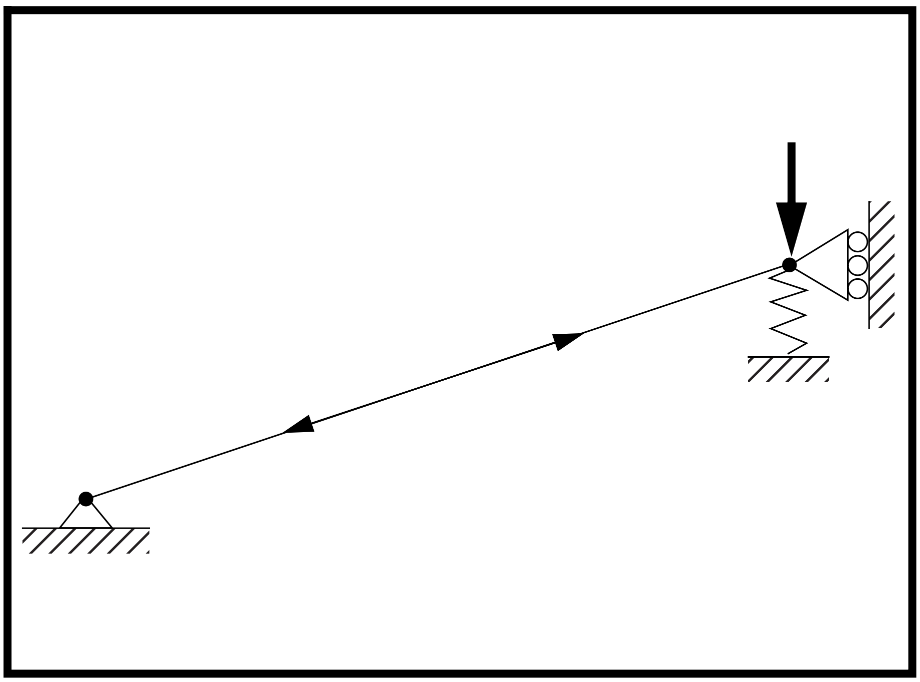
WORKSHOP PROBLEM 4b

Nonlinear Buckling Load Analysis (with spring)

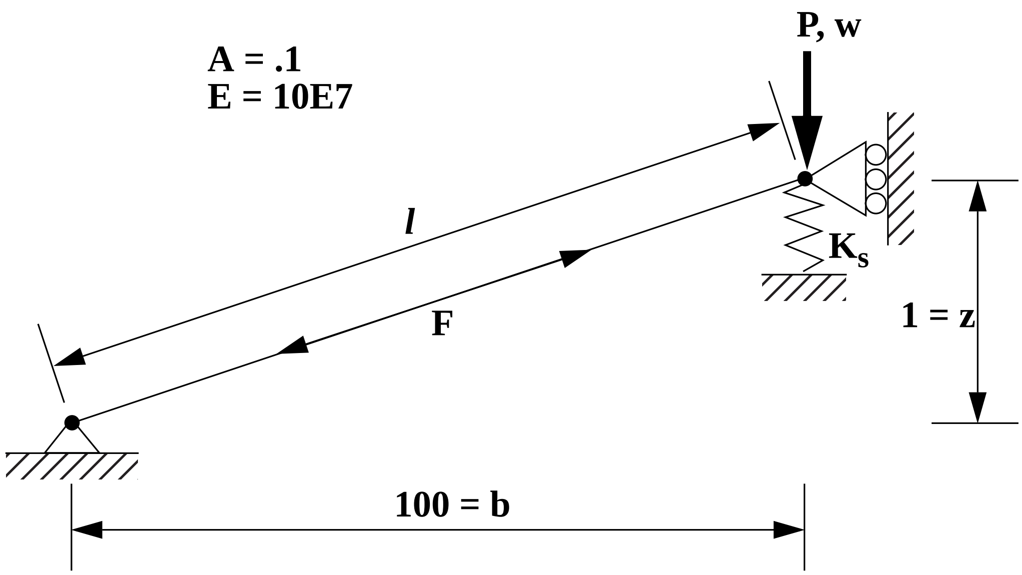


Objectives:

- Demonstrate the use of a nonlinear static analysis restarted with buckling parameters.

