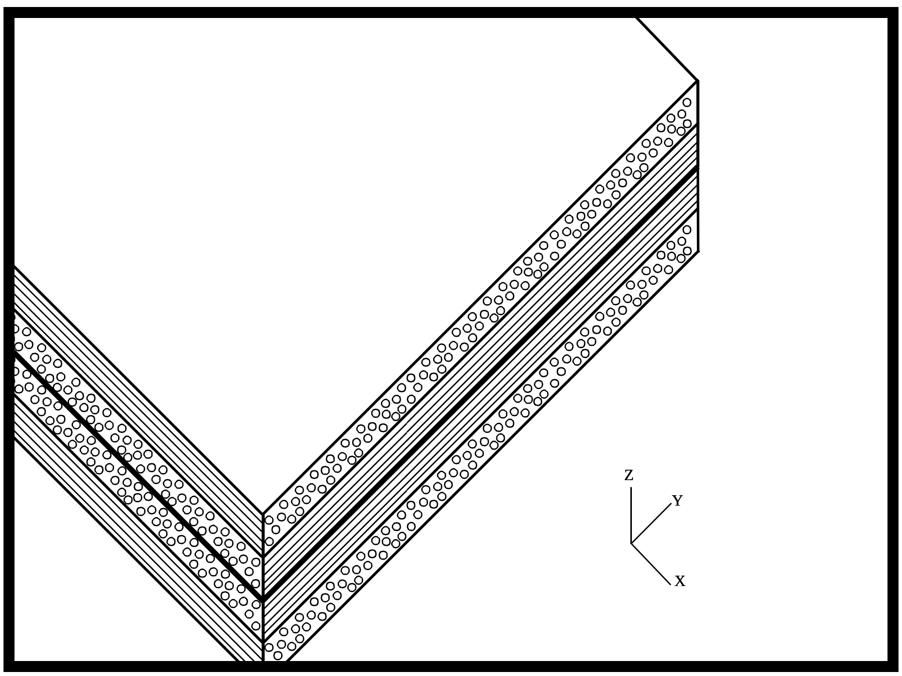
WORKSHOP PROBLEM 1b

LAYUP TYPES: Symmetric, Unsymmetric, Balanced, Unbalanced



Objectives:

- Change stacking sequence of lamina to different layups.
- Create a MSC/NASTRAN input file directly or by using MSC/PATRAN.
- Run the analysis using MSC/NASTRAN.
- Review results.

Uniaxial Loading - Part II

Model Description:

Use the Patran database from **problem 1a**.

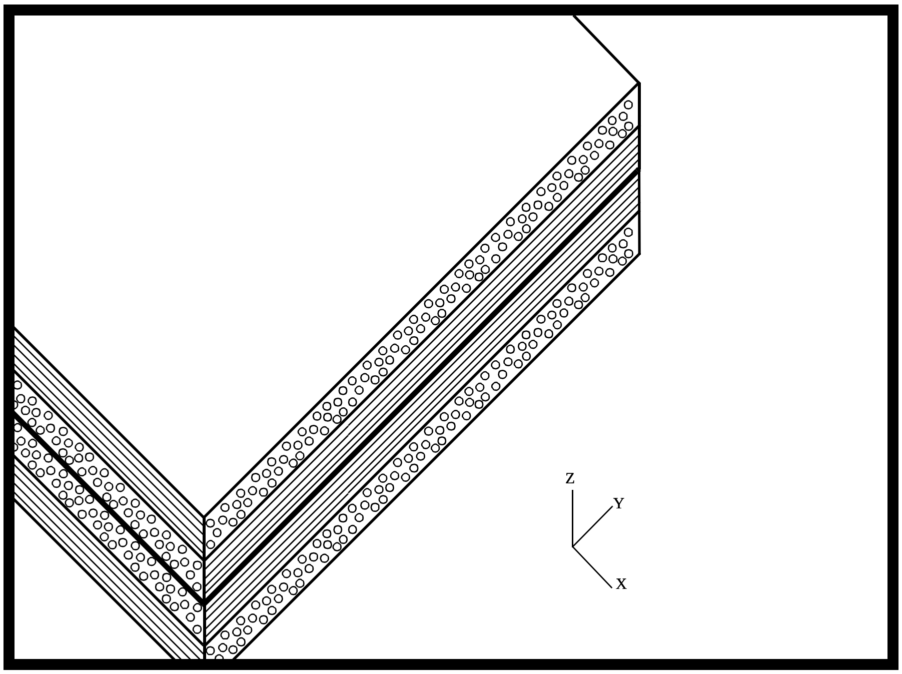
Suggested Exercise Steps:

- Read problem.
- Open Problem 1a database.
- Look at composite properties.
- Change the layup.
- Look at new composite properties.
- Prepare the model for a linear static analysis (SOL 101).
- Submit it for a linear static analysis.
- Review results.

Exercise Procedure:

The figure below shows a 4-ply composite that is symmetric about a neutral axis.

Figure 1b-1:



1. Open database **prob1a.db**.

File/New...

