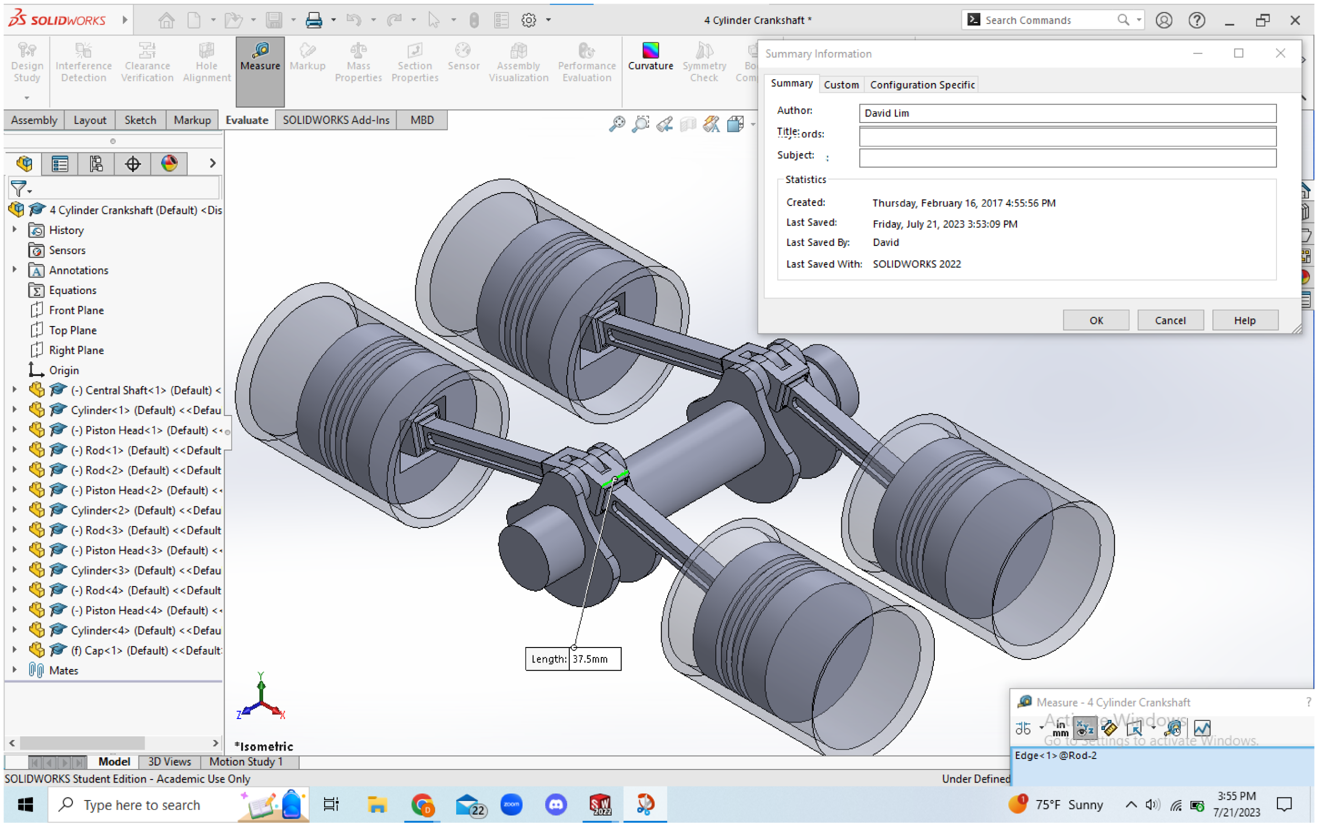
Homework 4

Problem 1

Link drive:



