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SHARP PC-1500 POCKET COMPUTER SOLUTIONS TO COMPOSITE
MATERIALS FORMULAS(U) UNIVERSAL ENERGY SYSTEMS INC
DAYTON OH W J PARK ET AL. DEC 82 AFWAL-TR-83-4016

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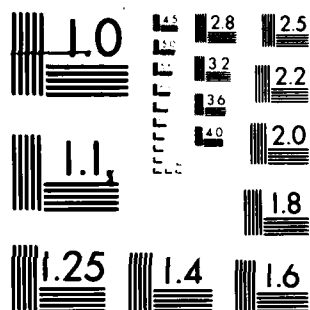
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AFWAL-TR-83-4016



SHARP PC-1500 POCKET COMPUTER SOLUTIONS
TO COMPOSITE MATERIALS FORMULAS

WON J. PARK
UNIVERSAL ENERGY SYSTEMS, INC.
DAYTON, OHIO 45432

and

THIERRY N. MASSARD (AFWAL/MLBM)
MATERIALS LABORATORY
AIR FORCE WRIGHT AERONAUTICAL LAB.
WRIGHT-PATTERSON AFB, DAYTON, OHIO 45433

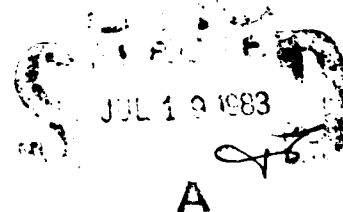
DECEMBER 1982

FINAL REPORT FOR PERIOD JUNE 1982-DECEMBER 1982

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WRIGHT-PATTERSON AFB, OHIO 45433

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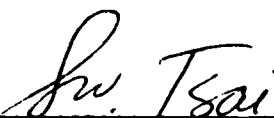
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This report has been reviewed by the Office of Public Affairs (ASD/PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.



S.W. TSAI, Project Engineer & Chief
Mechanics and Surface Interactions Branch
Nonmetallic Materials Division

FOR THE COMMANDER



F.D. CHERRY, Chief
Nonmetallic Materials Division

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18. SUPPLEMENTARY NOTES These programs use the language of BASIC and with additional 8KB RAM memories. The computer software contained in this report is theoretical and/or references and in no way reflect Air Force-owned or developed computer software.		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) BASIC Programming Composite Materials Properties of Unidirectional and Laminated Composite In-Plane and Flexural Stiffness and Strength		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This volume contains the description and instructions of the use of Sharp PC-1500 Pocket Computer for the key calculations of the stiffness and strength of symmetric laminated composites. Instant calculations can be made for practical use. The formulas and equation numbers used in the performed programming have been derived from a book entitled, <u>Introduction to Composite Materials</u> , co-authored by S. W. Tsai and H. T. Hahn, published by Technomic Publishing Company, Westport, CT, July 1980.		

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FOREWORD

This report was prepared in the Mechanics and Surface Interactions Branch (AFWAL/MLBM), Nonmetallic Materials Division, Materials Laboratory, Air Force Wright Aeronautical Laboratories, Wright-Patterson AFB, Ohio. The work was performed under Contract F33615-82-C-5001; SB5448-82-C-0086.

The time period covered by this report was from June to December 1982. Dr. Won J. Park was a senior scientist from Universal Energy Systems, Inc. and Professor of Mathematics and Statistics at Wright State University.

Dr. Thierry N. Massard was a visiting scientist at Materials Laboratory, Air Force Aeronautical Laboratories, Wright-Patterson AFB, Dayton, Ohio, and a Chief engineer at the Commissariat L'Energie Atomique, Montrouge, France.

The equations and table numbers which appear in the flow charts are the same as in Introduction to Composite Materials, co-authored by S.W. Tsai and H.T. Hahn, published by Technomic Publishing Company, Westport, CT, in July 1980.

Those who want to receive the programmed magnetic cassette tape should contact Stephen W. Tsai, AFWAL/MLBM, Wright-Patterson AFB, Dayton, Ohio 45433, Tel: 513-255-3068.

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SECTION I
USER GENERAL INSTRUCTIONS

- (1) The program language for PC-1500 Pocket Computer is BASIC and the elementary part of BASIC program instructions are given in the SHARP Instruction manual, which comes with PC-1500 Pocket Computer.
- (2) The 8 K RAM should be attached to the computer to increase its capacity. Printer is necessary for Version 1 and 2. If not available, choose Version 3 of the program.
- (3) The programs are called SYM-LAM 1, SYM-LAM 2, and SYM-LAM 3. They are three different displays of the same calculation:

SYM-LAM 1 (Version 1) gives vertical printing on the paper,

SYM-LAM 2 (Version 2) gives horizontal printing with matrix form
on the paper,

SYM-LAM 3 (Version 3) gives results on the display window and
does not require the printer.

The programs are started in mode RUN by instruction RUN (press the keys **R** **U** **N** and **ENTER**). User is guided through the programs by simple questions. The user types the chosen answer and presses the key **ENTER** .

- (4) The programs are recorded on a magnetic cassette with tape counter readings:

SYM-LAM 1 : 0 - 200

SYM-LAM 2 : 250 - 400

SYM-LAM 3 : 450 - 540

Instruction CLOAD "SYM-LAM 1" ("SYM-LAM 2" or "SYM-LAM 3") is used to load the program from the cassette recorder to the computer.

- (5) The program considers only symmetric laminates of composite materials.

SECTION II

CONTENTS OF PROGRAMS

The program performs specific operations and computations of composite materials:

- (1) Description of the laminates.
 - number of angles
 - number of plies for each angle
 - number of core plies (for flexural stiffness of sandwich plate only)
- (2) In-plane stiffness of symmetric laminates.
 - modulus and compliance
- (3) Engineering constants.
- (4) Normalized in-plane stiffness.
 - modulus and compliance
- (5) In-plane strength.
- (6) Stress failure envelope.
- (7) Strain failure envelope.
- (8) Flexural rigidity of symmetric sandwich plates.
 - modulus and compliance
- (9) Flexural strength of symmetric sandwich plates.

REMARKS:

- (a) The materials constants are stored in the program. When

REMARKS: (cont'd)

"MATERIAL N. =" is asked, input the material number or press M,
which gives the menu for materials numbers:

- 1 - T300/5208
- 2 - B(4)/5505
- 3 - AS-3501
- 4 - Schotchply/1002
- 5 - Kevlar 49/Epoxy

To add other materials (up to 10), user should type (in PRO mode)
for a material N. = x: (line 10 * x)

10 * x: DATA "Name of Material", E_x , E_y , ν_x , E_s , h_o , X, X',
Y, Y', S: RETURN

An example of adding a new material (Aluminum-material number 6)
is as follows:

Set PRO mode, write 60 DATA "ALUMINUM", 69E3, 69E3, .3, 26.5E3,
.125E-3, 400, 400, 400, 230: RETURN and press ENTER .

The unit of engineering constants are in MPa and thickness is in
meter.

