Exam 2 Take-Home Portion

Table of Contents

BIOE-3040-H01 Introduction to Biomechanics w/ Prof. Hunter Author(s): - Neil A. Kumar - Linea Gutierrez - Elise Carter Dependencies: - cls.m - Mixed2.05.mat - Prob2.04.mat - Prob2.05.mat - Prob2.06.mat - Graded_Bar1.mat - Graded_Bar2.mat - mech_main.m

Setup

```
% Generic Reset
cls; % alias used for ease; does following commands:
        % close all;          % Close all open windows / plots
        % clear;              % Clear the workspace of any variables
        % format short e;     % Reset command window formatting
        % clc;                % Clear the command line

% Formatting and Metadata
fprintf("<strong># ~/denkr/Documents/School/UCD/'5. BIOE.3020.H01 -
 BioMechanics'/Matlab/BiomechanicsExam2 m</strong>\n");
fprintf("<strong># File: run.m</strong>\n");
fprintf("<strong># Title: Exam 2 Take-Home Portion</strong>\n");
fprintf("<strong># Authors: Neil A. Kumar, Linea Gutierrez, and Elise
 Carter</strong>\n");
fprintf("<strong># Dependencies:</strong> cls.m | Mixed2.05.mat
 | Prob2.04.mat | Prob2.05.mat |\n                Prob2.06.mat |
 Graded_Bar1.mat | Graded_Bar2.mat |\n                mech_main.m\n");
```

```
<strong># ~/denkr/Documents/School/UCD/'5. BIOE.3020.H01 -
 BioMechanics'/Matlab/BiomechanicsExam2 m</strong>
<strong># File: run.m</strong>
<strong># Title: Exam 2 Take-Home Portion</strong>
<strong># Authors: Neil A. Kumar, Linea Gutierrez, and Elise Carter</
strong>
<strong># Dependencies:</strong> cls.m | Mixed2.05.mat | Prob2.04.mat
 | Prob2.05.mat |
                Prob2.06.mat | Graded_Bar1.mat | Graded_Bar2.mat |
                mech_main.m
```