Model Description:

For the structure below:



Add Case Control commands and Bulk Data Entries to:

1. Calculate “snap-through” buckling load with K_s=0.

2. Optionally, you can adjust the input file for K_s=3, and K_s=6. Use different solution points to see the effect on the calculated buckling load.

Suggested Exercise Steps:

- Modify the existing MSC/NASTRAN input file by adding appropriate loading conditions and nonlinear static analysis control parameters.
- For Case Control, insert the static load set selection (LOAD) and the nonlinear static analysis parameter selection (NLPARM) in for each subcase.
- For Bulk Data, insert all the relevant nonlinear static analysis parameters for each subcase (NLPARM).
- Prepare the model for a nonlinear static analysis.
  - PARAM, LGDISP, 1
- Generate an input file and submit it to the MSC/NASTRAN solver for nonlinear static analysis.
- Review the results.
- Restart the analysis, adding in input the appropriate restart parameters (RESTART, LOOPID, SUBID).
- Add in the appropriate parameters for an eigenvalue extraction (METHOD, EIGRL) and buckling analysis.
  - PARAM, BUCKLE, 1
- Generate another input file and submit it to the MSC/NASTRAN solver for a nonlinear static (with buckling parameter) analysis.
- Review the results.

Input File from Workshop 4a for Modification:

prob4a.dat

```
ASSIGN OUTPUT2 = 'prob4a.op2' , UNIT=12
ID NAS103, WORKSHOP 4A SOLUTION
TIME 10
SOL 105
CEND
TITLE=SIMPLE ONE DOF GEOMETRIC NONLINEAR PROBLEM
LABEL=REF: STRICKLIN AND HAISLER; COMP. AND STRUCT.; 7:125-136 (1977)
ECHO=UNSORT
  DISP(SORT2)=ALL
SUBCASE 10
   LOAD=6
SUBCASE 20
   METHOD=30
BEGIN BULK
PARAM,POST,0
$
$ GEOMETRY
GRID, 1,  , 0., 0., 0.,  , 123456
GRID, 2,  , 100., 1., 0.,  , 13456
$
$ CONNECTIVITY
CROD, 10, 10, 1, 2
$CELAS1, 20, 20, 2, 2, 0, 0
$
$ PROPERTIES
$
PROD, 10, 1, .1
$PELAS, 20, 3.
MAT1, 1, 10.E7
$
$ LOADS
$
FORCE, 6, 2,  , -6., 0., 1., 0.
$
$ SOLUTION STRATEGY
$
EIGB, 30, INV, 0.0, 3.0, 20, 2, 2,  , +EIGB
+EIGB, MAX
ENDDATA
```

Exercise Procedure:

1. Users who are not utilitizing MSC/PATRAN for generating an input file should go to Step 6, otherwise, proceed to step 3.

2. Open the existing database called **prob4a.db**.

File/Open...

Database List:	**prob4a.db**

OK

Whenever possible click ❑ **Auto Execute** (turn off).

3. Create a grounded spring at the right end of the beam.

First, create a 0-D element to be used for spring constant assignment at the end of the beam.

◆ **Finite Elements**

Action:	**Create**
Object:	**Element**
Method:	**Edit**
Shape:	**Point**
Topology:	**Point**
Node 1 =	**Node 2**
	(Select the node on the right.)

Apply

Next, create the grounded spring property for the recently created element.

◆ **Properties**

Action:	**Create**
Dimension:	**0D**
Type:	**Grounded Spring**
Property Set Name	**spring**

Input Properties...

Spring Constant	**0**
Dof at Node 1	**UY**

OK

Click in the Select Members databox. Click on the point element entity select icon to select the point element.

Point Element

Select Members	**Elm 2**
	(Select the point element previously created.)