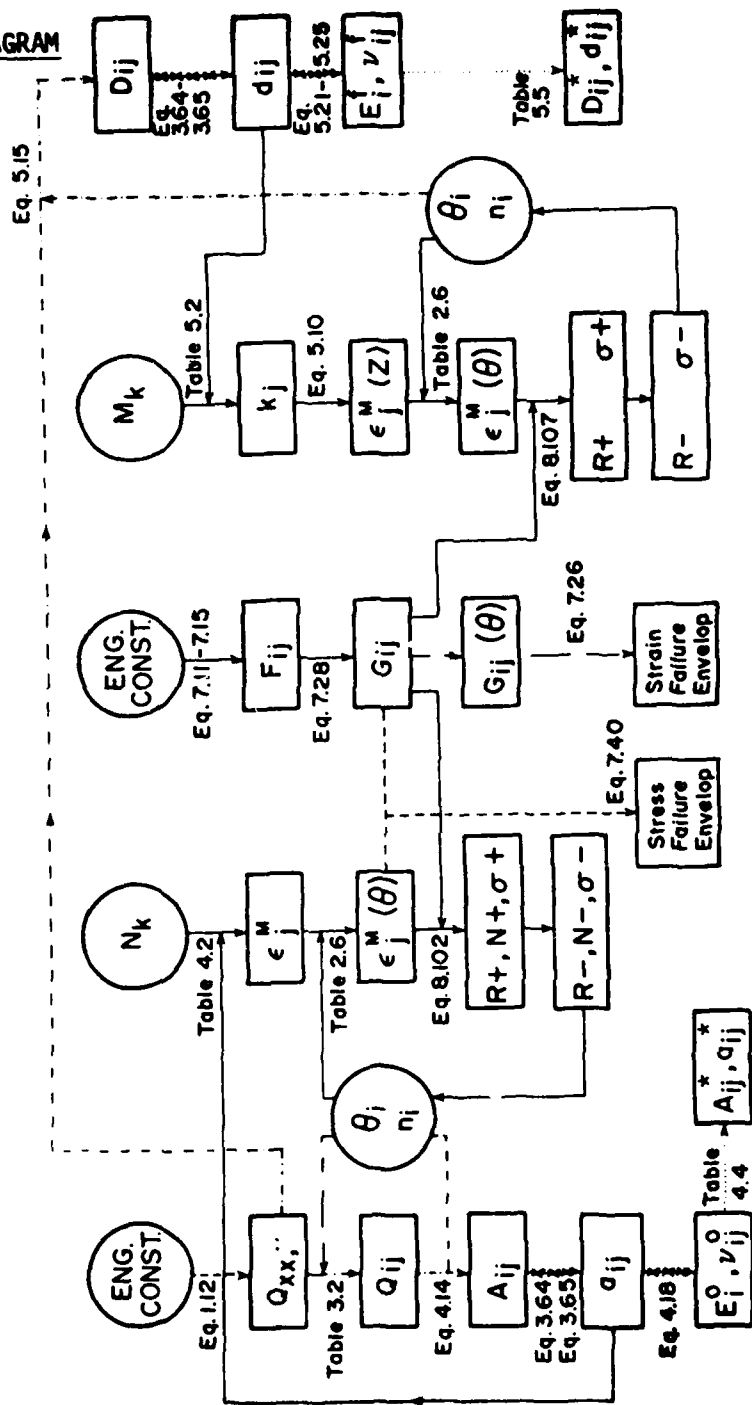
(Do not forget to save the modified program on the cassette tape
using instruction CSAVE "SYM-LAM1" ("SYM-LAM2" or "SYM-LAM3"). The
menu is set automatically up to date.

- (b) The order of angles to be entered starts from the angle closer to the mid-plane. This is very important in the flexural rigidity and strength computations.
- (c) The value of F_{xy}^* was programmed as $0 = -\frac{1}{2}$ in the program step 1025. For $F_{xy}^* \neq -\frac{1}{2}$, the new value should be entered directly in the program at this step (mode PRO).

SECTION III

PROGRAM DESCRIPTION

(A) FLOW DIAGRAM



(B) KEY OPERATION PROCEDURE (T300/5208, $[0_4/90_4]_s$ and version 1)

DISPLAY & OPERATION	PRINT OUT & REMARKS	DISPLAY & OPERATION	PRINT OUT & REMARKS
RUN ENTER		ENGINEERING CST Y ENTER	- Y/N? E1-o 95.991GPa E2-o 95.991GPa E6-o 7.170GPa v21o 0.030 v12o 0.030 v61o 0.000 v16o 0.000 v62o 0.000 v26o 0.000
COLOR (0,1,2,3) 0 ENTER	Color Numbers 0 - black 2 - green 1 - blue 3 - red		
MATERIAL N. = (M for MENU)? M ENTER	Menu for Materials		
MATERIAL N. = (M for MENU)? 1 ENTER	T300/5208	NORMALIZED CST Y ENTER	- Y/N? NORMALIZED CONST MODULUS A11* 96.078GPa A22* 96.078GPa A12* 2.896GPa A66* 7.170GPa A16* 0.000GPa A26* 0.000GPa INU. MAT. (TPa)-1 COMPLIANCE a11* 10.417 a22* 10.417 a12* -0.314 a66* 139.470 a16* 0.000 a26* 0.000
DEFINE THE LAMINATE HOW MANY ANGLES 2 ENTER ANGLE = 90 ENTER NO. OF PLIES 4 ENTER ANGLE = 0 ENTER NO. OF PLIES 4 ENTER N. OF CORE PLIES 0 ENTER	ANGLE 1 = 90 NO. OF PLIES = 4 ANGLE 2 = 0 NO. OF PLIES = 4 N. OF CORE PLIES 0	IN-PLANE STRENGTH - Y/N? Y ENTER N1 = (MN/m) ENTER ? 1 ENTER N2 = ENTER 0 ENTER N6 = ENTER 0 ENTER	N1 = 1.000MN/m N2 = 0.000MN/m N6 = 0.000MN/m ANGLE 1 = 90 N1 = 1.000 N2 = 0.000 N6 = 0.000 Sum = 102.3951MPa ANGLE 2 = 0 N1 = 1.000 N2 = 0.000 N6 = 0.000 Sum = 2208.818MPa ANGLE 2 = 0 N1 = 1.000 N2 = 0.000 N6 = 0.000 Sum = 681.882MPa ANGLE 2 = 0 N1 = 1.000 N2 = 0.000 N6 = 0.000 Sum = 102.3951MPa
IN-PLANE STIFFNESS - Y/N? Y ENTER	IN PLANE STIFFNE MODULUS A11 192.157MN/m A22 192.157MN/m A12 5.793MN/m A66 14.340MN/m A16 0.000MN/m A26 0.000MN/m COMPLIANCE a11 5.208m/kN a22 5.208m/kN a12 0.157m/kN a66 69.735m/kN a16 0.000m/kN a26 0.000m/kN		

DISPLAY & OPERATION	PRINT OUT & REMARKS	DISPLAY & OPERATION	PRINT OUT & REMARKS
FAIL. ENV. IN STRESS - Y/N? ☒ Y ENTER ANGLE NO. is= ☒ 1 ENTER COLOR NO. is= ☒ 0 ENTER ANGLE NO. is= ☒ 2 ENTER COLOR NO. is= ☒ 2 ENTER ANGLE NO. is=(*) ☒ 5 ENTER NEW SCALE - Y/N? ☒ Y ENTER W = ? ☒ 16 ENTER	(*)Entering an angle number greater than the number of angles on the laminate terminates the graphic operation	COLOR NO. IS = ☒ 2 ENTER ANGLE NO. IS = ☒ 5 ENTER NEW SCALE - Y/N? ☒ N ENTER	
ANGLE NO. is= ☒ 1 ENTER COLOR NO. is= ☒ 0 ENTER ANGLE NO. is= ☒ 2 ENTER COLOR NO. is= ☒ 2 ENTER ANGLE NO. is= ☒ 5 ENTER NEW SCALE? ☒ N ENTER FAIL. ENV. IN STRAIN - Y/N? ☒ Y ENTER ANGLE NO. IS = ☒ 1 ENTER COLOR NO. IS = ☒ 0 ENTER ANGLE NO. IS = ☒ 2 ENTER		FLEXURAL STIFFNESS - Y/N? ☒ Y ENTER	FLEX. STIFFNESS MODULUS D11 106.918N.m D22 21.186N.m D12 1.931N.m D66 4.780N.m D16 0.000N.m D26 0.000N.m INU. MAT. (kN.m)-1 COMPLIANCE d11 9.368 d22 47.278 d12 -0.853 d66 209.205 d16 0.000 d26 0.000
		ENGIN. FLEX. CST - Y/N? ☒ Y ENTER	E1-f 160.113GPa E2-f 31.726GPa E6-f 7.169GPa v21f 0.091 v12f 0.018 v61f 0.000 v16f 0.000 v62f 0.000 v26f 0.000
		NORM. FLEX. CST. - Y/N? ☒ Y ENTER	NORMALIZED CONST MODULUS D11* 160.378GPa D22* 31.729GPa D12* 2.896GPa D66* 7.170GPa D16* 0.000GPa D26* 0.000GPa INU. MAT. (TPa)-1 COMPLIANCE d11* 6.245 d22* 31.518 d12* -0.569 d66* 139.470 d16* 0.000 d26* 0.000