Program Main

```
% Load in example models
fprintf('\n- Loading in example models -\n'); % Look good formatting
 (lgf)
```

```
bar(1) = load('Example Models/Prob2.04.mat').bar;
 fprintf('Prob2.04.mat loaded into bar(1)\n'); %lgf
bar(2) = load('Example Models/Prob2.05.mat').bar;
 fprintf('Prob2.05.mat loaded into bar(2)\n'); %lgf
bar(3) = load('Example Models/Prob2.06.mat').bar;
 fprintf('Prob2.06.mat loaded into bar(3)\n'); %lgf
bar(4) = load('Example Models/Mixed2.05.mat').bar;
 fprintf('Mixed2.05.mat loaded into bar(4)\n'); %lgf

% Load in graded models
gradbar(1) = load('Graded Models/Graded_Bar1.mat').bar;
gradbar(2) = load('Graded Models/Graded_Bar2.mat').bar;

% Add graded models to bar (removes redundant fields)
bar(5) = rmfield(gradbar(1),'comment'); fprintf('Graded_Bar1.mat
 loaded into bar(5)\n'); %lgf
bar(6) = rmfield(gradbar(2),'comment'); fprintf('Graded_Bar2.mat
 loaded into bar(6)\n'); %lgf

for i = 1: 1: length(bar)
    fprintf('\nRunning mech_main.m on bar model %i\n', i); %lgf
    out(i) = mech_main(bar(i));
    fprintf('output for bar(i) \n')
    disp(struct2table(out(i)));
end
```

```
- Loading in example models -
Prob2.04.mat loaded into bar(1)
Prob2.05.mat loaded into bar(2)
Prob2.06.mat loaded into bar(3)
Mixed2.05.mat loaded into bar(4)
Graded_Bar1.mat loaded into bar(5)
Graded_Bar2.mat loaded into bar(6)

Running mech_main.m on bar model 1
****COMBINED MECHANICAL/THERMAL AXIAL LOADING ANALYSIS****
mech_main.m || Using bar model provided in call
mech_main.m || Calculating Free Deformation...
mech_main.m || Done!
mech_main.m || Checking if there is a gap...
mech_main.m || No Gap
mech_main.m || Done!
mech_main.m || Calculating Reaction Return...
mech_main.m || Done!
****END OF ANALYSIS****
output for bar(i)
                          UncLoad
              UncMDef
 UncTDef                                  React0          React1
                    TotLoad
           MecDef
 TotDef                                                          Stress
```

```
    0.0000e+00    6.0000e+05    6.0000e+05    9.0000e+05    0.0000e+00
    1.1250e-03    1.8000e-03    2.7000e-03    0.0000e+00    0.0000e+00
    0.0000e+00    0.0000e+00    -5.7692e+05    -3.2308e+05    -5.7692e
+05     2.3077e+04     2.3077e+04     3.2308e+05    -1.0817e-03
     4.3269e-05     6.9231e-05     9.6923e-04    -1.0817e-03
 4.3269e-05     6.9231e-05     9.6923e-04    -1.4423e+09     5.7692e
+07     9.2308e+07     1.2923e+09


Running mech_main.m on bar model 2
****COMBINED MECHANICAL/THERMAL AXIAL LOADING ANALYSIS****
mech_main.m || Using bar model provided in call
mech_main.m || Calculating Free Deformation...
mech_main.m || Done!
mech_main.m || Checking if there is a gap...
mech_main.m || Gap, problem may be statically determinate...
mech_main.m || Gap closed. Indeterminate
mech_main.m || Done!
mech_main.m || Calculating Reaction Return...
mech_main.m || Done!
****END OF ANALYSIS****
output for bar(i)
                          UncLoad
             UncMDef
 UncTDef                                  React0         React1
                    TotLoad
           MecDef
 TotDef                                                      Stress

    0.0000e+00    6.0000e+05    6.0000e+05    9.0000e+05    0.0000e+00
    1.1250e-03    1.8000e-03    2.7000e-03    0.0000e+00    0.0000e+00
    0.0000e+00    0.0000e+00    -1.1538e+05    -7.8462e+05    -1.1538e
+05     4.8462e+05     4.8462e+05     7.8462e+05    -2.1635e-04
     9.0865e-04     1.4538e-03     2.3538e-03    -2.1635e-04
 9.0865e-04     1.4538e-03     2.3538e-03    -2.8846e+08     1.2115e
+09     1.9385e+09     3.1385e+09
```

```
Running mech_main.m on bar model 3
****COMBINED MECHANICAL/THERMAL AXIAL LOADING ANALYSIS****
mech_main.m || Using bar model provided in call
mech_main.m || Calculating Free Deformation...
mech_main.m || Done!
mech_main.m || Checking if there is a gap...
mech_main.m || No Gap
mech_main.m || Done!
mech_main.m || Calculating Reaction Return...
mech_main.m || Done!
****END OF ANALYSIS****
output for bar(i)
            UncLoad                       UncMDef
 UncTDef                React0        React1                TotLoad
                  MecDef                          TotDef
      Stress
    _____________________________    _____________________________
  _______________________________    __________    ____________
    _____________________________    _____________________________
 _______________________________    _____________________________

    0.0000e+00    0.0000e+00    0.0000e+00    0.0000e+00
 -9.7500e-03    -9.7500e-03    1.8850e+04    -1.8850e+04    1.8850e
+04    1.8850e+04    6.5000e-03    1.3000e-02    -3.2500e-03
 3.2500e-03    1.5708e+04    3.1417e+04


Running mech_main.m on bar model 4
****COMBINED MECHANICAL/THERMAL AXIAL LOADING ANALYSIS****
mech_main.m || Using bar model provided in call
mech_main.m || Calculating Free Deformation...
mech_main.m || Done!
mech_main.m || Checking if there is a gap...
mech_main.m || Gap, problem may be statically determinate...
mech_main.m || Gap closed. Indeterminate
mech_main.m || Done!
mech_main.m || Calculating Reaction Return...
mech_main.m || Done!
****END OF ANALYSIS****
output for bar(i)
                           UncLoad
             UncMDef
 UncTDef                                  React0         React1
                     TotLoad
           MecDef
 TotDef                                                          Stress

    ____________________________________________________________
    ____________________________________________________________
    ____________________________________________________________
    ____________    ____________
 _______________________________________________________________
```

```
    0.0000e+00    6.0000e+05    6.0000e+05    9.0000e+05    0.0000e+00
    1.1250e-03    1.8000e-03    2.7000e-03    3.1590e-04    3.1590e-04
    3.1590e-04    3.1590e-04    -2.4498e+05    -6.5502e+05    -2.4498e
+05     3.5502e+05     3.5502e+05     6.5502e+05    -4.5935e-04
     6.6565e-04     1.0650e-03     1.9650e-03    -1.4345e-04
 9.8155e-04     1.3809e-03     2.2809e-03    -6.1246e+08     8.8754e
+08     1.4201e+09     2.6201e+09


Running mech_main.m on bar model 5
****COMBINED MECHANICAL/THERMAL AXIAL LOADING ANALYSIS****
mech_main.m || Using bar model provided in call
mech_main.m || Calculating Free Deformation...
mech_main.m || Done!
mech_main.m || Checking if there is a gap...
mech_main.m || Gap, problem may be statically determinate...
mech_main.m || Gap closed. Indeterminate
mech_main.m || Done!
mech_main.m || Calculating Reaction Return...
mech_main.m || Done!
****END OF ANALYSIS****
output for bar(i)
                          UncLoad
             UncMDef
 UncTDef                                React0         React1
                   TotLoad
           MecDef
 TotDef                                                    Stress

    ____________________________________________________________
    ____________________________________________________________
    ____________________________________________________________
    ____________    ____________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________

    0.0000e+00    5.0000e+04    1.2000e+05    2.6000e+05    0.0000e+00
    3.6032e-05    1.0477e-04    2.5374e-04    7.3150e-04    1.0450e-03
    1.8408e-03    3.3984e-03    -9.9330e+05    7.3330e+05    -9.9330e
+05    -9.4330e+05    -8.7330e+05    -7.3330e+05    -8.5782e-04
    -6.7978e-04    -7.6246e-04    -7.1564e-04    -1.2632e-04
 3.6522e-04     1.0783e-03     2.6828e-03    -8.9537e+08    -5.8588e
+08    -4.4477e+08    -5.0130e+08


Running mech_main.m on bar model 6
****COMBINED MECHANICAL/THERMAL AXIAL LOADING ANALYSIS****
mech_main.m || Using bar model provided in call
```

```
mech_main.m || Calculating Free Deformation...
mech_main.m || Done!
mech_main.m || Checking if there is a gap...
mech_main.m || No Gap
mech_main.m || Done!
mech_main.m || Calculating Reaction Return...
mech_main.m || Done!
****END OF ANALYSIS****
output for bar(i)
                                  UncLoad
                                   UncMDef
                                       UncTDef
              React0        React1
 TotLoad
  MecDef
    TotDef
       Stress
    _____________________________________________________________________________
    _____________________________________________________________________________

_____________________________________________________________________________
    __________    ___________
_____________________________________________________________________________
  ___________________________________________________________________________

_____________________________________________________________________________
    _____________________________________________________________________________

    0.0000e+00    1.7000e+05    1.3000e+05    1.8000e+05    1.1500e+05
    0.0000e+00    9.1224e-05    6.5000e-05    1.3576e-04    1.2151e-04
    -9.4050e-04    -6.6880e-04    -5.7330e-04    -7.0200e-04
 -8.2600e-04    8.3565e+05    -9.5065e+05    8.3565e+05    1.0056e
+06    9.6565e+05    1.0156e+06    9.5065e+05    9.1759e-04
 5.3964e-04    4.8282e-04    7.6605e-04    1.0045e-03    -2.2906e-05
   -1.2916e-04    -9.0476e-05    6.4051e-05    1.7848e-04    1.0014e
+09    8.5148e+08    6.8975e+08    8.1107e+08    9.8808e+08
```