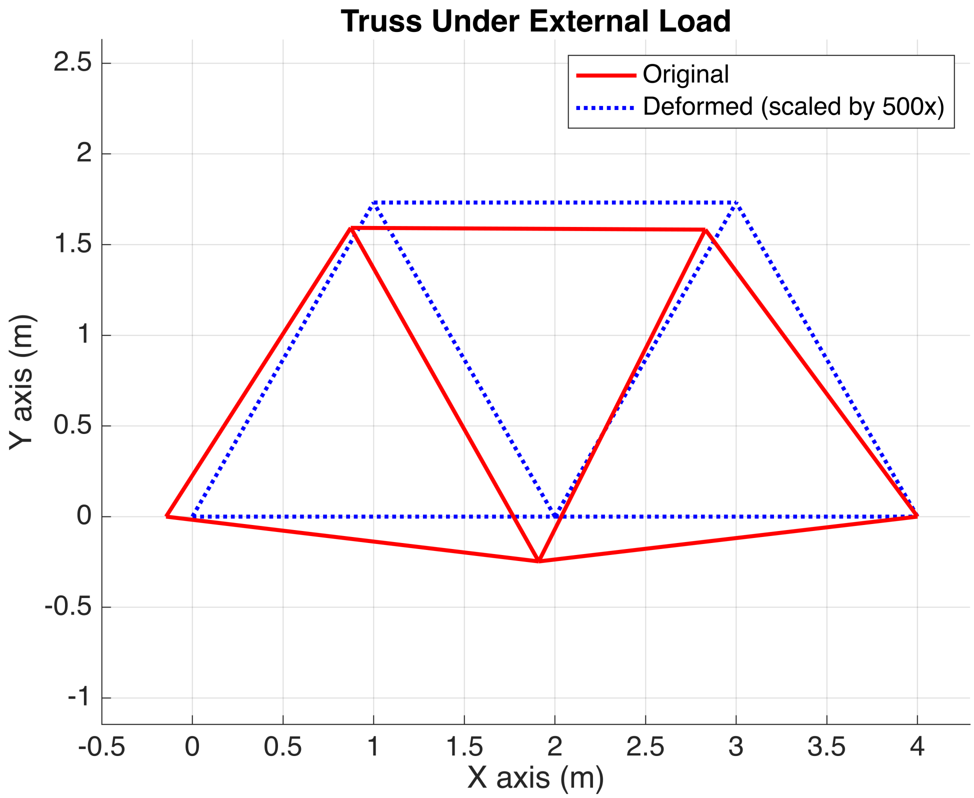
Cylinder crankshaft:



Problem 2

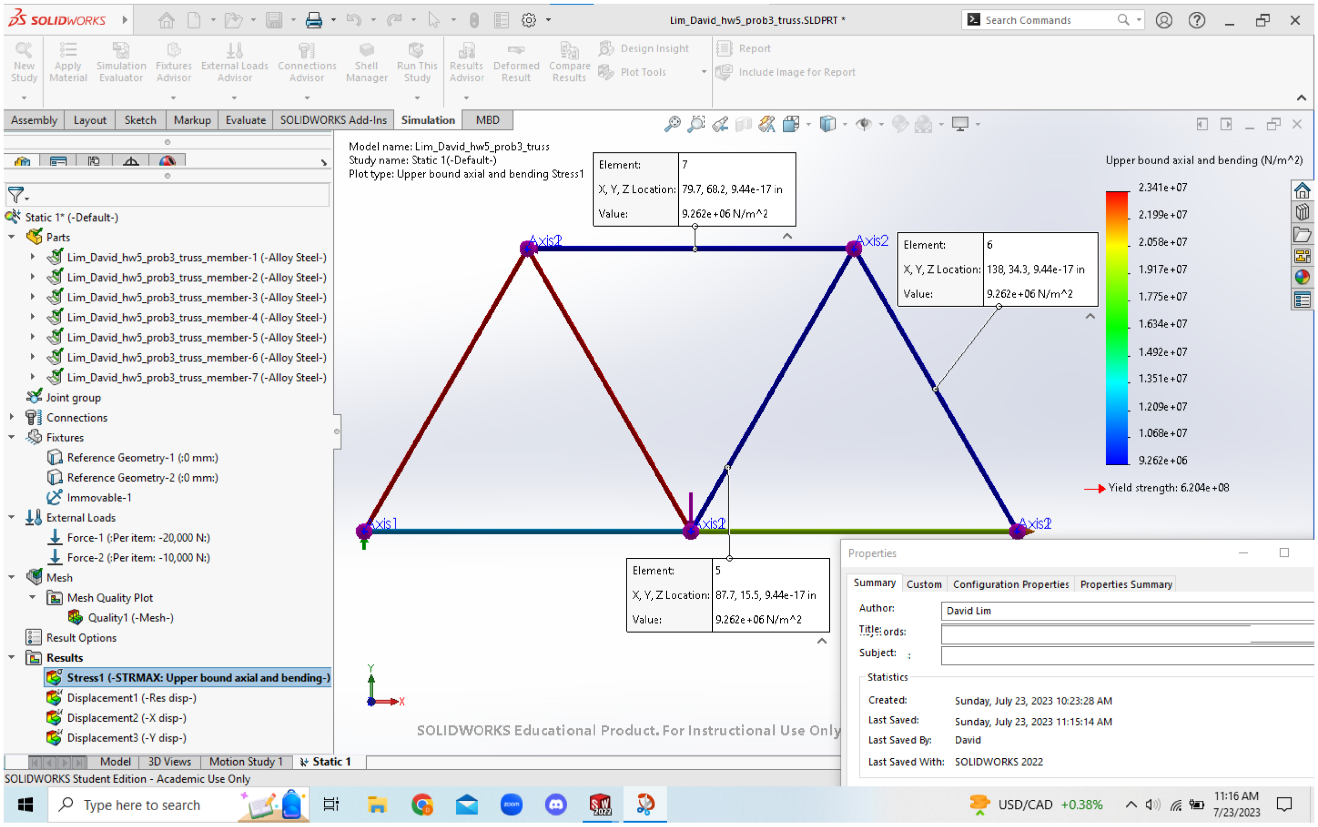
```
Part(a)

K_e1 =

   1.0e+07 *

    7.4220         0   -7.4220         0
         0         0         0         0
   -7.4220         0    7.4220         0
         0         0         0         0

K_e2 =

   1.0e+07 *

    7.4220         0   -7.4220         0
         0         0         0         0
   -7.4220         0    7.4220         0
         0         0         0         0

K_e3 =

   1.0e+07 *

    1.8555    3.2138   -1.8555   -3.2138
    3.2138    5.5665   -3.2138   -5.5665
   -1.8555   -3.2138    1.8555    3.2138
   -3.2138   -5.5665    3.2138    5.5665

K_e4 =

   1.0e+07 *

    1.8555   -3.2138   -1.8555    3.2138
   -3.2138    5.5665    3.2138   -5.5665
   -1.8555    3.2138    1.8555   -3.2138
    3.2138   -5.5665   -3.2138    5.5665

(Units: Pa/m)



Part(b)

K_G =

   1.0e+08 *

    0.9278    0.3214   -0.7422         0         0         0   -0.1856   -0.3214         0         0
    0.3214    0.5567         0         0         0         0   -0.3214   -0.5567         0         0
   -0.7422         0    1.8555   -0.0000   -0.7422         0   -0.1856    0.3214   -0.1856   -0.3214
         0         0   -0.0000    1.1133         0         0    0.3214   -0.5567   -0.3214   -0.5567
         0         0   -0.7422         0    0.9278   -0.3214         0         0   -0.1856    0.3214
         0         0         0         0   -0.3214    0.5567         0         0    0.3214   -0.5567
   -0.1856   -0.3214   -0.1856    0.3214         0         0    1.1133   -0.0000   -0.7422         0
   -0.3214   -0.5567    0.3214   -0.5567         0         0   -0.0000    1.1133         0         0
         0         0   -0.1856   -0.3214   -0.1856    0.3214   -0.7422         0    1.1133   -0.0000
         0         0   -0.3214   -0.5567    0.3214   -0.5567         0         0   -0.0000    1.1133

(Units: N/m)
```

```
Part(c)

d =

   1.0e-03 *

   -0.2903
         0
   -0.1788
   -0.4940
         0
         0
   -0.2526
   -0.2792
   -0.3408
   -0.2986

(Units: m)



Part(d)

F_1y =

   1.4330e+04

F_3x =

   1.0000e+04

F_3y =

   5.6699e+03

(Units: N)
```