DISPLAY & OPERATION	PRINT OUT & REMARKS	DISPLAY & OPERATION	PRINT OUT & REMARKS
FLEXURAL STRENGTH - Y/N? Y ENTER			ANGLE 2 = 0 R+ = 0.000 S _{gm} + = 1187.969MPa
M1 = ENTER 1 ENTER	M1 = 1.000MN M2 = 0.000MN M6 = 0.000MN		R- = 0.001 S _{gm} - = 1205.573MPa
M2 = ENTER 0 ENTER	ANGLE 1 = 90 R+ = 0.000 S _{gm} + = 1253.541MPa	At the end of the program it starts again to IN-PLANE STIFFNESS. To end or stop the program, press the key [ON] ("break")	
M6 = ENTER 0 ENTER	R- = 0.004 S _{gm} - = 2213.872MPa		

(C) MEMORY CONTENTS

Memory	DESCRIPTION	VERSION			Memory	DESCRIPTION	VERSION			Memory	DESCRIPTION	VERSION		
		1	2	3			1	2	3			1	2	3
A	E_x				S	y'				A(2)	E_2^0 E_2^f			
B	E_y				T	S				A(3)	E_6^0 E_6^f			
C	v_x				U	x_0				A(4)	v_{21}^0 v_{21}^f			
D	E_s				V	y_0				A(5)	v_{12}^0 " v_{12}^f			
F	$m=(1-v_x v_y)^{-1}$				W	scale factor			x	A(6)	v_{61}^0 " v_{61}^f			
G	k = number of Angles				X	x				A(7)	v_{16}^0 " v_{16}^f			
H	*				Y	y				A(8)	v_{62}^0 " v_{62}^f			
I	*				Z	*				A(9)	v_{26}^0 v_{26}^f			
J	*				AA	**				B(1)	N+			
K	N_1 M_1				BB	**				B(2)	N-			
L	N_2 M_2				CC	**			x	B(3)	σ^+			
M	N_6 M_6				II	*	x		x	B(4)	σ^-			
N	*				LL	**	x		x	B(10)	H_{11}			
O	F_{xy}^*				PP	**	x		x	B(20)	H_{12}			
P	X				TT	*				B(21)	H_{22}			
Q	X'				XX	*				B(23)	H_1			
R	Y				A(1)	E_1^0 E_1^f				B(24)	H_2			

Memory	DESCRIPTION	VERSION			Memory	DESCRIPTION	VERSION			Memory	DESCRIPTION	VERSION		
		1	2	3			1	2	3			1	2	3
U(1)	F_{xx}				U(21)	G_{12}				V(16)	A_{66}^* D_{66}^*			
U(2)	F_x				U(22)	G_{66}				V(17)	A_{16}^* D_{16}^*			
U(3)	F_{yy}				U(23)	G_1				V(18)	A_{26}^* D_{26}^*			
U(4)	F_y				U(24)	G_2				V(19)	a_{11}^* d_{11}^*			
U(5)	F_{ss}				V(1)	A_{11} D_{11}				V(20)	a_{22}^* d_{22}^*			
U(6)	F_{xy}				V(2)	A_{22} D_{22}				V(21)	a_{12}^* d_{12}^*			
U(7)	G_{xx}				V(3)	A_{12} D_{12}				V(22)	a_{66}^* d_{66}^*			
U(8)	G_{yy}				V(4)	A_{66} D_{66}				V(23)	a_{16}^* d_{16}^*			
U(9)	G_{xy}				V(5)	A_{16} D_{16}				V(24)	a_{26}^* d_{26}^*			
U(10)	G_{ss}				V(6)	A_{26} D_{26}				V(25)	graphic variables			x
U(11)	G_x				V(7)	a_{11} d_{11}				V(31)				x
U(12)	G_y				V(8)	a_{22} d_{22}				X(1)	Q_{xx}			
U(13)	α				V(9)	a_{12} d_{12}				X(2)	Q_{yy}			
U(14)	A'				V(10)	a_{66} d_{66}				X(3)	Q_{xy}			
U(15)	B'				V(11)	a_{16} d_{16}				X(4)	Q_{ss}			
U(16)	D' R^+				V(12)	a_{26} d_{26}				X(5)	m^4			
U(17)	E' R^-				V(13)	A_{11}^* D_{11}^*				X(6)	$m^3 n$			
U(19)	G_{11}				V(14)	A_{22}^* D_{22}^*				X(7)	$m^2 n^2$			
U(20)	G_{22}				V(15)	A_{12}^* D_{12}^*				X(8)	mn^3			

	DESCRIPTION	VERSION				DESCRIPTION	VERSION				DESCRIPTION	VERSION		
		1	2	3			1	2	3			1	2	3
X(9)	n^4				Y(I)	θ_i				L\$	"v ₁₂ "			
X(10)	$h, \frac{h^2}{6}, \frac{h^3}{12}$				Z(I)	n_i				M\$	"v ₂₁ "			
X(11)	Q_{ij}				A\$	"11"				N\$	"v ₁₆ "			
X(16)					B\$	"22"				O\$	"v ₆₁ "			
X(17)	$\epsilon_1^0 k_1$				C\$	"12"				P\$	"v ₂₆ "			
X(18)	$\epsilon_2^0 k_2$				D\$	"66"				Q\$	"v ₆₂ "			
X(19)	$\epsilon_6^0 k_6$				E\$	"16"				T\$(1)	" "			
X(20)	ϵ_x				F\$	"26"				T\$(2)	" * "			
X(21)	ϵ_y				G\$	Y/N				AA\$(1)	"MODULUS"			
X(22)	ϵ_s				H\$	ANGLE				AA\$(2)	"COMPLIANCE"			
X(23)	m^2				I\$	"E1-"				W\$	"MATERIAL"			
X(24)	n^2				J\$	"E2-"				C(I,J)	MATRIX ENTRY VARIABLES	x		x
X(25)	mn				K\$	"E6-"				E	h_0			
X(26)	X(1)													
X(29)	X(4)													

* Control variable

** - Formate or Printing variable

x - memory is not applicable

α = rotation angle for ellipse

A' - E = Coefficient of elliptic equation rotated

(D) SAMPLE PROBLEMS

1. T300/5208, $[0_2/90_2/\pm 45_2]_s$ (Version 1)

2. T300/5208, $[0_4/90_4]_s$ (Version 2)

3. T300/5208, $[0/90/\pm 45/\text{CORE}_4]_s$ (Version 1)

1. T300/5208, $[0_2/90_2/\pm 45_2]_s$ (Version 1)

T300/5208

ANGLE 1 = 45
NO. OF PLYS = 2
ANGLE 2 = 45
NO. OF PLYS = 2
ANGLE 3 = 90
NO. OF PLYS = 2
ANGLE 4 = 0
NO. OF PLYS = 2
N. OF CORE PLYS = 0

IN PLANE STIFFNESS
MODULUS

A11 152.736MN/m
A22 152.736MN/m
A12 45.214MN/m
A66 53.760MN/m
A16 0.000MN/m
A26 0.000MN/m

COMPLIANCE

a11 7.176m/kN
a22 7.176m/kN
a12 -2.124m/kN
a66 18.600m/kN
a16 0.000m/kN
a26 0.000m/kN

E1-o 69.675GPa
E2-o 69.675GPa
E6-o 26.880GPa
v21o 0.296
v12o 0.296
v61o 0.000
v16o 0.000
v62o 0.000
v26o 0.000

NORMALIZED CONST
MODULUS

A11* 76.368GPa
A22* 76.368GPa
A12* 22.607GPa
A66* 26.880GPa
A16* 0.000GPa
A26* 0.000GPa