Add

Apply

4. Now you are ready to generate an input file for the analysis.

Click on the **Analysis** radio button on the Top Menu Bar and set up the subcases as follows:

◆ **Analysis**

Action:	**Analyze**
Object:	**Entire Model**
Method:	**Analysis Deck**
Job Name	**prob4b_1**

Solution Type...

Solution Type:	◆ **NONLINEAR STATIC**

OK

Subcase Create...

Subcase Name	**nonlin,k=0**

Output Requests...

Form Type:	**Advanced**
Output Requests	*(Deselect all except **DISPL...**)*

Delete

Output Requests **DISPLACEMENT**

Sorting: **By Freq/Time**

Modify

Intermediate Output Option: **Yes**

OK

Apply

Cancel

Subcase Select...

Subcases for Solution Sequence **nonlin,k=0**

Subcases Selected *(Deselect **Default**.)*

OK

Apply

An input file called **prob4b_1.bdf** will be generated. This process of translating your model into an input file is called the Forward Translation. The Forward Translation is complete when the Heartbeat turns green. MSC/PATRAN users should now proceed to **Step 6**.

Generating an input file for MSC/NASTRAN Users:

5. MSC/NASTRAN users can generate an input file using the data from the Model Description. The result should be similar to the output below (**prob4b_1.dat**):

```
ASSIGN OUTPUT2 = 'prob4b_1.op2' , UNIT=12
ID NAS103, WORKSHOP 4A SOLUTION
TIME 10
SOL 106
CEND
TITLE=SIMPLE ONE DOF GEOMETRIC NONLINEAR PROBLEM
LABEL=REF: STRICKLIN AND HAISLER; COMP. AND STRUCT.; 7:125-136 (1977)
ECHO=UNSORT
  DISP(SORT2)=ALL
SUBCASE 10
   LOAD=6
   NLPARM=20
BEGIN BULK
PARAM,POST,0
PARAM,LGDISP,1
$
$ GEOMETRY
GRID, 1,  , 0., 0., 0.,  , 123456
GRID, 2,  , 100., 1., 0.,  , 13456
$
$ CONNECTIVITY
CROD, 10, 10, 1, 2
CELAS1, 20, 20, 2, 2, 0, 0
$
$ PROPERTIES
PROD, 10, 1, .1
PELAS, 20, 0.
MAT1, 1, 10.E7
$
$ LOADS
$
FORCE, 6, 2,  , -6., 0., 1., 0.
$
$ SOLUTION STRATEGY
$
NLPARM, 20, 10, , , , , , YES
ENDDATA
```

Submit the file for analysis:

6. Submit the input file to MSC/NASTRAN for analysis.

   6a. To submit the MSC/PATRAN **.bdf** file, find an available UNIX shell window. At the command prompt enter **nastran prob4b_1.bdf scr=no**. Monitor the analysis using the UNIX **ps** command.

   6b. To submit the MSC/NASTRAN **.dat** file, find an available UNIX shell window and at the command prompt enter **nastran prob4b_1.dat**. Monitor the analysis using the UNIX **ps** command.

7. When the analysis is completed, edit the **prob4b_1.f06** file and search for the word **FATAL**. If no matches exist, search for the word **WARNING**. Determine whether the existing WARNING messages indicate any modeling errors.

7a. While still editing **prob4b_1.f06**, search for the word:

D I S P L A C E (spaces are necessary).

What is the y-displacement of Node 2 at the end of the last step?

T2 = ____________________

Comparison of Results:

8. Compare the results obtained in the **.f06** file with the results on the following page:

0 SUBCASE 1

POINT-ID = 2

D I S P L A C E M E N T   V E C T O R

STEP	TYPE	T1	T2	T3	R1	R2	R3
1.000000E-01	G	0.0	-6.649350E-02	0.0	0.0	0.0	0.0
2.000000E-01	G	0.0	-1.535875E-01	0.0	0.0	0.0	0.0
3.000000E-01	G	0.0	-3.066659E-01	0.0	0.0	0.0	0.0
4.000000E-01	G	0.0	-2.185338E+00	0.0	0.0	0.0	0.0
5.000000E-01	G	0.0	-2.221229E+00	0.0	0.0	0.0	0.0
6.000000E-01	G	0.0	-2.254592E+00	0.0	0.0	0.0	0.0
7.000000E-01	G	0.0	-2.285845E+00	0.0	0.0	0.0	0.0
8.000000E-01	G	0.0	-2.315302E+00	0.0	0.0	0.0	0.0
9.000000E-01	G	0.0	-2.343210E+00	0.0	0.0	0.0	0.0
1.000000E+00	G	0.0	-2.369764E+00	0.0	0.0	0.0	0.0