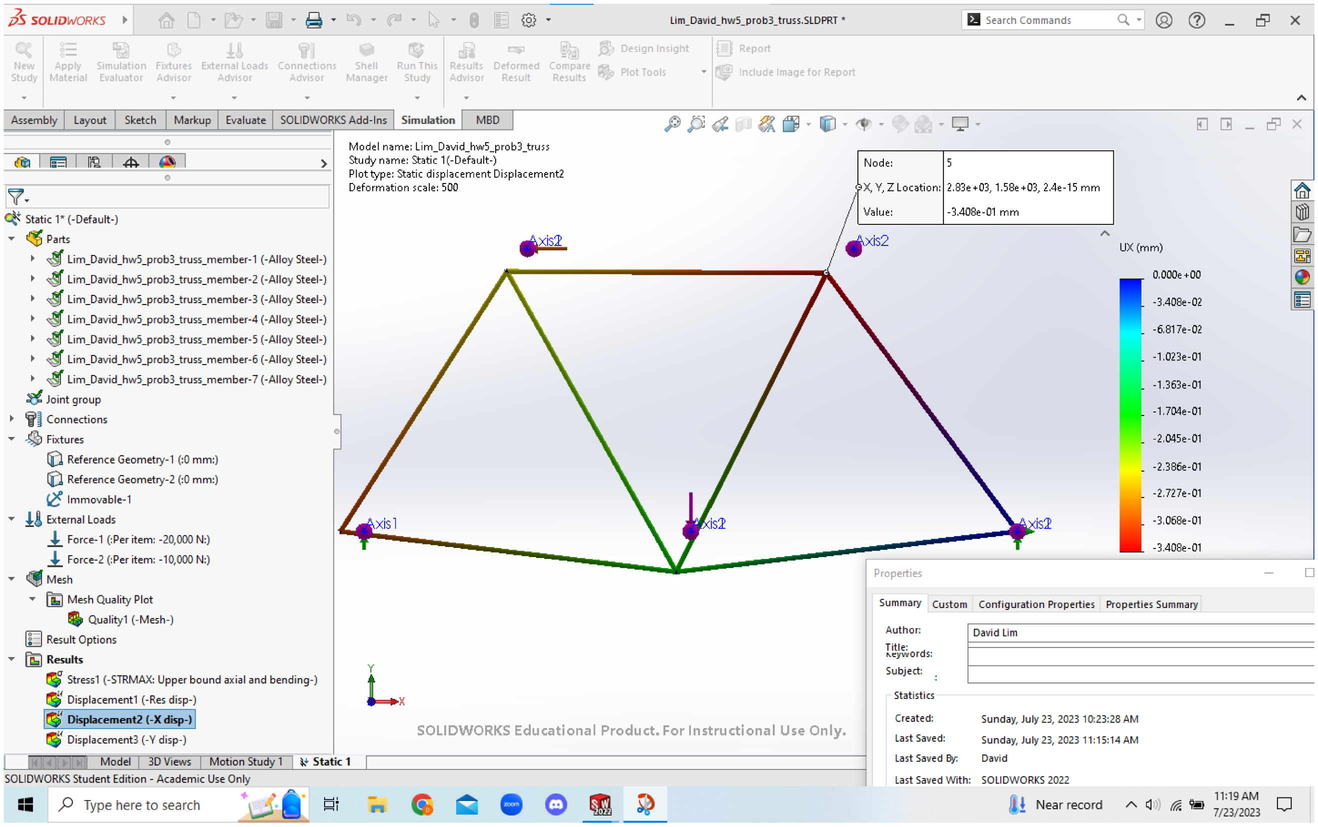


Truss Under External Load
Original
Deformed (scaled by 500x)
Y axis (m)
X axis (m)
2.5
2
1.5
1
0.5
0
-0.5
-1
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4