INV. MAT. (TPa)⁻¹
COMPLIANCE

a11* 14.352
a22* 14.352
a12* -4.248
a66* 37.201
a16* 0.000
a26* 0.000

N1 = 1.000MN/m
N2 = 0.000MN/m
N6 = 0.000MN/m

ANGLE 1 = 45
R+ = 0.693
N+ = 24.000
Sgm+ = 46.995MPa

R- = 1.350
N- = 12.000
Sgm- = 675.075MPa

ANGLE 2 = 45
R+ = 0.693
N+ = 24.000
Sgm+ = 46.995MPa

R+ = 1.350
N+ = 12.000
Sgm+ = 675.075MPa

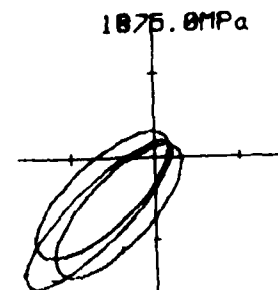
ANGLE 3 = 90
R+ = 0.582
N+ = 30.000
Sgm+ = 276.114MPa

R- = 2.500
N- = 8.000
Sgm- = 1292.584MPa

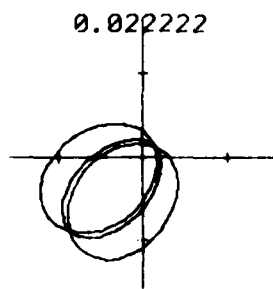
ANGLE 4 = 0
R+ = 1.160
N+ = 14.000
Sgm+ = 581.811MPa

R- = 1.130
N- = 16.000
Sgm- = 561.417MPa

STRESS STATE



STRAIN SPACE

FLEX. STIFFNESS
MODULUS

D11 26.842N.m
D22 44.692N.m
D12 5.216N.m
D66 8.065N.m
D16 2.679N.m
D26 2.679N.m

INV. MAT. (kN.m)-1
COMPLIANCE

d11 13.240
d22 22.958
d12 -1.307
d66 127.697
d16 -3.963
d26 -2.192

E1-f 113.287GPa
E2-f 65.334GPa
E6-f 11.746GPa
v21f 0.098
v12f 0.056
v61f -0.299
v16f -0.031
v62f 0.313
v26f -0.056

NORMALIZED CONST
MODULUS

D11* 115.263GPa
D22* 67.038GPa
D12* 7.824GPa
D66* 12.097GPa
D16* 4.018GPa
D26* 4.018GPa

INV. MAT. (TPa)-1
COMPLIANCE

d11* 8.827
d22* 15.305
d12* -0.871
d66* 85.131
d16* -2.642
d26* -4.794

M1 = 1.000MN
M2 = 0.000MN
M6 = 0.000MN

ANGLE 1 = -45
R+ = 0.001
Sgm+ = 2349.468MPa

R- = 0.003
Sgm- = 4963.999MPa

ANGLE 2 = 45
R+ = 0.000
Sgm+ = 1007.201MPa

R- = 0.001
Sgm- = 2954.782MPa

ANGLE 3 = 90
R+ = 0.000
Sgm+ = 584.184MPa

R- = 0.002
Sgm- = 3149.567MPa

ANGLE 4 = 0
R+ = 0.000
Sgm+ = 818.912MPa

R- = 0.000
Sgm- = 1143.139MPa

2. T300/5208, [0₄/90₄]_s

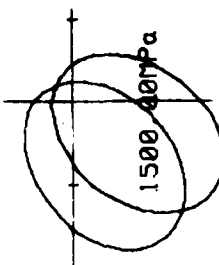
T300/5208		IN PLANE STIFF.			
ANGLE 1 = 90		$A(i,j)$	MN/m		
NO OF PLYS = 4		192.157	5.793		E1-0
ANGLE 2 = 0		5.793	192.157	0.000	E2-0
NO OF PLYS = 4		0.000	0.000	14.340	E6-0
					✓210
					✓120
					✓160
					✓620
					✓250
N.OF CORE PLYS = 0				69.735	

NORMALIZED MATRI

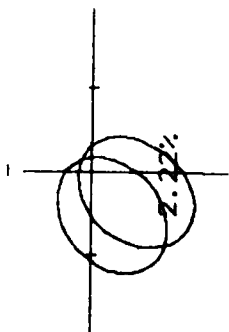
$\sigma^*(\text{eV})$	TPa-1
96.078	-0.314
2.836	-0.417
0.000	0.000
	:39.470

N1 =	1.00MN/m	ANGLE 2 =	0
N2 =	0.00MN/m	R+ =	1.3637
N6 =	0.00MN/m	N+ =	12.0000
		Sgm+ =	681.8820MPa
ANGLE 1 =	90	R- =	2.2154
R+ =	0.7467	N- =	8.0000
N+ =	22.0000	Sgm- =	1107.7053MPa
Sgm+ =	373.3955MPa		
R- =	4.5376		
R+ =	4.0000		
Sgm- =	2269.8188MPa		

STRESS SPACE



STRAIN SPACE



FLEX. STIFF.

D(i,j) N.m
106.918
1.931
0.000
d(i,j) (kN.m)-1
9.368
-0.853
0.000

E1-f 160.113GPa
E2-f 31.726GPa
E6-f 7.169GPa
v21f 0.091
v12f 0.018
v61f 0.000
v16f 0.000
v62f 0.000
v26f 0.000

1.931 0.000
21.186 0.000
0.000 4.780
-0.853 0.000
47.278 0.000
0.000 209.205

NORMALIZED FLEX.

D*(i,j) GPa
160.378 2.896
2.896 31.779
0.000 0.000
d*(i,j) IPa-1
6.245 -0.569
-0.569 31.518
0.000 0.000

M1 = 1.00MN
M2 = 0.00MN
M6 = 0.00MN

ANGLE 1 = 90
R+ = 0.000
Sgm+ = 1253.541MPa
R- = 0.004
Sgm- = 7213.872MPa

ANGLE 2 = 0
R+ = 0.000
Sgm+ = 1187.969MPa
R- = 0.001
Sgm- = 1705.573MPa

3. T300/5208, [0/90/±45/CORE₄]_s (Version 1)

T300/5208

ANGLE 1 = -45
NO.OF PLIES = 1
ANGLE 2 = 45
NO.OF PLIES = 1
ANGLE 3 = 90
NO.OF PLIES = 1
ANGLE 4 = 0
NO.OF PLIES = 1
N.OF CORE PLIES 4

IN PLANE STIFFNE MODULUS

A11 76.368MN/m
A22 76.368MN/m
A12 22.607MN/m
A66 26.880MN/m
A16 -0.000MN/m
A26 -0.000MN/m

COMPLIANCE

a11 14.352m/kN
a22 14.352m/kN
a12 -4.248m/kN
a66 37.201m/kN
a16 0.000m/kN
a26 0.000m/kN

E1-o 69.675GPa
E2-o 69.675GPa
E6-o 26.880GPa
ν1o 0.296
ν12o 0.296
ν61o 0.000
ν16o 0.000
ν62o 0.000
ν26o 0.000

NORMALIZED CONST MODULUS

A11* 76.368GPa
A22* 76.368GPa
A12* 22.607GPa
A66* 26.880GPa
A16* -0.000GPa
A26* -0.000GPa

INU. MAT. (TPa)-1 COMPLIANCE

a11* 14.352
a22* 14.352
a12* -4.248
a66* 37.201
a16* 0.000
a26* 0.000

N1 = 1.000MN/m
N2 = 0.000MN/m
N6 = 0.000MN/m

ANGLE 1 = -45
R+ = 0.346
N+ = 24.000
Sgm+ = 346.995MPa

R- = 0.675
N- = 12.000
Sgm- = 625.075MPa

ANGLE 2 = 45
R+ = 0.346
N+ = 24.000
Sgm+ = 346.995MPa

R- = 0.675
N- = 12.000
Sgm- = 625.075MPa

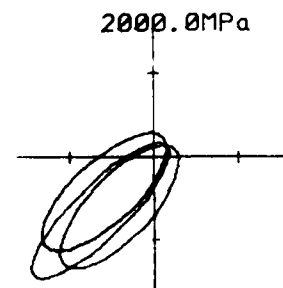
ANGLE 3 = 90
R+ = 0.076
N+ = 34.000
Sgm+ = 116.119MPa