Existing Database Name:	**prob1a**
OK	

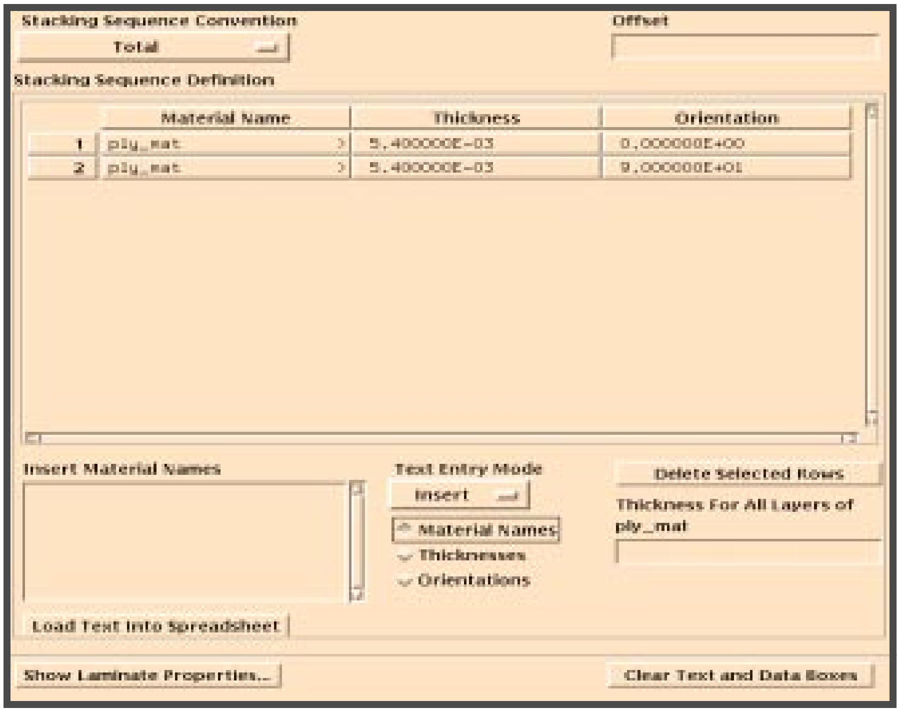
2. Look at the "unsymmetric" properties.

◆ **Materials**

Action:	**Modify**
Object:	**Composite**
Method:	**Laminate**
Laminated Composites:	**composite1**

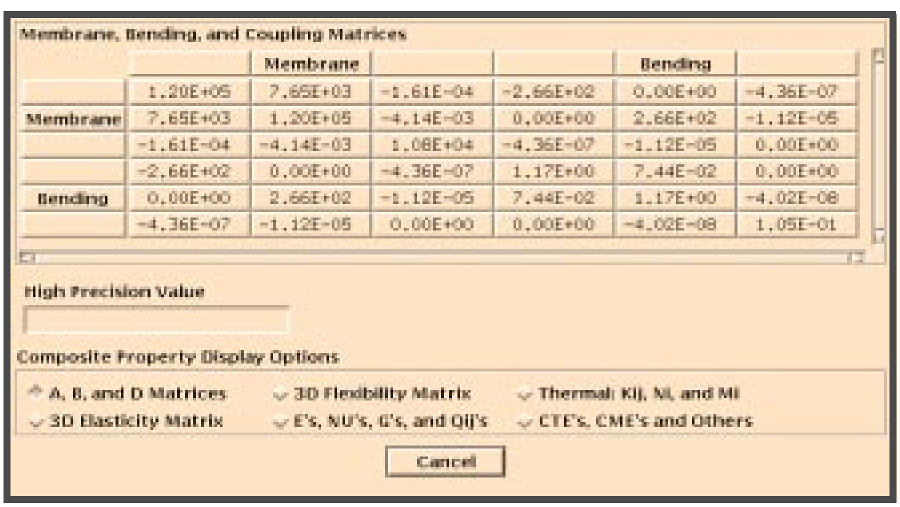
The **Laminated Composite** form should look like the following:

Fig 1b-2: The original layup.



Show Laminate Properties...

Fig 1b-3: A, B, and D Matrices.

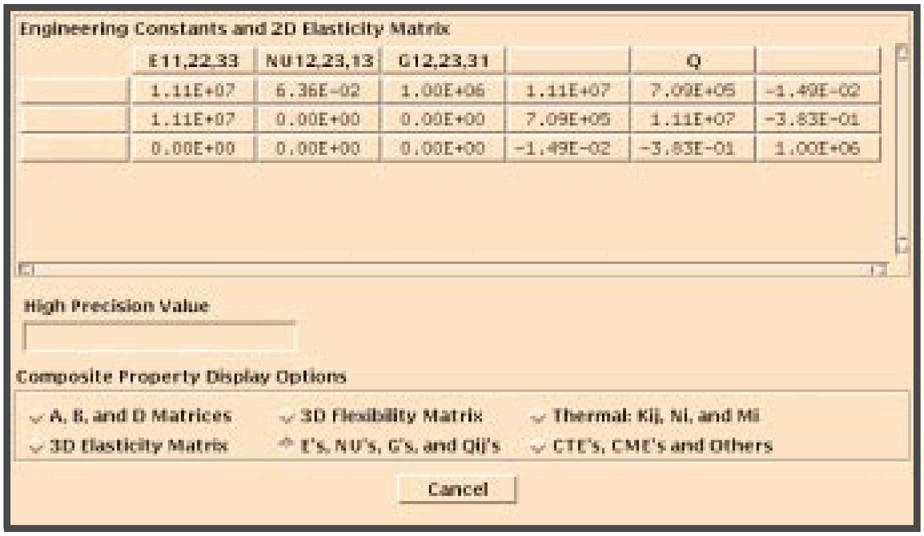


		Membrane			Bending	
	1.20E+05	7.65E+03	-1.61E-04	-2.66E+02	0.00E+00	-4.36E-07
Membrane	7.65E+03	1.20E+05	-4.14E-03	0.00E+00	2.66E+02	-1.12E-05
	-1.61E-04	-4.14E-03	1.08E+04	-4.36E-07	-1.12E-05	0.00E+00
	-2.66E+02	0.00E+00	-4.36E-07	1.17E+00	7.44E-02	0.00E+00
Bending	0.00E+00	2.66E+02	-1.12E-05	7.44E-02	1.17E+00	-4.02E-08
	-4.36E-07	-1.12E-05	0.00E+00	0.00E+00	-4.02E-08	1.05E-01

Note that the populated “B matrix” means that the model will bow in the presence of axial loads. (***B matrix***: Membrane/Bending 3x3 matrix in the *upper right corner* of 6x6 matrix above)

Composite Property Display Options: ◆ **E's, NU's, G's, and Qij's**

Fig 1b-4: E's, NU's, G's, and Qij's.