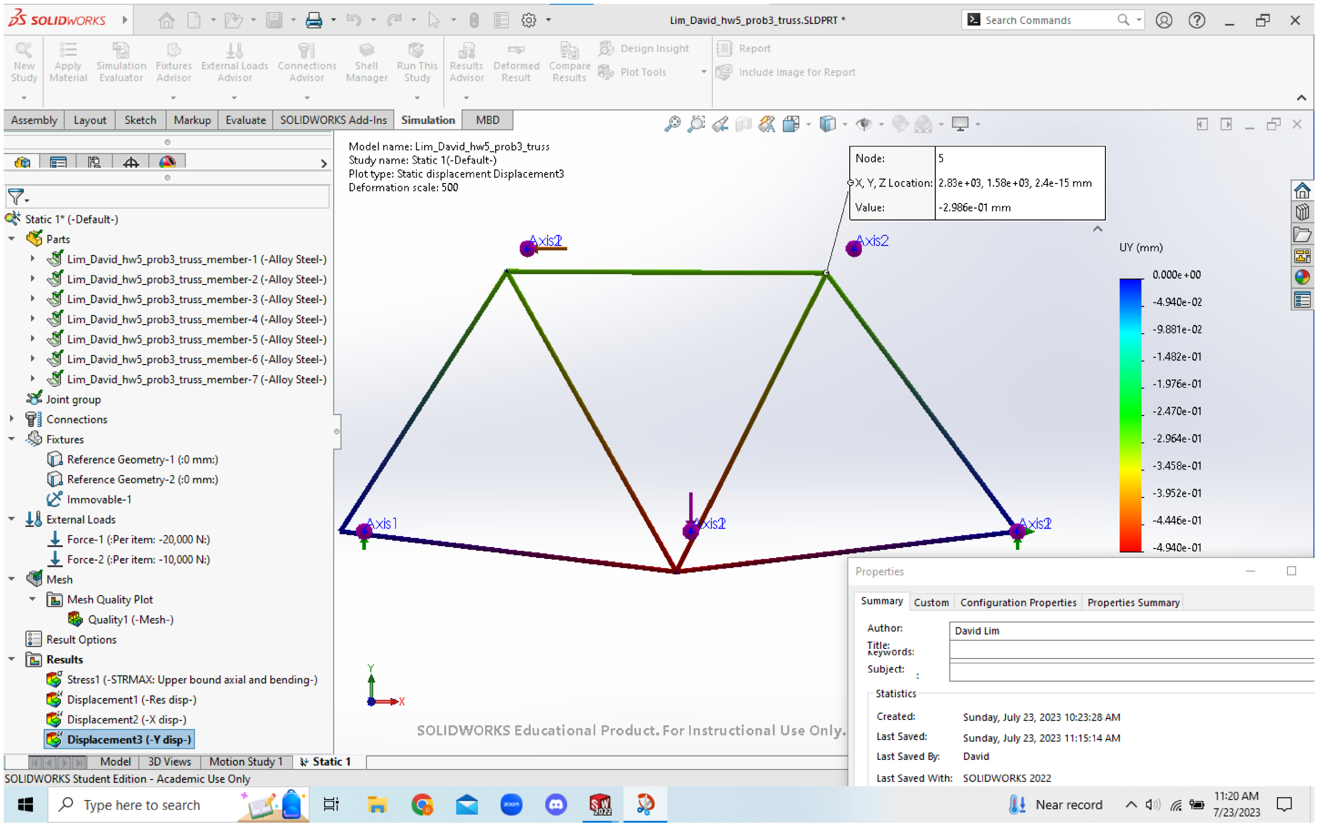
Problem 3



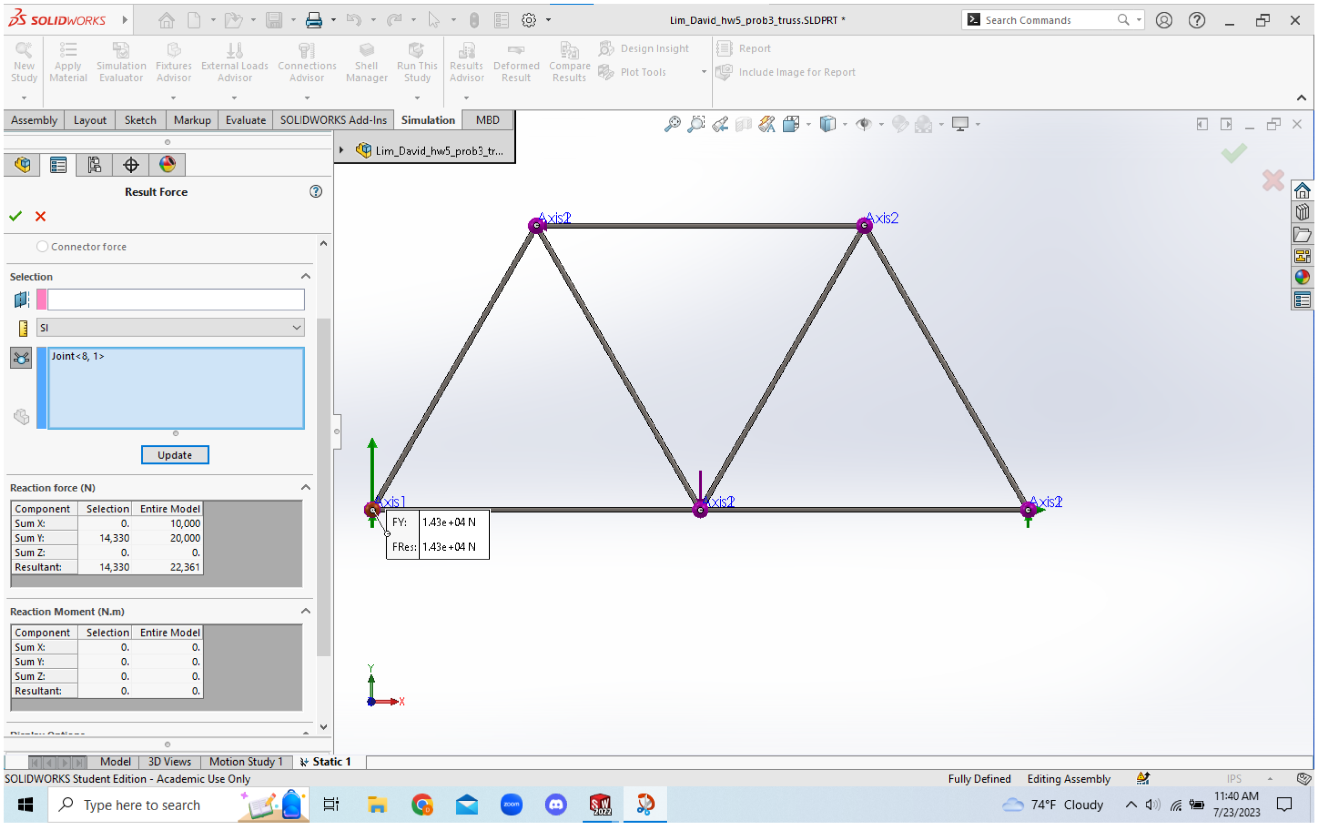
a) Axial stress

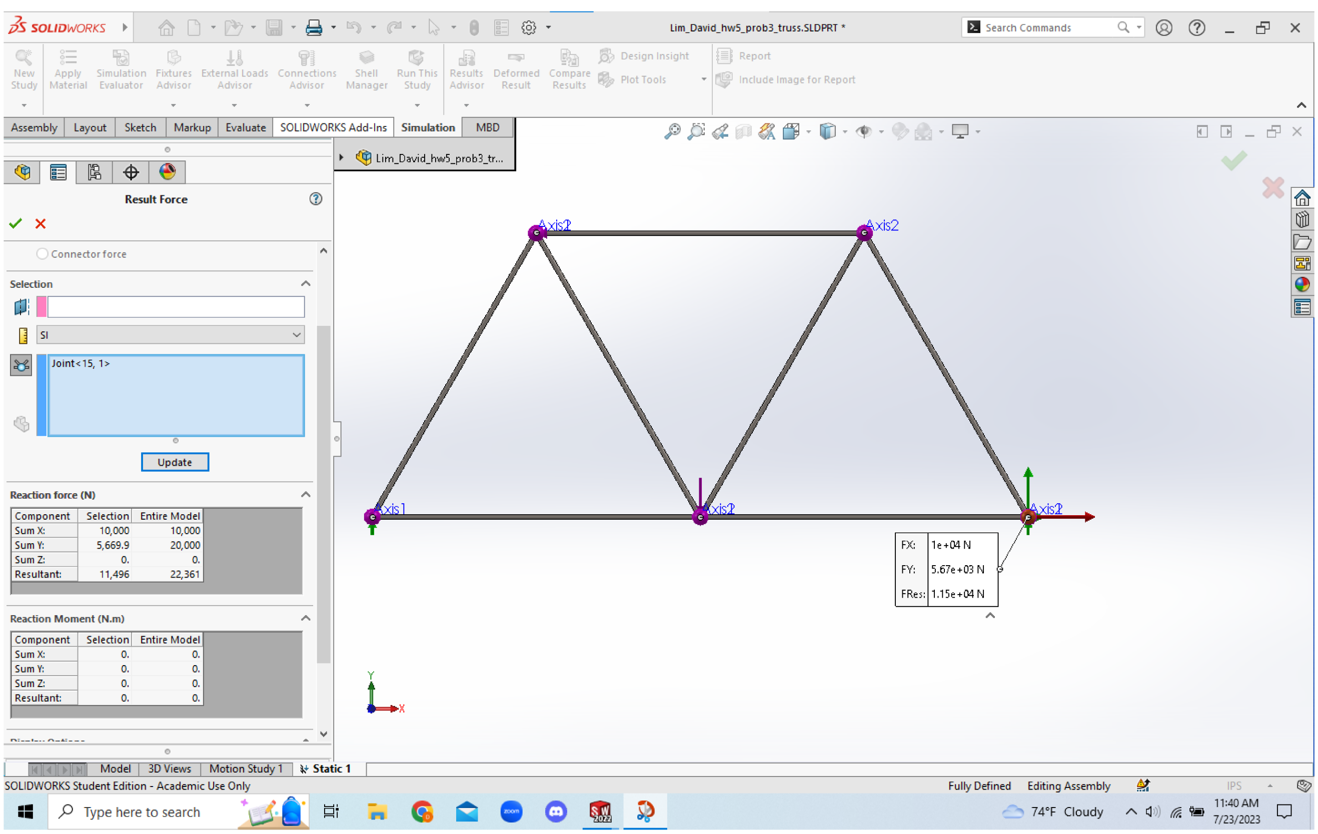


b) X-displacement



c) Y-displacement


Lim_David_hw5_prob3_truss.SLDPRT *
Result Force
Connector force
Selection
SI
Joint<8, 1>
Update
Reaction force (N)
Component | Selection | Entire Model
Sum X: | 0. | 10,000
Sum Y: | 14,330 | 20,000
Sum Z: | 0. | 0.
Resultant: | 14,330 | 22,361
Reaction Moment (N.m)
Component | Selection | Entire Model
Sum X: | 0. | 0.
Sum Y: | 0. | 0.