R- = 1.197
N- = 0.000
Sgm- = 116.119MPa

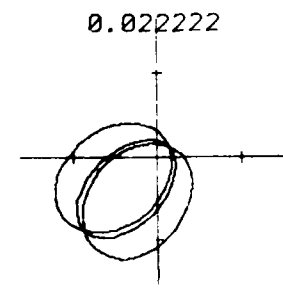
ANGLE 4 = 0
R+ = 0.581
N+ = 34.000
Sgm+ = 346.995MPa

R- = 0.565
N- = 16.000
Sgm- = 625.075MPa

STRESS SPACE



STRAIN SPACE



FLEX. STIFFNESS MODULUS

D11 52.932N.m
D22 43.555N.m
D12 9.491N.m
D66 11.984N.m
D16 1.674N.m
D26 1.674N.m

INU. MAT. (kN.m)-1 COMPLIANCE

d11 19.716
d22 23.983
d12 -4.213
d66 84.129
d16 -2.166
d26 -2.762

E1-f 76.079GPa
 E2-f 62.542GPa
 E6-f 17.829GPa
 v21f 0.213
 v12f 0.175
 v61f -0.109
 v16f -0.025
 v62f -0.115
 v26f -0.032

M1 = 1.000MN
 M2 = 0.000MN
 M6 = 0.000MN

ANGLE 1 = -45
 R+ = 0.000
 Sgm+ = 617.319MPa

R- = 0.000
 Sgm- = 1258.085MPa

NORMALIZED CONST MODULUS

D11* 79.398GPa
 D22* 65.333GPa
 D12* 14.237GPa
 D66* 17.976GPa
 D16* 2.511GPa
 D26* 2.511GPa

ANGLE 2 = 45
 R+ = 0.000
 Sgm+ = 486.485MPa

R- = 0.000
 Sgm- = 1115.317MPa

INV. MAT. (TPa)-1 COMPLIANCE

d11* 13.144
 d22* 15.989
 d12* -2.808
 d66* 56.086
 d16* -1.444
 d26* -1.841

ANGLE 3 = 90
 R+ = 0.000
 Sgm+ = 342.839MPa

R- = 0.001
 Sgm- = 1739.766MPa

ANGLE 4 = 0
 R+ = 0.000
 Sgm+ = 606.418MPa

R- = 0.000
 Sgm- = 684.798MPa

(E) PROGRAM LISTING

1. SYM - LAM 1

```
1: "SYM-LAM1":
  INPUT "COLOR ?
    (0, 1, 2, 3)"; CC:
  COLOR CC
2: TEXT
3: DIM X(30), Y(20
  ), Z(20), U(25),
  A(31), B(31), U(
  24), A$(2)
4: DATA "11", "22"
  , "12", "66", "16
  ", "26"
5: RESTORE 4: FOR
  I=1 TO 6: READ @
  $(I): NEXT I
6: DATA "E1-", "E2
  -", "E6-", "U21"
  , "U12", "U61", "
  U16", "U62", "U2
  6"
7: RESTORE 6: FOR
  I=9 TO 17: READ
  @$(I): NEXT I
8: INPUT "MATERIA
  L N.=(M FOR ME
  NU)"; G$: IF G$=
  "M" GOTO 195
9: I=VAL G$*10:
  GOSUB 1:
  RESTORE 1: READ
  W$, A, B, C, D, E, P
  , Q, R, S, T:
  LPRINT W$: GOTO
  200
10: DATA "1300/520
  8", "1817, 3, 10.3E
  3, 128, 1, 1.1E3,
  125E-3, 1500, 15
  00, 40, 246, 68.
  RETURN
20: DATA "1842/550
  5", "20423, 18.1E
  3, 123, 5.59E3,
  125E-3, 1260, 25
  00, 61, 202, 67.
  RETURN
30: DATA "AS/3501"
  , "138E3, 8.90E3,
  30, 2.10E3, 1.12
  5E-3, 1447, 1447
  , 51, 2, 206, 93:
  RETURN
40: DATA "SCOTCHPL
  Y/1002", 38.6E3
  , 8.273, .26, 4.1
  4E3, .125E-3, 10
  62, 610, 31, 118,
  72: RETURN
50: DATA "KEULAR 4
  9/EPOXY", 76E3,
  5.5E3, .34, 2.30
  E3, .125E-3, 140
  0, 235, 12, 53, 34
  : RETURN
60: DATA " ":
  RETURN
70: DATA " ":
  RETURN
80: DATA " ":
  RETURN
90: DATA " ":
  RETURN
100: DATA " ":
  RETURN
190: USING "####"
  ###.###":
  RETURN
191: USING "#####
  #####":
  RETURN
195: FOR I=1 TO 10:
  GOSUB 1*10:
  RESTORE 1*10:
  READ W$
  197: PAUSE I:
  "W$. NEXT I:
  GOTO 8
200: IF (1): A$(1)="
  MODULUS": A$(2)
  ="COMPLIANCE":
  AA=190: BB=191
210: PAUSE "DEFINE
  THE LAMINATE"
220: F=1/(1-C*C*B/A
  )
230: X(1)=F*A, X(2)=
  F*B, X(3)=F*C*B
  , X(4)=D
260: INPUT "HOW MAN
  Y ANGLES="; G
270: FOR I=1 TO G
280: INPUT "ANGLE="
  : Y(I)
290: H$="ANGLE "+
  STR$(I)+"="
300: LPRINT H$; Y(I)
310: INPUT "NO. OF P
  LIES="; Z(I)
315: LPRINT " NO. OF
  PLIES = "; Z(I
  )
316: NEXT I
317: INPUT "N. OF CO
  RE PLIES=(FLEX
  )"; Z(0)
318: LPRINT USING "
  #####"; "N. OF CO
  RE PLIES"; Z(0)
320: PAUSE "ANSWER
  Y/N FOR LISTIN
  G"
323: INPUT "IN-PLAN
  E STIFFNESS =
  Y/N?"; G$:
  324: X$="IN PLANE S
  TIFFNESS"
  327: GOSUB 670:
  GOSUB 680
  329: FOR I=1 TO 6
  330: GOSUB 700
  335: X(10)=X(10)+2*
  E*Z(I)
  340: U(10)=2*Z(I)*E
  350: GOSUB 1100
  360: NEXT I
  365: A=65, T=0, XX:
  U$="MN", IF
  C$="Y" GOSUB 38
  0
  375: GOTO 540
  380: IF (1): COLOR 1
  390: GOSUB BR:
  LPRINT X$, A$(1
  )*(6+1): LF (1)
  400: GOSUB AA: FOR I
  1 TO 6
  405: LPRINT CHR$(7+
  @$(I)); X(1+I)*
  XX; U$
  410: NEXT I: RETURN
  490: IF (1): COLOR 1
  497: U$="CPa"
  500: FOR I=1 TO 9
  505: XX=1E-3: IF 1>3
  THEN LET XX=1,
  U$=""
```

```

510:GOSUB 190:
  LPRINT @$(1+8)
  +CHR$ Z;A(I)*X
  X;U$
515:NEXT I
518:RETURN
540:GOSUB 800
560:X$="":Z=97:TT=
  6:XX=1E3:U$="m
  /KN":IF G$="Y"
  GOSUB 380
580:GOSUB 1200
585:Z=111
590:INPUT "ENGINEE
  RING CST - Y/N
  ? ";G$
592:IF G$="Y"GOSUB
  490
600:INPUT "NORMALI
  ZED CST - Y/N?
  ";G$
602:X$="NORMALIZED
  CONST."
605:Z=65:TT=12:XX=
  1E-3:U$="GPa":
  IF G$="Y"GOSUB
  630
610:X$="INU. MAT. (
  TPa)-1"
615:Z=97:TT=18:XX=
  1E6:U$="":IF G
  $="Y"GOSUB 630
620:GOTO 1300
630:LF (1):GOSUB 1
  91:LPRINT X$,A
  $((TT-9)/6+1):
  LF (1)
640:FOR I=1 TO 6
645:GOSUB AA:
  LPRINT CHR$ Z+
  @$(I)+"*";U(I+
  TT)*XX;U$
650:NEXT I:RETURN
670:FOR J=10 TO 16
672:X(J)=0:NEXT J
675:RETURN
680:FOR I=1 TO 6
684:U(I)=0
688:NEXT I
690:RETURN
700:X(5)=(COS Y(1)
  )^4,X(6)=(COS
  Y(1))^3*SIN Y(
  1)
710:X(7)=(COS Y(1)
  *SIN Y(1))^2,X
  (8)=COS Y(1)*C
  SIN Y(1)^3