9. **This ends the first part of the exercise for MSC/NASTRAN users and should proceed to step 13. MSC/PATRAN users should proceed to the next step.**

10. Proceed with the Reverse Translation process, that is, importing the **prob4b_1.op2** results file into MSC/PATRAN. To do this, return to the ***Analysis*** form and proceed as follows:

◆ **Analysis**

Action:	**Read Output2**
Object:	**Result Entities**
Method:	**Translate**
Select Results File...	
Selected Results File:	**prob4b_1.op2**
OK	
Apply	

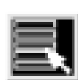
11. When the translation is complete bring up the **Results** form.

Now we will generate the fringe plot of the model.

◆ **Results**

Action:	**Create**
Object:	**Fringe**

Now click on the **Select Results** icon.

 **Select Results**

Select Result Case(s)	**Default, PW Linear: 100.% of Load**
Select Fringe Result	**Displacements, Translational**
Quantity:	**Magnitude**

Next click on the **Target Entities** icon.

 **Target Entities**

Target Entity: **Current Viewport**

Click on the **Display Attributes** icon.

 **Display Attributes**

Style: **Discrete/Smooth**

Display: **Free Edges**

For better visual quality of the fringe plot, change the width of the line.

Width: *(Select the third line from top.)*

Now click on the **Plot Options** icon.

 **Plot Options**

Coordinate Transformation: **None**

Scale Factor **1.0**

Apply

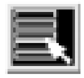
The resulting fringe plot should display the displacement spectrum superimposed over the undeformed bar. The final fringe plot displaying the physical deformation of the model can be created as follows:

◆ **Results**

Action: **Create**

Object: **Deformation**

Now click on the **Select Results** icon.

 **Select Results**

Select Result Case(s)	**Default, PW Linear: 100.% of Load**
Select Fringe Result	**Displacements, Translational**
Show As:	**Resultant**

Click on the **Display Attributes** icon.

 **Display Attributes**

Line Width:	*(Select the third line from top.)*

In order to see the deformation results accurately, set the Scale Interpretation to True Scale with a Scale Factor of 1.

Scale Interpretation	◆ *True Scale*
Scale Factor	**1.0**
■ *Show Undeformed*	
Line Width:	*(Select the third line from top.)*

Now click on the **Plot Options** icon.

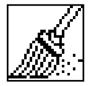
 **Plot Options**

Coordinate Transformation:	**None**
Scale Factor	**1.0**

Apply

Now that you have seen the fringe plot of the results of the nonlinear static analysis, reset the graphics and prepare to run a restart to obtain the eigenvalues of the loaded model.

To clear the post-processing results and obtain the original model in the viewport, select the **Reset Graphics** icon.

 **Reset Graphics**

12. Prepare an analysis restart with buckling parameters.

Click on the **Analysis** radio button on the Top Menu Bar and set up the subcases as follows:

◆ **Analysis**

Action:	**Analyze**
Object:	**Restart**
Method:	**Analysis Deck**
Select An Initial Job:	**prob4b_1**
Restart Job Name:	**prob4b_1b**
Subcase Create...	
Subcase Name:	**buck,k=0**
Subcase Parameters...	
Num of Load Increments =	**70**
Matrix Update Method:	**Controlled Iters.**
Num of Iters per Update =	**1**
OK	
Apply	
Cancel	
Subcase Select...	
Subcases for Solution Sequence:	**buck,k=0**
Subcases Selected should appear as:	**nonlin,k=0** **buck,k=0**
OK	
Restart Parameters...	
Start from Version Number =	**1**
Start from Increment Number (LOOPID) =	**3**

Start from Subcase Number (SUBID+1) = **2**

■ **Save Old Restart Data**

OK

Apply

An input file called **prob4b_1b.bdf** will be generated. At this time, MSC/PATRAN does not allow for Direct Text input on a restart. What you will need to do is to modify the input file using a text editor.