Cancel

3. Now, modify our composite material to "symmetric".

   Add material layers to the composite: (1) Under *Material Name* in the *Laminated Composite* form, click the second cell. (2) Click on **ply_mat** in the "*Existing Materials*" databox twice.

   Add layer thicknesses: (1) Click "*Thickness For All Layers of...*" databox in the *Laminated Composite* form, (2) type **.0054**, and (3) hit **Enter**.

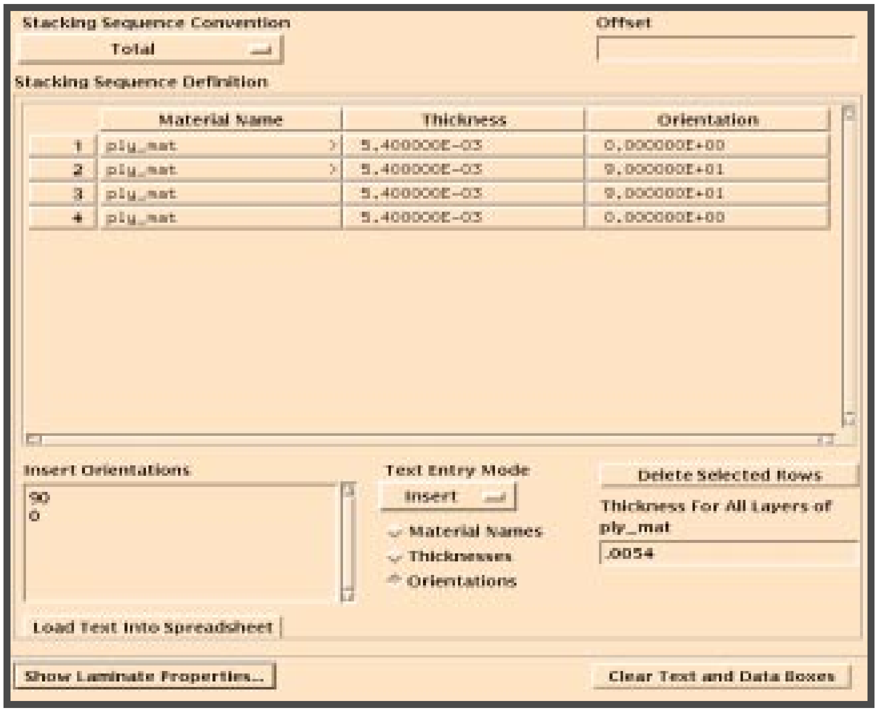
   Add layer orientations: (1) Under *Orientation*, click cell on the third row. (2) Click *Overwrite Orientations* databox, (3) type **90**, **Enter**, and **0, Enter**. Then:

Load Text Into Spreadsheet

Apply

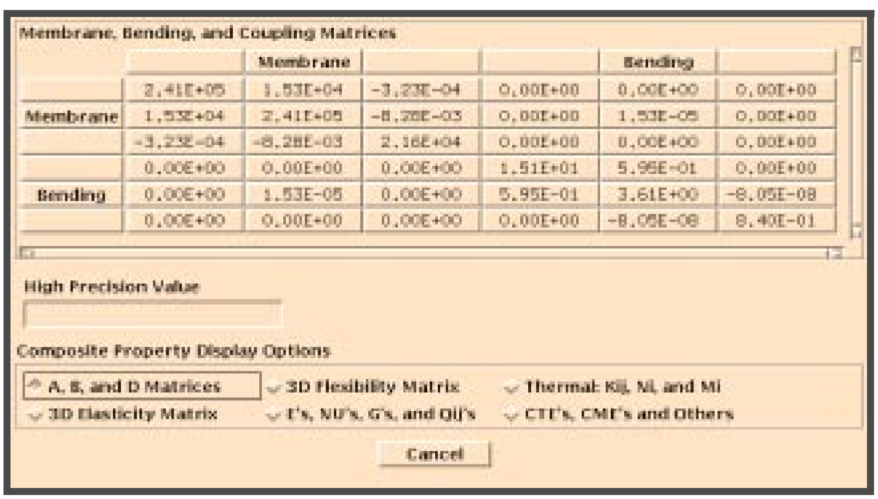
The modified **Laminated Composite** form should look like the following:

Fig 1b-5: Modified layup.



Show Laminate Properties...

Fig 1b-6: Modified A, B, and D Matrices.



Note that the B matrix is null for "symmetric" layup. This means no bowing from in-plane loads.

Composite Property Display Options:	◆ **E's, NU's, G's, and Qij's**

In the modified composite, notice that the "lumped" properties (E's, NU's, G's, and Qij's) remain the same as those shown in **Fig 1b-4**.

Cancel

◆ **Results**

Action:	**Delete**
Object:	**Result Cases**
Existing Result Cases:	**Default, Static Subcase**

4. Submit model for linear static analysis.

◆ **Analysis**

Action:	**Delete**
Object:	**Job**
Existing Jobs:	**prob1a**

Apply

Action:	**Analyze**
Object:	**Entire Model**
Method:	**Analysis Deck**
Job Name:	**prob1b**

Apply

An MSC/NASTRAN input file called **prob1b.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.