```

```

720:X(9)=(SIN Y(1)
  )^4
740:X(11)=X(1)*X(5)
  +X(2)*X(9)+2*
  X(7)*X(3)+2*X
  (4))
750:X(12)=X(1)*X(9)
  +X(2)*X(5)+2*
  X(7)*X(3)+2*X
  (4))
760:X(13)=X(7)*X(
  1)+X(2)-4*X(4)
  +X(3)*X(5)+X
  (9))
770:X(14)=X(7)*X(
  1)+X(2)-2*X(3)
  +X(4)*X(5)-2
  *X(7)+X(9))
780:X(15)=X(1)*X(6)
  -X(2)*X(8)+(X
  (8)-X(6))*X(3)
  +2*X(4))
790:X(16)=X(1)*X(8)
  -X(2)*X(6)+(X
  (6)-X(8))*X(3)
  +2*X(4))
795:RETURN
800:DT=U(1)*U(2)*U
  (4)+2*U(3)*U(6)
  +U(5)-U(2)*U(
  5)^2-U(4)*U(3)
  ^2-U(1)*U(6)^2
820:U(7)=(U(2)*U(4)
  )-U(6)^2)/DT
825:U(8)=(U(1)*U(4)
  )-U(5)^2)/DT
830:U(9)=(U(5)*U(6)
  )-U(3)*U(4))/D
  T
840:U(10)=(U(1)*U(
  2)-U(3)^2)/DT
850:U(11)=(U(3)*U(
  6)-U(2)*U(5))/
  DT
860:U(12)=(U(3)*U(
  5)-U(1)*U(6))/
  DT
980:RETURN
1000:U(1)=1/P/Q,U
  (2)=1/P-1/Q
1010:U(3)=1/R/S,U
  (4)=1/R-1/S,
  U(5)=1/T/T
1020:U(3)=1/R/S,U
  (4)=1/R-1/S,
  U(5)=1/T/T
1025:0=-1/2

```

```

1030:U(6)=0*U(U(1)
  )*U(3))
1040:U(7)=U(1)*X(
  1)^2+2*U(6)*
  X(1)*X(3)+U(
  3)*X(3)^2
1050:U(8)=U(1)*X(
  3)^2+2*U(6)*
  X(3)*X(2)+U(
  3)*X(2)^2
1060:U(9)=U(1)*X(
  1)*X(3)+U(6)
  *(X(1)*X(2)+
  X(3)^2)+U(3)
  *X(3)*X(2)
1070:U(10)=U(5)*X
  (4)^2,U(11)=
  U(2)*X(1)+U(
  4)*X(3),U(12)
  =U(2)*X(3)+
  U(4)*X(2)
1080:RETURN
1100:U(1)=U(1)+U(
  1)*X(11),U(2)
  =U(2)+U(1)*
  X(12),U(3)=U
  (3)+U(1)*X(1
  3)
1110:U(4)=U(4)+U(
  1)*X(14),U(5)
  =U(5)+U(1)*
  X(15),U(6)=U
  (6)+U(1)*X(1
  6)
1130:RETURN
1200:A(1)=1/X(10)
  /U(7),A(2)=1
  /X(10)/U(8),
  A(3)=1/X(10)
  /U(10)
1210:A(4)=-U(9)/U
  (7),A(5)=-U(
  9)/U(8),A(6)
  =U(11)/U(7)
1220:A(7)=U(11)/U
  (10),A(8)=U(
  12)/U(8),A(9)
  =U(12)/U(10)
  )
1230:FOR J=1 TO 6
1235:U(J+12)=U(J)
  /X(10)
1237:U(J+18)=U(J+
  6)*X(10)
1240:NEXT J
1270:RETURN

```

```

1300: TEXT : COLOR
      2
1320: INPUT "IN PL
      ANE STRENGTH
      Y/N?"; C$
1330: IF (1). IF G$
      ="N" GOTO 260
      0
1340: Z=28. U$="MN/
      m": GOSUB 139
      0
1350: GOTO 1420
1390: IF (1): FOR I
      =1 TO 13
1395: X$=CHR$ Z+
      MID$ (C$(1-2
      ), 2, 1)+ " =";
      PRINT X$+"("
      +U$+" )";
      INPUT M(1)
1400: GOSUB AA.
      LPRINT X$; M(
      1); U$
1410: NEXT I.
      RETURN
1420: X(17)=U(2)*K
      +U(9)*L+U(11
      )*M
1430: X(18)=U(9)*K
      +U(8)*L+U(12
      )*M
1440: X(19)=U(11)*
      K+U(12)*L+U(
      10)*M
1450: FOR I=1 TO 6
1460: U$="ANGLE " +
      CIR$ (1)+
      "
1470: IF (1)
1480: USING "####&
      &&&&####"
1490: IF G$="Y"
      LPRINT H$; Y(
      1)
1500: GOSUB 1550
1510: GOSUB 1000
1520: GOSUB 1600
1530: NEXT I
1540: GOTO 2600
1550: Y(1)=Y(1)
1555: X(23)=(COS Y
      (1))^2, X(24)
      =(SIN Y(1))^
      2, X(25)=COS
      Y(1)*SIN Y(1
      )

```

```

1560: X(20)=X(17)*
      X(23)+X(18)*
      X(24)+X(19)*
      X(25)
1570: X(21)=X(17)*
      X(24)+X(18)*
      X(23)-X(19)*
      X(25)
1580: X(22)=2*X(25
      )*(X(18)-X(1
      7))+X(19)*(X
      (23)-X(24))
1585: Y(1)=-Y(1)
1590: RETURN
1600: U(13)=U(7)*X
      (20)^2+2*U(9
      )*X(20)*X(21
      )+U(8)*X(21)
      ^2+U(10)*X(2
      2)^2
1605: U(14)=U(11)*
      X(20)+U(12)*
      X(21)
1610: U(15)=U(14)/
      U(13)/2
1615: U(16)=-U(15)
      +J(U(15)^2+1
      /U(13))
1620: U(17)=U(15)+
      J(U(15)^2+1/
      U(13))
1625: B(1)=INT (X(
      10)/E/U(16)/
      2+1)*2, B(2)=
      INT (X(10)/E
      /U(17)/2+1)*
      2
1630: B(3)=U(16)/X
      (10), B(4)=U(
      17)/X(10)
1635: RETURN
1650: IF G$="N"
      THEN 1685
1653: USING "####&
      ####.###"
1655: LPRINT "R+
      =" ; U(16)
1657: IF U$="MN"
      THEN 1665
1660: LPRINT "N+
      =" ; B(1)
1665: LPRINT "Sgm+
      =" ; B(3); "MPa
      "
1670: LPRINT "R-
      =" ; U(17)
1672: IF U$="MN"
      THEN 1680
1675: LPRINT "N-
      =" ; B(2)

```

```

1680: LPRINT "Sgm-
      =" ; B(4); "MPa
      "
1685: RETURN
1700: GRAPH . COLOR
      2
1701: GLCURSOR (12
      0, -120);
      SORGN
1702: LINE (0, -100
      )-(0, 100), 0,
      1
1703: LINE (-100, 0
      )-(100, 0), 0,
      1
1705: INPUT "ANGLE
      NO. IS="; I
1710: IF I>6 THEN 2
      570
1711: AREAD Y(1)
1712: AREAD Z(1)
1715: INPUT "COLOR
      NO. IS="; I
1717: X(26)=X(1), X
      (27)=X(2), X(
      28)=X(3), X(2
      9)=X(4)
1720: GOSUB 1000
1730: X(1)=U(2), X(
      2)=U(8), X(3)
      =U(9), X(4)=U
      (10)
1740: GOSUB 670
1750: GOSUB 700
1760: X(1)=X(26), X
      (2)=X(27), X(
      3)=X(28), X(4
      )=X(29)
1810: U(19)=X(11),
      U(20)=X(12),
      U(21)=X(13),
      U(22)=X(14)
1820: X(23)=(C(2)
      (1))^2, X(24)
      =(SIN Y(1))^
      2
1830: U(23)=U(11)*
      X(23)+U(12)*
      X(24), U(24)=
      U(11)*X(24)+
      U(12)*X(23)
1835: IF N=2 THEN 2
      300
1840: B(19)=U(19)*
      U(2)^2+U(21)
      *U(7)*U(9)+U
      (20)*U(9)^2+