13. Modify **prob4b_1b.bdf** using a text editor to allow for an eigenvalue analysis within a nonlinear static restart.

Below **PARAM, SUBID, 2** add the following:

METHOD = 30

Below **BEGIN BULK** add the following:

PARAM, BUCKLE, 1

Below the second **NLPARM** entry, add the following:

EIGRL, 30, 0.0, 3.0, 20

Save the file, and proceed to **Step 14**.

Generating an input file for MSC/NASTRAN Users:

14. MSC/NASTRAN users need to generate a restart input file. The result should be similar to the output below (**prob4b_1b.dat**):

```
ASSIGN OUTPUT2 = ‘prob4b_1b.op2’ , UNIT=12
ASSIGN MASTER=’prob4b_1.MASTER’
RESTART VERSION=1,KEEP
ID NAS103, WORKSHOP 4A SOLUTION
TIME 10
SOL 106
CEND
TITLE=SIMPLE ONE DOF GEOMETRIC NONLINEAR PROBLEM
LABEL=REF: STRICKLIN AND HAISLER; COMP. AND STRUCT.; 7:125-136 (1977)
PARAM,LOOPID,3
PARAM,SUBID,2
METHOD=30
ECHO=UNSORT
 DISP(SORT2)=ALL
SUBCASE 10
  LOAD=6
  NLPARM=20
SUBCASE 11
  LOAD=6
  NLPARM=21
BEGIN BULK
PARAM,BUCKLE,1
$
NLPARM, 21, 70, , ITER, 1, , , YES
EIGRL, 30, 0.0, 3.0, 20
ENDDATA
```

Submit the input file for analysis:

15. Submit the input file to MSC/NASTRAN for analysis.

    15a. To submit the MSC/PATRAN **.bdf** file, find an available UNIX shell window. At the command prompt enter **nastran prob4b_1b.bdf**. Monitor the analysis using the UNIX **ps** command.

    15b. To submit the MSC/NASTRAN **.dat** file, find an available UNIX shell window and at the command prompt enter **nastran prob4b_1b.dat**. Monitor the analysis using the UNIX **ps** command.

16. When the analysis is completed, edit the **prob4b_1b.f06** file and search for the word **FATAL**. If no matches exist, search for the word **WARNING**. Determine whether existing WARNING messages indicate any modeling errors.

16a. While still editing **prob4b_1b.f06**, search for the word:

R E A L E I G E N V A L U E S (spaces are necessary).

What is the first eigenvalue obtained from the analysis?

EIG = ____________________

What is the critical buckling load (eigenvalue * applied load)?

P_{cr} = ____________________

While still editing **prob4b_1b.f06**, search for the word:

D I S P L A C E M E N T S (spaces are necessary).

What is the y-displacement of Node 2?

T2 = ____________________

Comparison of Results:

17. Compare the results obtained in the **.f06** file with the results on the following page:

0 SUBCASE 2

R E A L   E I G E N V A L U E S

MODE NO.	EXTRACTION ORDER	EIGENVALUE	RADIANS	CYCLES	GENERALIZED MASS	GENERALIZED STIFFNESS
1	1	3.338991E-01	5.778400E-01	9.196609E-02	1.172280E+00	3.914231E-01

0 SUBCASE 2

D I S P L A C E M E N T   V E C T O R

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
1	G	0.0	0.0	0.0	0.0	0.0	0.0
2	G	0.0	-4.211797E-01	0.0	0.0	0.0	0.0

-

18. This ends the exercise for MSC/NASTRAN users. MSC/PATRAN users should proceed to the next step.

19. Proceed with the Reverse Translation process, that is, importing the **prob4b_1b.op2** results file into MSC/PATRAN. To do this, return to the **Analysis** form and proceed as follows:

◆ **Analysis**

Action:	**Read Output2**
Object:	**Result Entities**
Method:	**Translate**
Select Results File...	
Selected Results File:	**prob4b_1b.op2**
OK	
Apply	

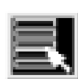
20. When the translation is complete bring up the **Results** form.