Generating an input file for MSC/NASTRAN Users:

5. The generated input file (prob1b.bdf) should be similar to the following:

(Type “**more prob1b.bdf**” at UNIX shell window to compare.)

```
$ NASTRAN input file created by the MSC MSC/NASTRAN input file
$ translator (  MSC/PATRAN Version 7.5 ) on January   22, 1998 at
$ 16:49:00.
ASSIGN OUTPUT2 = 'prob1b.op2', UNIT = 12
$ Direct Text Input for File Management Section
$ Linear Static Analysis, Database
SOL 101
TIME 600
$ Direct Text Input for Executive Control
CEND
SEALL = ALL
SUPER = ALL
TITLE = MSC/NASTRAN job created on 22-Jan-98 at 16:48:29
ECHO = NONE
MAXLINES = 999999999
$ Direct Text Input for Global Case Control Data
SUBCASE 1
$ Subcase name : Default
   SUBTITLE=Default
   SPC = 2
   LOAD = 2
   DISPLACEMENT(SORT1,REAL)=ALL
   SPCFORCES(SORT1,REAL)=ALL
   STRESS(SORT1,REAL,VONMISES,BILIN)=ALL
BEGIN BULK
PARAM    POST    -1
PARAM    PATVER  3.
PARAM    AUTOSPC YES
PARAM    INREL   0
PARAM    ALTRED  NO
PARAM   COUPMASS -1
PARAM    K6ROT   0.
PARAM    WTMASS  1.
PARAM,NOCOMPS,-1
PARAM   PRTMAXIM YES
$ Direct Text Input for Bulk Data
$ Elements and Element Properties for region : plate
$ Composite Property Record created from P3/PATRAN composite material
$ record : composite1
$ Composite Material Description :
PCOMP    1                                   0.     0.            +
A
+      A 1      .0054   0.     YES     1      .0054   90.    YES    +
B
+      B 1      .0054   90.    YES     1      .0054   0.     YES
CQUAD4   1       1       1       2       5       4       1
CQUAD4   2       1       2       3       6       5       1
CQUAD4   3       1       4       5       8       7       1
```

```
CQUAD4   4       1       5       6       9       8       1
$ Referenced Material Records
$ Material Record : ply_mat
$ Description of Material : Date: 15-Jan-98          Time: 17:40:54
MAT8     1       2.+7    2.+6    .35     1.+6
$ Nodes of the Entire Model
GRID     1               0.      0.      0.
GRID     2               .5      0.      0.
GRID     3               1.      0.      0.
GRID     4               0.      .5      0.
GRID     5               .5      .5      0.
GRID     6               1.      .5      0.
GRID     7               0.      1.      0.
GRID     8               .5      1.      0.
GRID     9               1.      1.      0.
$ Loads for Load Case : Default
SPCADD   2       1       3
LOAD     2       1.      1.      1
$ Displacement Constraints of Load Set : simple_constraint
SPC1     1       135     1       4       7
$ Displacement Constraints of Load Set : y_constraint
SPC1     3       2       1
$ Distributed Loads of Load Set : uniform_load
FORCE    1       3               3.75    1.      0.      0.
FORCE    1       6               3.75    1.      0.      0.
FORCE    1       6               3.75    1.      0.      0.
FORCE    1       9               3.75    1.      0.      0.
$ Referenced Coordinate Frames
CORD2R   1               0.      0.      0.      0.      0.      1.
+      C
+      C 0.      1.      0.
ENDDATA b2449674
```

SUBMITTING THE INPUT FILE FOR MSC/NASTRAN and MSC/PATRAN USERS:

6. Submit the input file to MSC/NASTRAN for analysis by finding an available UNIX shell window. At the command prompt enter **nastran prob1b.bdf scr=yes**. Monitor the run using the UNIX **ps** command.

7. Proceed with the Reverse Translation process, that is, importing the **prob1b.op2** results file into MSC/PATRAN. To do this, return to the **Analysis** form and proceed as follows:

◆ **Analysis**

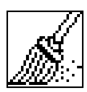
Action:	**Read Output 2**
Object:	**Result Entities**
Method:	**Translate**

Select Results File...

Selected Results File	**prob1b.op2**

Apply

Before postprocessing the results, clear the LBC markers from the screen by selecting the following main menu icon:



Reset Graphics

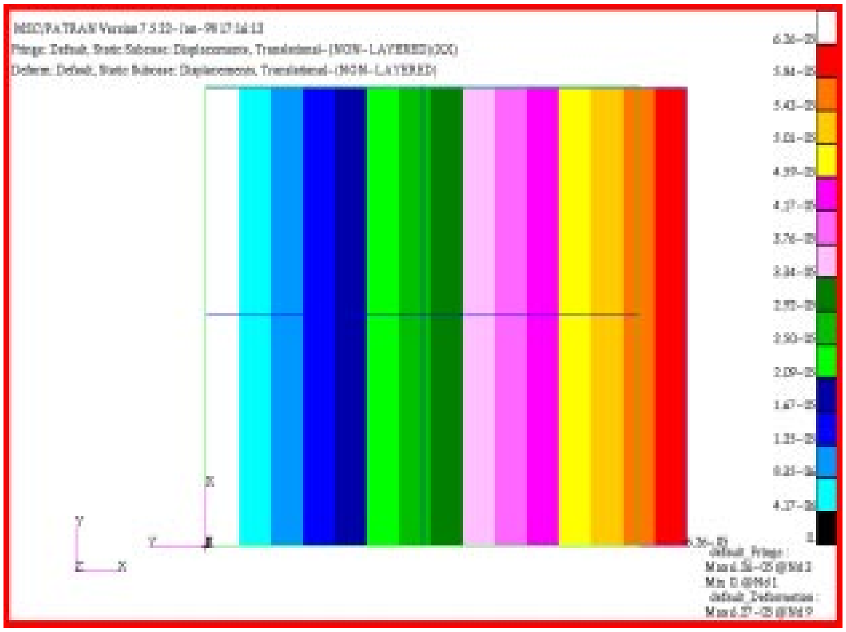
8. When the translation is complete and the Heartbeat turns green, bring up the **Results** form.

