Exam 2 Take-Home Portion

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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('\n Output for bar(%d) \n', i)
    disp(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(1)
    UncLoad: [0 600000 600000 900000]
    UncMDef: [0 1.1250e-03 1.8000e-03 2.7000e-03]
    UncTDef: [0 0 0 0]
     React0: -5.7692e+05
     React1: -3.2308e+05
    TotLoad: [-5.7692e+05 2.3077e+04 2.3077e+04 3.2308e+05]
     MecDef: [-1.0817e-03 4.3269e-05 6.9231e-05 9.6923e-04]
     TotDef: [-1.0817e-03 4.3269e-05 6.9231e-05 9.6923e-04]
```

```
     Stress: [-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(2)
    UncLoad: [0 600000 600000 900000]
    UncMDef: [0 1.1250e-03 1.8000e-03 2.7000e-03]
    UncTDef: [0 0 0 0]
     React0: -1.1538e+05
     React1: -7.8462e+05
    TotLoad: [-1.1538e+05 4.8462e+05 4.8462e+05 7.8462e+05]
     MecDef: [-2.1635e-04 9.0865e-04 1.4538e-03 2.3538e-03]
     TotDef: [-2.1635e-04 9.0865e-04 1.4538e-03 2.3538e-03]
     Stress: [-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(3)
    UncLoad: [0 0]
    UncMDef: [0 0]
    UncTDef: [-9.7500e-03 -9.7500e-03]
     React0: 1.8850e+04
     React1: -1.8850e+04
    TotLoad: [1.8850e+04 1.8850e+04]
     MecDef: [6.5000e-03 1.3000e-02]
     TotDef: [-3.2500e-03 3.2500e-03]
     Stress: [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(4)
    UncLoad: [0 600000 600000 900000]
    UncMDef: [0 1.1250e-03 1.8000e-03 2.7000e-03]
    UncTDef: [3.1590e-04 3.1590e-04 3.1590e-04 3.1590e-04]
     React0: -2.4498e+05
     React1: -6.5502e+05
    TotLoad: [-2.4498e+05 3.5502e+05 3.5502e+05 6.5502e+05]
     MecDef: [-4.5935e-04 6.6565e-04 1.0650e-03 1.9650e-03]
     TotDef: [-1.4345e-04 9.8155e-04 1.3809e-03 2.2809e-03]
     Stress: [-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(5)
    UncLoad: [0 50000 120000 260000]
    UncMDef: [0 3.6032e-05 1.0477e-04 2.5374e-04]
    UncTDef: [7.3150e-04 1.0450e-03 1.8408e-03 3.3984e-03]
     React0: -9.9330e+05
     React1: 7.3330e+05
    TotLoad: [-9.9330e+05 -9.4330e+05 -8.7330e+05 -7.3330e+05]
     MecDef: [-8.5782e-04 -6.7978e-04 -7.6246e-04 -7.1564e-04]
     TotDef: [-1.2632e-04 3.6522e-04 1.0783e-03 2.6828e-03]
     Stress: [-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(6)
    UncLoad: [0 170000 130000 180000 115000]
    UncMDef: [0 9.1224e-05 6.5000e-05 1.3576e-04 1.2151e-04]
    UncTDef: [-9.4050e-04 -6.6880e-04 -5.7330e-04 -7.0200e-04
 -8.2600e-04]
     React0: 8.3565e+05
     React1: -9.5065e+05
    TotLoad: [8.3565e+05 1.0056e+06 9.6565e+05 1.0156e+06 9.5065e+05]
     MecDef: [9.1759e-04 5.3964e-04 4.8282e-04 7.6605e-04 1.0045e-03]
     TotDef: [-2.2906e-05 -1.2916e-04 -9.0476e-05 6.4051e-05
 1.7848e-04]
     Stress: [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>");
```

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

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