Now we will generate the fringe plot of the model.

◆ **Results**

Action:	**Create**
Object:	**Fringe**

Now click on the **Select Results** icon.



Select Results

Select Result Case(s)	*(Select the last case.)*
Select Fringe Result	**Displacements, Translational**
Quantity:	**Magnitude**

Next click on the **Target Entities** icon.

 **Target Entities**

Target Entity: **Current Viewport**

Note: This feature allows you to view fringe plots of specific elements of your choice.

Click on the **Display Attributes** icon.

 **Display Attributes**

Style: **Discrete/Smooth**

Display: **Free Edges**

For better visual quality of the fringe plot, change the width of the line.

Width: *(Select the third line from top.)*

Now click on the **Plot Options** icon.

 **Plot Options**

Coordinate Transformation: **None**

Scale Factor **1.0**

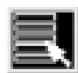
Apply

The resulting fringe plot should display the displacement spectrum superimposed over the undeformed bar. The final fringe plot displaying the physical deformation of the model can be created as follows:

◆ **Results**

Action:	**Create**
Object:	**Deformation**

Now click on the **Select Results** icon.

 **Select Results**

Select Result Case(s)	*(Select the last case.)*
Select Fringe Result	**Displacements, Translational**
Show As:	**Resultant**

Click on the **Display Attributes** icon.

 **Display Attributes**

In order to see the deformation results accurately, set the Scale Interpretation to True Scale with a Scale Factor of 1.

Scale Interpretation	◆ *True Scale*
Scale Factor	**1.0**
■ *Show Undeformed*	
Line Width:	*(Select the third line from top.)*

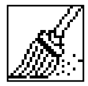
Now click on the **Plot Options** icon.

 **Plot Options**

Coordinate Transformation:	**None**
Scale Factor	**1.0**

Apply

To clear the post-processing results and obtain the original model In the viewport, select the **Reset Graphics** icon.



Reset Graphics

If you wish, you may adjust the spring constant and repeat the previous exercise to see the effect.

Quit MSC/PATRAN when you have completed this exercise.

MSC/PATRAN .bdf file: prob4b_1.bdf

```
$ NASTRAN input file created by the MSC MSC/NASTRAN input file
$ translator ( MSC/PATRAN Version 7.5 ) on January   15, 1998 at
$ 14:19:44.
ASSIGN OUTPUT2 = 'prob4b_1.op2', UNIT = 12
$ Direct Text Input for File Management Section
$ Nonlinear Static Analysis, Database
SOL 106
TIME 600
$ Direct Text Input for Executive Control
CEND
SEALL = ALL
SUPER = ALL
TITLE = MSC/NASTRAN job created on 15-Jan-98 at 14:11:15
ECHO = NONE
MAXLINES = 999999999
$ Direct Text Input for Global Case Control Data
SUBCASE 1
$ Subcase name : nonlin,k=0
  SUBTITLE=Default
  NLPARM = 1
  SPC = 2
  LOAD = 2
  DISPLACEMENT(SORT2,REAL)=ALL
$ Direct Text Input for this Subcase
BEGIN BULK
PARAM    POST    -1
PARAM    PATVER  3.
PARAM    AUTOSPC YES
PARAM   COUPMASS -1
PARAM    K6ROT   100.
PARAM    WTMASS  1.
PARAM    LGDISP  1
PARAM,NOCOMPS,-1
PARAM   PRTMAXIM YES
NLPARM   1       10              AUTO    5       25      PW      YES     +       A
+       A       .001    1.-7
$ Direct Text Input for Bulk Data
$ Elements and Element Properties for region : beam
PROD     1       1       .1
CROD     1       1       1       2
$ Elements and Element Properties for region : spring
PELAS    2       0.
CELAS1   2       2       2       2
$ Referenced Material Records
```

```
$ Material Record : mat_1
$ Description of Material : Date: 11-Jun-97         Time: 11:15:21
MAT1     1       1.+8
$ Nodes of the Entire Model
GRID     1               0.      0.      0.
GRID     2               100.    1.      0.
$ Loads for Load Case : Default
SPCADD   2       1       3
LOAD     2       1.      1.      1
$ Displacement Constraints of Load Set : constraint_1
SPC1     1       123456  1
$ Displacement Constraints of Load Set : constraint_2
SPC1     3       13456   2
$ Nodal Forces of Load Set : load_1
FORCE    1       2       0       6.      0.      -1.     0.
$ Referenced Coordinate Frames
ENDDATA 8f96f867
```