◆ **Results**

Action:	**Create**
Object:	**Quick Plot**
Select Result Cases:	**Default, Static Subcase**
Select Fringe Result:	**Displacements,Translational**
Result Quantity:	**X Component**
Select Deformation Result:	**Displacements,Translational**

Apply

Figure 1b-7: Fringe plot of X Displacement.



Using the formula $x = F/k$, where $k = AE/l$ and E is E_{11} from **Fig 1b-4**, notice that the maximum displacement of 0.0000626 equals:

$$x = \frac{15 lbf}{\left(\frac{0.0216 in^2 \cdot (1.1 \times 10^7 lbf/in^2)}{1 in}\right)}$$

Result Quantity: **Z Component**

Apply

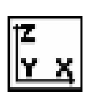
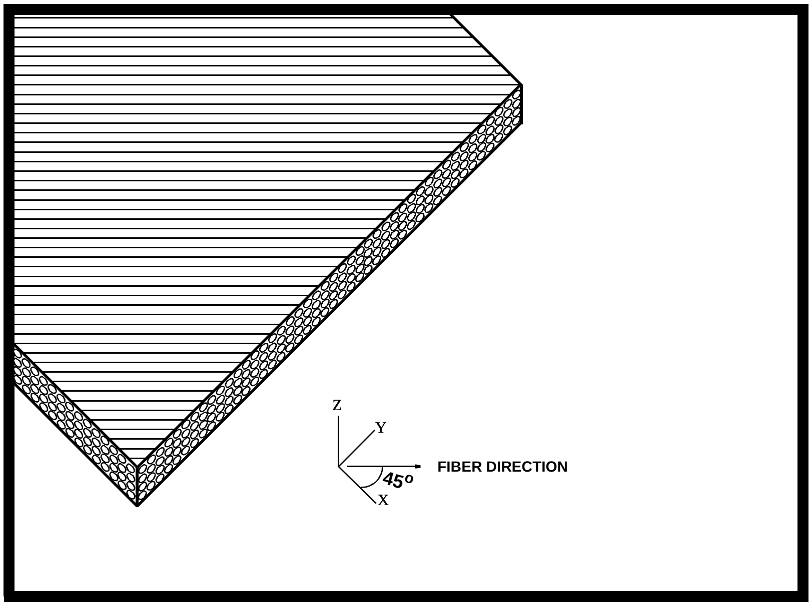
Bottom View:  **Bottom View**

Figure 1b-8: Fringe plot of Z Displacement.

Notice that there is no z-displacement in the model. This is because the model is now symmetrically layered, and the material orientation does not cause a bowing effect due to varying moduli on either side of the composite centerline. This can also be seen in the composite constituative matrices by the null B matrix (**in Fig 1b-6**).

UNBALANCED

Figure 1b-8: An unbalanced layup.



A *balanced layup* is where there is an equal number of positive angled plies as negative angled plies. As can be seen in the above figure, this layup is *unbalanced* because there is only a positive angled ply, and no negative angled ones.

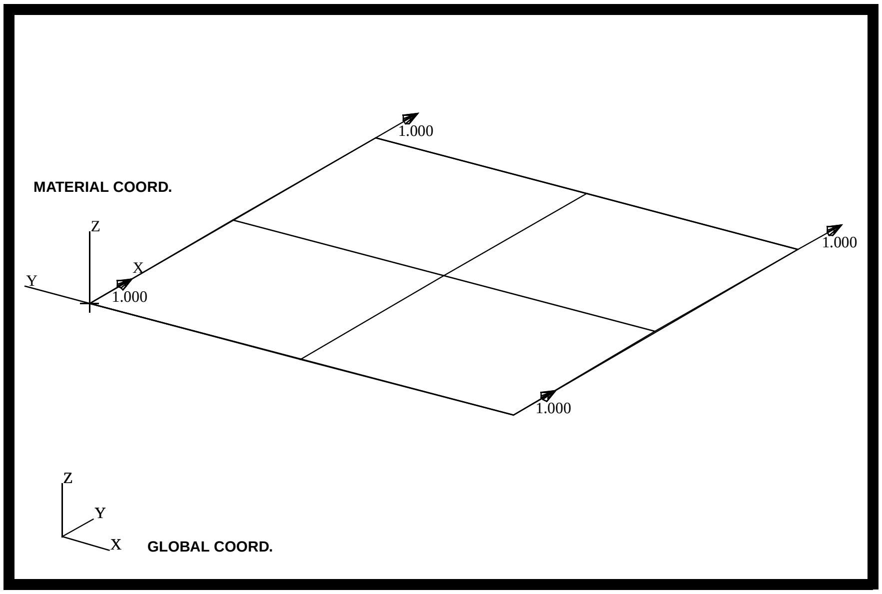
The *ply-orientation angle* is the angle measured from X_m (x-axis of the material coordinate system) to the 1 direction of the ply coordinate system (ply fiber direction).