Prove Convergence for a Bar (Problem 2.05)

Prove convergence by changing step size

```
fprintf('\n -Proving Convergence- \n'); %lgf

% Load prob 2.05
convbar = load('Example Models/Prob2.05.mat').bar;

% Store original solve structure in a cell
fprintf('\nRunning mech_main.m on convergence bar model 1\n'); %lgf
convbar_out{1} = mech_main(convbar);

% Define original number of steps (Nistp)
step_original = convbar.Nistp;
```

```
% Define new number of steps to be tested
step_new = step_original * 100;

% Set Nistp equal to 200 steps and solve
fprintf('\nRunning mech_main.m on convergence bar model 2\n'); %lgf
convbar.Nistp = step_new;
convbar_out{2} = mech_main(convbar);

% Relative error between bar elements with 20 and 2000 steps
rel_error = (convbar_out{1}.UncMDef - convbar_out{2}.UncMDef) ./
 convbar_out{1}.UncMDef;
tol = 1e-6; % tolerance

if any(rel_error > tol) % relative error greater than tolerance
    fprintf('\n Does not converge with original step size. Original
 Step Size Insufficient \n'); %lgf
else % relative error less than tolerance
     fprintf('\n Convergence Proved! Original Step Size Sufficient
 \n'); %lgf
end

% EXPLANATION: convbar_out.UncMDef is assigned to the output of the
 first
% time our integration funtion is used in mech_main. If the relative
 error
% between UncMDef when solved with original Nistp value is within a
 tolerance (1e-6) of
% UncMDef solved with Nistp*100 steps, it is concluded that solving
 with
% the original step size does indeed converge within the integration
 function.
```

```
 -Proving Convergence-

Running mech_main.m on convergence bar model 1
****COMBINED MECHANICAL/THERMAL AXIAL LOADING ANALYSIS****
mech_main.m || Using bar model provided in call
mech_main.m || Calculating Free Deformation...
mech_main.m || Done!
mech_main.m || Checking if there is a gap...
mech_main.m || Gap, problem may be statically determinate...
mech_main.m || Gap closed. Indeterminate
mech_main.m || Done!
mech_main.m || Calculating Reaction Return...
mech_main.m || Done!
****END OF ANALYSIS****

Running mech_main.m on convergence bar model 2
****COMBINED MECHANICAL/THERMAL AXIAL LOADING ANALYSIS****
mech_main.m || Using bar model provided in call
mech_main.m || Calculating Free Deformation...
mech_main.m || Done!
```

```
mech_main.m || Checking if there is a gap...
mech_main.m || Gap, problem may be statically determinate...
mech_main.m || Gap closed. Indeterminate
mech_main.m || Done!
mech_main.m || Calculating Reaction Return...
mech_main.m || Done!
****END OF ANALYSIS****

 Convergence Proved! Original Step Size Sufficient
```

Progam End

```
fprintf("\n<strong>## End of Progam</strong>\n");
```

```
<strong>## End of Progam</strong>
```

Program Workspace / Debug Station

A place to mess around with ideas if unsure where it will be placed organizationally. Ideally there should be nothing in this section once the file is complete.

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