MSC/PATRAN .bdf file: prob4b_1b.bdf

```
$ NASTRAN input file created by the MSC MSC/NASTRAN input file
$ translator ( MSC/PATRAN Version 7.5 ) on January   15, 1998 at
$ 21:38:10.
ASSIGN OUTPUT2 = ‘prob4b_1b.op2’, UNIT = 12
$ Direct Text Input for File Management Section
ASSIGN MASTER=’prob4b_1.MASTER’
RESTART VERSION=LAST,KEEP
$ Nonlinear Static Analysis, Database
SOL 106
TIME 600
$ Direct Text Input for Executive Control
CEND
SEALL = ALL
SUPER = ALL
TITLE = MSC/NASTRAN job created on 15-Jan-98 at 21:38:06
PARAM,LOOPID,3
PARAM,SUBID,2
METHOD = 30
ECHO = NONE
MAXLINES = 999999999
$ Direct Text Input for Global Case Control Data
SUBCASE 1
$ Subcase name : nonlin,k=0
  SUBTITLE=Default
  NLPARM = 1
  SPC = 2
  LOAD = 2
  DISPLACEMENT(SORT2,REAL)=ALL
$ Direct Text Input for this Subcase
SUBCASE 2
$ Subcase name : buck,k=0
  SUBTITLE=Default
  NLPARM = 2
  SPC = 2
  LOAD = 4
  DISPLACEMENT(SORT2,REAL)=ALL
$ Direct Text Input for this Subcase
BEGIN BULK
/,1,999999
PARAM, BUCKLE, 1
PARAM    POST    -1
PARAM    PATVER  3.
PARAM    AUTOSPC YES
PARAM   COUPMASS -1
```

```
PARAM    K6ROT   100.
PARAM    WTMASS  1.
PARAM    LGDISP  1
PARAM,NOCOMPS,-1
PARAM   PRTMAXIM YES
NLPARM   1      10            AUTO    5      25     PW     YES    +     A
+      A        .001    1.-7
NLPARM   2      70            ITER    1      25     PW     YES    +     B
+      B        .001    1.-7
EIGRL, 30, 0., 3., 20
$ Direct Text Input for Bulk Data
$ Elements and Element Properties for region : beam
PROD     1       1       .1
CROD     1       1       1       2
$ Elements and Element Properties for region : spring
PELAS    2       0.
CELAS1   2       2       2       2
$ Referenced Material Records
$ Material Record : mat_1
$ Description of Material : Date: 11-Jun-97          Time: 11:15:21
MAT1     1       1.+8
$ Nodes of the Entire Model
GRID     1               0.      0.      0.
GRID     2               100.    1.      0.
$ Loads for Load Case : Default
SPCADD   2       4       6
LOAD     2       1.      1.      3
$ Loads for Load Case : Default
LOAD     4       1.      1.      3
$ Displacement Constraints of Load Set : constraint_1
SPC1     4       123456  1
$ Displacement Constraints of Load Set : constraint_2
SPC1     6       13456   2
$ Nodal Forces of Load Set : load_1
FORCE    3       2       0       6.      0.      -1.     0.
$ Referenced Coordinate Frames
ENDDATA 743d3acf
```