In order to properly model the fiber direction shown in the above figure, the proper sign of the ply-orientation angle must be determined.

Nastran defines the “positive” ply-orientation angle following the “right hand rule” around Z_m. In other words, the positive angular direction is the angular direction going from the X_m to the Y_m axis rotating about the Z_m axis.

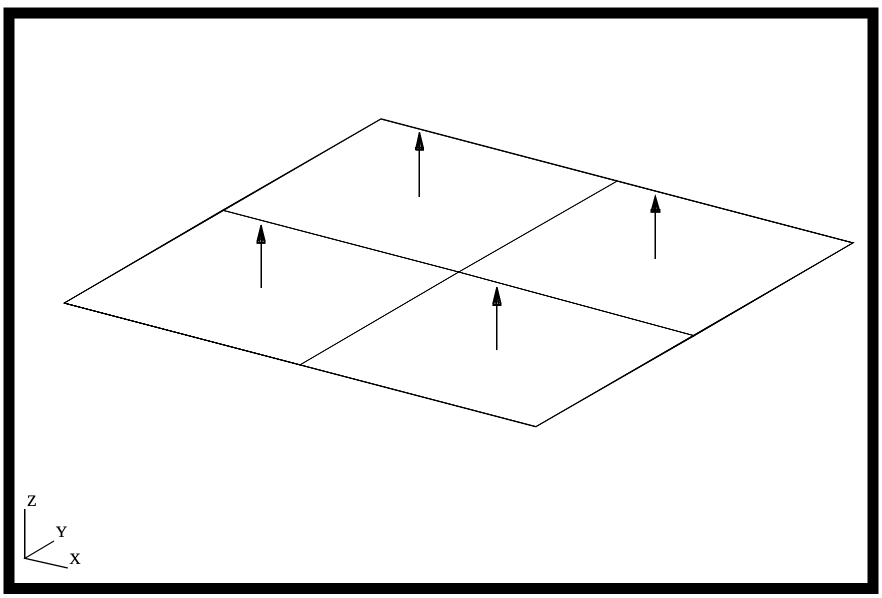
Patran shows the X_m direction as the 1.000 direction in Figure 1b-9 below:

Figure 1b-9: Material coordinate system shown.



Patran shows the Z_m axis as element normals in Fig 1b-10 below:

Figure 1b-10: Normal vectors displayed.



We saw in Figure 1b-8 that the fiber direction is **+45 degrees** from the x-axis of the global coordinate system. But the *ply-orientation angle* is defined in the material coordinate system which is offset by +90 degrees from the global system (shown in Figure 1b-9). Thus the proper ply-orientation angle is **-45 degrees** (in the material coordinate system).

9. Modify layup to “single-ply” with orientation angle of **-45^{o}**.

◆ **Materials**

Action:	**Modify**
Object:	**Composite**
Method:	**Laminate**
Laminated Composites:	**composite1**

Delete existing layers: In the *Laminated Composite* form, delete all layers using **Delete Selected Rows**.

Add material layers to the composite: Click on **ply_mat** in the “*Existing Materials”* databox once.

Add layer thicknesses: (1) Click “*Thickness For All Layers of...”* databox in the *Laminated Composite* form, (2) type **.0054**, and (3) hit **Enter**.

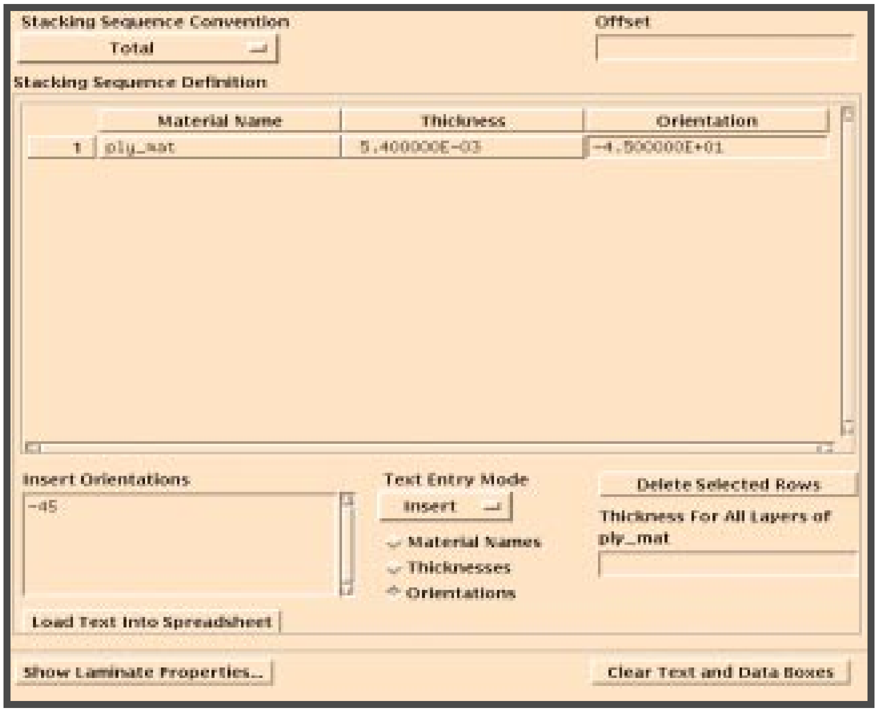
Add layer orientations: (1) Under *Orientation*, click cell. (2) Click *Overwrite Orientations* databox, (3) delete previous data, (4) type **-45**, **Enter**. Then:

Load Text Into Spreadsheet

Apply

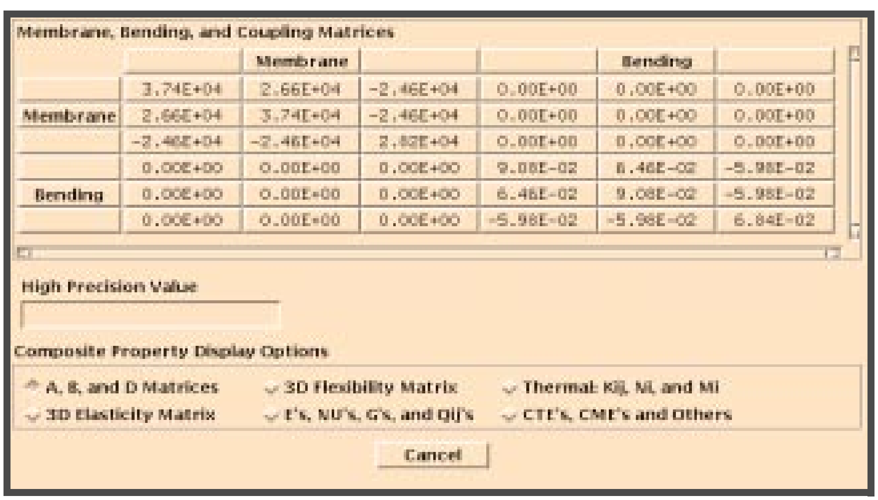
The modified **Laminated Composite** form should look like the following:

Figure 1b-11: Single-ply layup.



Show Laminate Properties...

Fig 1b-12: Modified A, B, and D Matrices.

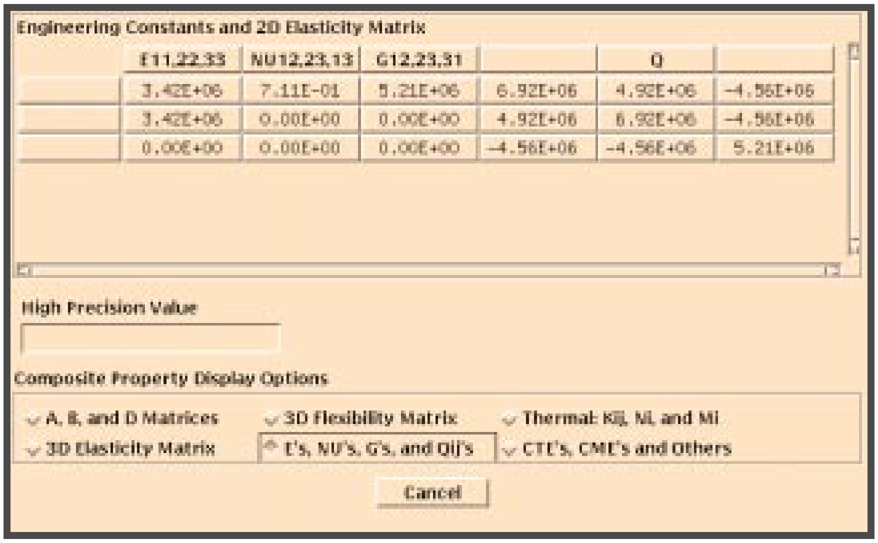


Notice that the A_{23} term in the "A matrix" is now -2.46E+04, which indicates that a load in the Y_m direction will cause a shearing displacement as well as an axial displacement. (***A matrix****:* Membrane/Membrane 3x3 in the *upper left corner* of the 6x6 matrix.)

Composite Property Display Options: ◆ **E's, NU's, G's, and Qij's**

The elasticity printout shows that an angled laminate has a much lower modulus than the 0-90 laminates previously run.

Fig 1b-13: E's, NU's, G's, and Qij's.



Cancel

◆ **Results**

Action: **Delete**

Object: **Result Cases**

Existing Result Cases: **Default, Static Subcase**

10. Submit model for linear static analysis.

◆ **Analysis**

Action: **Delete**

Object: **Job**

Existing Jobs: **prob1b**

Apply

Action: **Analyze**

Object: **Entire Model**

Method: **Analysis Deck**

Job Name: **prob1c**

Apply

An MSC/NASTRAN input file called **prob1c.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.

Generating an input file for MSC/NASTRAN Users:

11. The generated input file (prob1c.bdf) should be similar to the following:

(Type “**more prob1b.bdf**” at UNIX shell window to compare.)

```
$ NASTRAN input file created by the MSC MSC/NASTRAN input file
$ translator (  MSC/PATRAN Version 7.5 ) on January   30, 1998 at
$ 18:30:09.
ASSIGN OUTPUT2 = 'prob1c.op2', UNIT = 12
$ Direct Text Input for File Management Section
$ Linear Static Analysis, Database
SOL 101
TIME 600
$ Direct Text Input for Executive Control
CEND
SEALL = ALL
SUPER = ALL
TITLE = MSC/NASTRAN job created on 22-Jan-98 at 16:48:29
ECHO = NONE
MAXLINES = 999999999
$ Direct Text Input for Global Case Control Data
SUBCASE 1
$ Subcase name : Default
   SUBTITLE=Default
   SPC = 2
   LOAD = 2
   DISPLACEMENT(SORT1,REAL)=ALL
   SPCFORCES(SORT1,REAL)=ALL
   STRESS(SORT1,REAL,VONMISES,BILIN)=ALL
BEGIN BULK
PARAM    POST    -1
PARAM    PATVER  3.
PARAM    AUTOSPC YES
PARAM    INREL   0
PARAM    ALTRED  NO
PARAM   COUPMASS -1
PARAM    K6ROT   0.
PARAM    WTMASS  1.
PARAM,NOCOMPS,-1
PARAM   PRTMAXIM YES
$ Direct Text Input for Bulk Data
$ Elements and Element Properties for region : plate
$ Composite Property Record created from P3/PATRAN composite material
$ record : composite1
$ Composite Material Description :
PCOMP    1                                       0.      0.
+      A
+      A 1       .0054   -45.    YES
CQUAD4   1       1       1       2       5       4       1
CQUAD4   2       1       2       3       6       5       1
CQUAD4   3       1       4       5       8       7       1
CQUAD4   4       1       5       6       9       8       1
$ Referenced Material Records
$ Material Record : ply_mat
$ Description of Material : Date: 15-Jan-98           Time: 17:40:54
```

```
MAT8     1       2.+7    2.+6    .35     1.+6
$ Nodes of the Entire Model
GRID     1               0.      0.      0.
GRID     2               .5      0.      0.
GRID     3               1.      0.      0.
GRID     4               0.      .5      0.
GRID     5               .5      .5      0.
GRID     6               1.      .5      0.
GRID     7               0.      1.      0.
GRID     8               .5      1.      0.
GRID     9               1.      1.      0.
$ Loads for Load Case : Default
SPCADD   2       1       3
LOAD     2       1.      1.      1
$ Displacement Constraints of Load Set : simple_constraint
SPC1     1       135     1       4       7
$ Displacement Constraints of Load Set : y_constraint
SPC1     3       2       1
$ Distributed Loads of Load Set : uniform_load
FORCE    1       3               3.75    1.      0.      0.
FORCE    1       6               3.75    1.      0.      0.
FORCE    1       6               3.75    1.      0.      0.
FORCE    1       9               3.75    1.      0.      0.
$ Referenced Coordinate Frames
CORD2R   1              0.      0.      0.      0.      0.      1.      +
B
+      B 0.      1.      0.
ENDDATA af4f4c04
```

SUBMITTING THE INPUT FILE FOR MSC/NASTRAN and MSC/PATRAN USERS:

12. Submit the input file to MSC/NASTRAN for analysis by finding an available UNIX shell window. At the command prompt enter **nastran prob1c.bdf scr=yes**. Monitor the run using the UNIX **ps** command.MSC/NASTRAN Users have finished this exercise. MSC/PATRAN Users should proceed to the next step.

13. Proceed with the Reverse Translation process, that is, importing the **prob1c.op2** results file into MSC/PATRAN. To do this, return to the **Analysis** form and proceed as follows:

◆ **Analysis**

Action: **Read Output 2**

Object: **Result Entities**

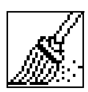
Method: **Translate**

Select Results File...

Selected Results File **prob1c.op2**

Apply

Before postprocessing the results, clear the LBC markers from the screen by selecting the following main menu icon:

 **Reset Graphics**

14. When the translation is complete and the Heartbeat turns green, bring up the **Results** form.

◆ **Results**

Action: **Create**

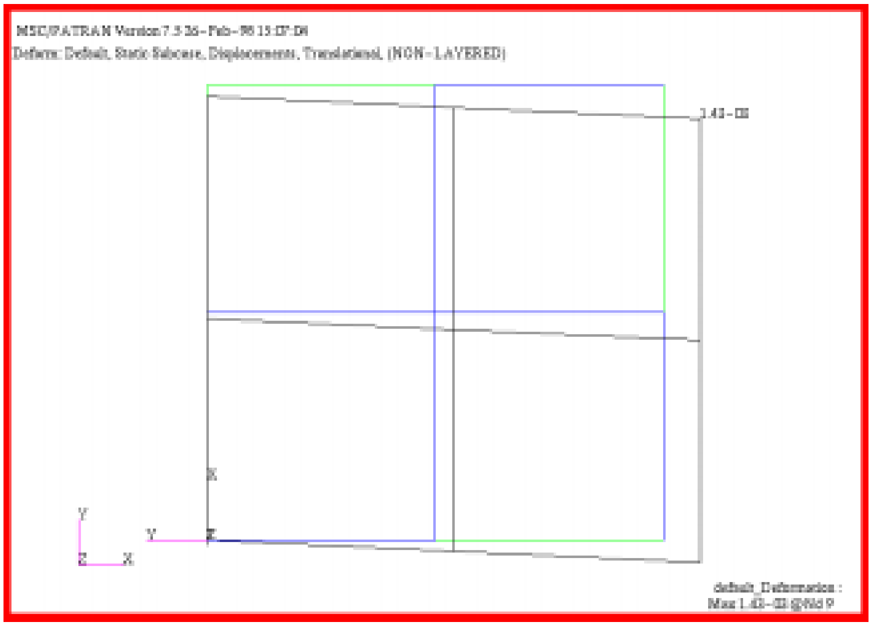
Object: **Deformation**

Select Result Cases: **Default, Static Subcase**

Select Deformation Result: **Displacements,Translational**

Apply

Fig 1b-14: Deformation plot.



The 45 degree orientation of the model is responsible for the shear displacement seen in Figure 1b-14. This is because the secondary direction of the material feels the same loading as the primary direction of the model, 0.707 times the applied load. This secondary direction, however, has a modulus 10 times less than that of the primary direction, and therefore yields much easier. Notice that the deformation tends towards -45 degrees, the same orientation as the secondary direction.

If you wish, you may view the z-displacement of the model. You will find, however, that there is none because the laminate is symmetric with respect to its center line.

Quit MSC/PATRAN when you have completed this exercise.