Sum Z: | 0. | 0.
Resultant: | 0. | 0.
FY: 1.43e+04 N
FRes: 1.43e+04 N
Model | 3D Views | Motion Study 1 | Static 1
SOLIDWORKS Student Edition - Academic Use Only
Fully Defined
Editing Assembly
11:40 AM
7/23/2023


Lim_David_hw5_prob3_truss.SLDPRT *
Result Force
Connector force
Selection
SI
Joint<15, 1>
Update
Reaction force (N)
Component | Selection | Entire Model
Sum X: | 10,000 | 10,000
Sum Y: | 5,669.9 | 20,000
Sum Z: | 0. | 0.
Resultant: | 11,496 | 22,361
Reaction Moment (N.m)
Component | Selection | Entire Model
Sum X: | 0. | 0.
Sum Y: | 0. | 0.
Sum Z: | 0. | 0.
Resultant: | 0. | 0.
FX: 1e+04 N
FY: 5.67e+03 N
FRes: 1.15e+04 N
Model | 3D Views | Motion Study 1 | Static 1
SOLIDWORKS Student Edition - Academic Use Only
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Editing Assembly
11:40 AM
7/23/2023

d) Reaction forces

The results calculated in Matlab and Solidworks are the same. Solidworks uses uses the same assumptions as in the FEA of trusses (two force members, loads applied at nodes only, weightless, frictionless, etc).

Table of Contents

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```
clear
close all
```

Initialization

Parameters

```
L = 2; % meters
H = L*sind(60); % meters

d = 0.030; % meters
A = pi*(d/2)^2; % square meters
E = 210*10^9; % GPa

% Define node positions
 % node: 1 2   3   4     5
nodes = [0 L 2*L L/2 3*L/2;  % x
         0 0   0   H     H]; % y

% Define element-node connections
 % element: 1 2 3 4 5 6 7
elements = [1 2 1 2 2 3 4;  % node i
            2 3 4 4 5 5 5]; % node j

n = length(nodes);
m = length(elements);
```

Construct stiffness matrices

Initialize arrays in loop

```
Ke = cell(m,1);
KG = zeros(2*n);

% Loop through elements
for el = 1:m
    i = elements(1,el);
    j = elements(2,el);

    p1 = nodes(:,i);
```

```
    p2 = nodes(:,j);

    beta = atan2(p2(2)-p1(2),p2(1)-p1(1));
    c = cos(beta);
    s = sin(beta);
    c2 = c^2;
    s2 = s^2;
    cs = c*s;
    Ke{el} = A*E/L*[ c2  cs -c2 -cs;
                     cs  s2 -cs -s2;
                    -c2 -cs  c2  cs;
                    -cs -s2  cs  s2];

    Kt = zeros(2*n);
    Kt([2*i-1,2*i,2*j-1,2*j],[2*i-1,2*i,2*j-1,2*j]) = Ke{el};
    KG = KG + Kt;
end
```

Solving for unknowns

Define force vector

```
F = zeros(2,n); % Newtons
F(1,1) = 0;
F(2,1) = NaN;
F(2,2) = -20*10^3;
F(1,3) = NaN;
F(2,3) = NaN;
F(1,4) = -10*10^3;

% Indexing array for reduction (displacement = 0 at reaction forces)
redux = ~isnan(F);

% Reduce KG and F
Kr = KG(redux,redux);
Fr = F(redux);

% Solve for unknown displacements
dr = Kr\Fr;

% Define complete displacement vector
d = zeros(2*n,1);
d(redux) = dr;

% Reduce KG (reduce opposite rows)
Kr = KG(~redux,redux);

% Solve for unknown forces
Fr = Kr*dr;
```

Parts (a)-(d): Print results

```
fprintf('Part(a)\n\n')
```

```
fprintf('K_e1 =\n\n')
disp(Ke{1})
fprintf('K_e2 =\n\n')
disp(Ke{2})
fprintf('K_e3 =\n\n')
disp(Ke{3})
fprintf('K_e4 =\n\n')
disp(Ke{4})
fprintf('(Units: Pa/m)\n')

fprintf('\n\n\n')
fprintf('Part(b)\n\n')
fprintf('K_G =\n\n')
disp(KG)
fprintf('(Units: N/m)\n')

fprintf('\n\n\n')
fprintf('Part(c)\n\n')
fprintf('d =\n\n')
disp(d)
fprintf('(Units: m)\n')

fprintf('\n\n\n')
fprintf('Part(d)\n\n')
fprintf('F_1y =\n\n')
disp(Fr(1))
fprintf('F_3x =\n\n')
disp(Fr(2))
fprintf('F_3y =\n\n')
disp(Fr(3))

fprintf('(Units: N)\n')
```

Part (e): Plotting

```
scale = 500;
linewidth = 2;
fontsize = 14;
color1 = 'b';
color2 = 'r';

close all
figure
clf
hold on
for el = 1:length(elements)
    j = elements(:,el);
    x = nodes(1,j);
    y = nodes(2,j);
    plot(x,y,':','Color',color1,'Linewidth',linewidth);
end
nodes_new = nodes + scale*reshape(d,2,5);
for el = 1:length(elements)
```

```
    j = elements(:,el);
    x = nodes_new(1,j);
    y = nodes_new(2,j);
    plot(x,y,'-','Color',color2,'Linewidth',linewidth);
end
hold off
grid on
axis equal
axis padded
title('Truss Under External Load')
xlabel('X axis (m)')
ylabel('Y axis (m)')
set(gca,'FontSize',fontsize)
h = get(gca,'Children');
legend([h(1),h(m+1)],'Original',sprintf('Deformed (scaled by %dx)',scale))
```

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