```

```

2575: IF N=1 THEN
      LET K=60/XX/
      W:GOTO 2585
2580: K=60/W
2585: GLCURSOR (-6
      0, 90):SORGN
2586: IF N=2 THEN 2
      588
2587: USING "####
      #.###&&":GOTO
      2590
2588: USING "##.##
      #####
2590: LPRINT K;U$.
      TEXT .LF 10
2591: TEXT .RETURN
2600: XX=X(10):N=1
      G$="MPa":
      INPUT "FAIL
      ENU. IN STRES
      S - Y/N?":G$
      IF G$="N"
      THEN 2640
2601: USING "#####
      #####
      #####
2605: TEXT .LF (2)
2610: W=30
2615: LPRINT " S
      TRESS SPACE"
2620: GOSUB 1700
2630: INPUT "NEW S
      CALE ?Y/N?":
      G$: IF G$="N"
      GOTO 2640
2635: INPUT "W= ?"
      :W:GOTO 2615
2640: N=2:G$="":
      INPUT "FAIL
      ENU. IN STRAI
      N - Y/N?":G$
      IF G$="N"
      THEN 2700
2641: USING "#####
      #####
      #####
2645: TEXT .LF (2)
2650: W=2700
2655: LPRINT " S
      TRAIN SPACE"
2660: GOSUB 1700
2670: INPUT "NEW S
      CALE ?Y/N?":G
      $. IF G$="N"
      GOTO 2700
2680: INPUT "W= ?"
      :W:GOTO 2655

```

```

2700:GOSUB RR,LF
      (1)
2710:INPUT "FLEXU
      RAL STIFFNESS
      S = Y/N? ";G$
2720:X$="FLEX. ST
      IFFNESS"
2740:LF (1):GOSUB
      670:GOSUB 68
      0
2765:X(10)=Z(0)*E
2770:FOR I=110 TO
2780:GOSUB 700
2785:X(10)=X(10)+
      E*Z(1)
2790:U(1)=2/3*(X(
      10)^3-(X(10)
      Z(1)*E)^3)
2800:GOSUB 1100
2820:NEXT I
2850:IF 68:TI=0:XX
      =1E6:U$="N.m
      " IF G$="Y"
      GOSUB 380
2910:GOSUB 800
2920:X$="INV. MAT.
      (KN.m)-1"
2930:IF 100:TI=0:X
      X=1E-3:U$="
      " IF G$="Y"
      GOSUB 380
2940:X(10)=2*X(10
      )^3/3
2950:GOSUB 1200
2960:IF 102
2985:INPUT "ENGIN
      E FLEX. STIFFN
      ESS? ";G$
2990:IF 6$ "Y"
      GOSUB 400
3000:INPUT "NORM.
      FLEX. STIFFN
      ESS? ";G$
3005:X$="NORMALIZ
      ED CONST"
3010:IF 68:TI=12:X
      X=1E-3:U$="G
      Pa" IF G$="Y"
      GOSUB 630
3040:X$="INV. MAT.
      (Pa)-1"
3050:IF 100:TI=18:
      XX=1E6:U$="
      " IF G$="Y"
      GOSUB 630
3160:COLOR 2
3165:INPUT "FLE
      XURAL STRENG
      TH = Y/N? ";
      G$
3170:IF G$="N"
      GOTO 3330
3180:Z=77:U$="MN"
      :GOSUB 1390
3200:X(17)=U(7)*K
      +U(9)*L+U(11
      )*M
3210:X(18)=U(9)*K
      +U(8)*L+U(12
      )*M
3220:X(19)=U(11)*
      K+U(12)*L+U(
      10)*M
3230:A(0)=Z(0)*E
3232:W=X(10)
3235:X(10)=1/6*
      EXP (2/3*LN
      (X(10)*12))
3240:FOR I=110 TO
3250:A(1)=A(1-1)+
      Z(1)*E
3255:LF (1)
3260:H$="ANGLE " +
      STR$ (1) + " =
      "
3268:IF U$="N"
      GOTO 3275
3270:USING "88888
      88888888####"
      LPRINT H$;Y(
      1)
3275:GOSUB 1555
3277:Y(1)=Y(1)
3280:GOSUB 1800
3285:X(20)=X(20)*
      A(1),X(21)=X
      (21)*A(1),X(
      22)=X(22)*A(
      1)
3290:GOSUB 1600
3300:GOSUB 1650
3310:NEXT I
3320:X(10)=W
3330:GOTO 323

```

2. SYM - LAM 2

```

1: "SYM-LAM2":
  INPUT "COLOR ?
    (0, 1, 2, 3)"; CC
  : COLOR CC
2: GRAPH .ROTATE
  1. KK=1.
  GLCURSOR (200,
    0). 11=1: SORGN
3: DIM X(30), Y(20)
  , C(3, 3), U(24)
  , T$(2), Z(20), U
  (25), A(31), B(3
  1)
7. DATA 1, 3, 5, 3, 2
  . 6, 5, 6, 4. FOR I
  =1 TO 3: FOR J=1
  TO 3: READ C(I,
  J): NEXT J: NEXT
  I: GOSUB 140
8. INPUT "MATERIA
  L N. (M FOR M
  ENU)"; G$. IF G$
  = "M" GOTO 195
9. : EVAL G$*10:
  GOSUB 1.
  RESTORE 1. READ
  W$, A, B, C, D, E, P
  , Q, R, S, T:
  LPRINT W$: GOTO
  200
10. DATA "T300/520
  8", 181E3, 10.3E
  3, .128, 2.12E3, .
  125E-3, 1500, 15
  00, 40, 246, 68:
  RETURN
20: DATA "B(4)/550
  5", 204E3, 18.5E
  3, .123, 5.59E3, 1
  25E-3, 1260, 250
  0, 61, 202, 62.
  RETURN
30. DATA "AS/3501"
  . 138E3, 8.96E3,
  . 30, 2.10E3, .12
  5E-3, 1442, 1442
  . 51, 2, 206, 93.
  RETURN
40. DATA "SCOTCHPL
  Y 1002", 38.6E3
  . 8.22E3, .126, 4.
  14E3, .125E-3,
  . 062, 610, 31, 118
  . 22. RETURN
50: DATA "KEULAR 4
  9/EPOXY", 76E3,
  5.5E3, .34, 2.30
  E3, .125E-3, 140
  0, 235, 12, 53, 34
  : RETURN
60: DATA "": RETURN
70: DATA "": RETURN
80: DATA "": RETURN
90: DATA "": RETURN
100: DATA "": RETURN
140: DATA "E1-", "E2
  -", "E6-", "021"
  , "012", "061", "
  016", "062", "02
  6"
150: RESTORE 140:
  FOR I=9 TO 17:
  READ Q$(I):
  NEXT I: RETURN
190: USING "#####
  #####": RETURN
191: USING "#####
  #####": RETURN
195: FOR I=1 TO 10:
  GOSUB 1*10.
  RESTORE 1*10.
  READ W$
  197. PAUSE 1:
  : W$: NEXT I.
  GOTO 8
200: T$(1)="". T$(2)
  ="*". AA=191. PP
  =4E3: LL=5E3
210: PAUSE "DEFINE
  THE LAMINATE"
220: F=1/(1-C*C*B/A
  )
230: X(1)=F*A, X(2)=
  F*B, X(3)=F*C*B
  , X(4)=0
260: INPUT "HOW MAN
  Y ANGLES="; G
270: J=0: FOR I=1 TO
  G: I=J+1
280: INPUT "ANGLE="
  : Y(I)
290: H$="ANGLE "+
  STR$(I)+"="
300: GOSUB LL.
  LPRINT H$: Y(I)
310: INPUT "NO. OF P
  LIES="; Z(I)
313: GOSUB LL:
  LPRINT " No OF
  PLIES = "; Z(I)
  : IF J=4 GOSUB
  PP: J=0
315: NEXT I
316: INPUT "N.OF CO
  RE PLIES=(FLEX
  )"; Z(0)
317: GOSUB LL: GOSUB
  LL: LPRINT
  USING "#####
  #####":
  N.OF CORE PLIE
  S"; Z(0)
318. KK=1.1: GOSUB P
  P
320: PAUSE "ANSWER
  Y/N FOR"
322: INPUT "IN-PLAN
  E STIFFNESS -
  Y/N?"; G$: X$="I
  N PLANE STIFF.
  "; N=1
328: GOSUB 670.
  GOSUB 680
329: FOR I=1 TO 6
  330. GOSUB 700
  335: X(10)=X(10)+2*
  E*Z(I)
  340: U(1)=2*Z(1)*E
  350: GOSUB 1100
  360: NEXT I
  365. GOSUB 800:
  GOSUB 1200
  370: IF C$="Y" GOSUB
  620: GOSUB 385
  375. GOTO 590
  385: Z=65. W=19: TT=0
  : U$="MN/m". XX=
  1. GOSUB 630
  390: Z=32. W=20: TT=6
  : U$="(kN/m)-1"
  : XX=1E3. GOSUB
  630
  332. GOSUB PP:
  RETURN
497: KK=1. U$="GPa"
  500: FOR I=1 TO 9
  505: XX=1E-3. IF I>3
  THEN LET XX=1,
  U$=""
  510: GOSUB LL:

```

```

LPRINT USING "
&&&&&":@$(1+8)
+CHR$(Z);USING
"####.###";A(1)
)*XX;USING '&&
8";U$
515:NEXT I:GOSUB P
P:RETURN
590:INPUT "ENGINEE
RING CST- Y/N
? ";G$
592:Z=111:IF G$='Y
"GOSUB 497
600:INPUT "NORMALI
ZED CST - Y/N
? ";G$:X$="NOR
MALIZED MATRIX
":N=2
605:IF G$="Y"GOSUB
620:GOSUB 625
610:GOTO 1300
620:KK=2:GOSUB 190
:LPRINT X$:11=
1:GOSUB LL:
RETURN
625:GOSUB LL:Z=65:
W=19:U$="GPd":
TT=12:XX=1E-3:
GOSUB 630
627:GOSUB LL:Z=97:
W=20:U$="TPd-1
":TT=18:XX=1E6
:GOSUB 630:
GOSUB PP.
RETURN
630:GOSUB 190:
LPRINT CHR$(Z)+
T$(N)+T$(1)
"+U$;@$(W):
GOSUB AA:GOSUB
LL
634:FOR I=1TO 3:
FOR J=1TO 3
636:LPRINT U(1,1)
)+TT)*XX:NEXT
I:GOSUB LL:
NEXT J:RETURN
670:FOR J=1TO 16:
X(J)=0:NEXT J:
RETURN
680:FOR I=1TO 6:U(
I)=0:NEXT I:
RETURN
700:X(5)=(COS Y(1)
)^4,X(6)=(COS
Y(1))^3*SIN Y(
1)
710:X(7)=(COS Y(1)
*SIN Y(1))^2,X
(8)=COS Y(1)*
SIN Y(1))^3
720:X(9)=(SIN Y(1)
)^4
740:X(11)=X(1)*X(5)
)+X(2)*X(9)+2*
X(7)*(X(3)+2*X
(4))
750:X(12)=X(1)*X(9)
)+X(2)*X(5)+2*
X(7)*(X(3)+2*X
(4))
760:X(13)=X(7)*(X(
1)+X(2)-4*X(4)
)+X(3)*(X(5)+X
(9))
770:X(14)=X(7)*(X(
1)+X(2)-2*X(3)
)+X(4)*(X(5)-2
*X(7)+X(9))
780:X(15)=X(1)*X(6)
)-X(2)*X(8)+(X
(8)-X(6))*X(3)
)+2*X(4))
790:X(16)=X(1)*X(8)
)-X(2)*X(6)+(X
(6)-X(8))*X(3)
)+2*X(4))
795:RETURN
800:DT=U(1)*U(2)*U
(4)+2*U(3)*U(6)
)*U(5)-U(2)*U(
5)^2-U(4)*U(3)
)^2-U(1)*U(6)^2
820:U(7)=(U(2)*U(4)
)-U(6)^2)/DT
825:U(8)=(U(1)*U(4)
)-U(5)^2)/DT
830:U(9)=(U(5)*U(6)
)-U(3)*U(4))/D
T
840:U(10)=(U(1)*U(
2)-U(3)^2)/DT
850:U(11)=(U(3)*U(
6)-U(2)*U(5))/
DT
860:U(12)=(U(3)*U(
5)-U(1)*U(6))/
DT:RETURN
1000:U(1)=1/P/Q,U
(2)=1/P-1/Q
1010:U(3)=1/R/S,U
(4)=1/R-1/S,
U(5)=1/T/T
1020:U(3)=1/R/S,U
(4)=1/R-1/S,
U(5)=1/T/T
1025:O=-.5:U(6)=O
*J(U(1)*U(3)
)
1040:U(7)=U(1)*X(
1)^2+2*U(6)*
X(1)*X(3)+U(
3)*X(3)^2
1050:U(8)=U(1)*X(
3)^2+2*U(6)*
X(3)*X(2)+U(
3)*X(2)^2
1060:U(9)=U(1)*X(
1)*X(3)+U(6)
*(X(1)*X(2)+
X(3)^2)+U(3)
*X(3)*X(2)
1070:U(10)=U(5)*X
(4)^2,U(11)=
U(2)*X(1)+U(
4)*X(3),U(12)
)=U(2)*X(3)+
U(4)*X(2).
RETURN
1100:U(1)=U(1)+U(
1)*X(11),U(2)
)=U(2)+U(1)*
X(12),U(3)=U
(3)+U(1)*X(1
3)
1110:U(4)=U(4)+U(
1)*X(14),U(5)
)=U(5)+U(1)*
X(15),U(6)=U
(6)+U(1)*X(1
6):RETURN
1200:A(1)=1/X(10)
)/U(7),A(2)=1
/X(10)/U(8),
A(3)=1/X(10)
)/U(10)
1210:A(4)=U(9)/U
(7),A(5)=U(
9)/U(8),A(6)
)=U(11)/U(7)
1220:A(7)=U(11)/U
(10),A(8)=U(
12)/U(8),A(9)
)=U(12)/U(10)
)
1230:FOR J=1TO 6
1235:U(J+12)=U(J)
/X(10)
1240:U(J+18)=U(J+
6)*X(10).

```



```

1810: U(19)=X(11),
      U(20)=X(12),
      U(21)=X(13),
      U(22)=X(14)
1820: X(23)=COS Y
      (1))^2, X(24)
      =(SIN Y(1))^2
1830: U(23)=U(11)*
      X(23)+U(12)*
      X(24), U(24)=
      U(11)*X(24)+
      U(12)*X(23)
1835: IF N=2 THEN 2
      300
1840: B(19)=U(19)*
      U(7)^2+U(21)*
      U(7)*U(9)+U
      (20)*U(9)^2+
      U(22)*U(11)^
      2
1850: B(20)=U(19)*
      U(9)^2+U(21)*
      U(9)*U(8)+U
      (20)*U(8)^2+
      U(22)*U(12)^
      2
1860: B(21)=U(19)*
      U(7)*U(9)+U(
      21)*U(7)*U(8
      )+U(20)*U(9)
      *U(8)
1870: B(21)=B(21)+
      U(22)*U(11)*
      U(12)
1880: B(23)=U(23)*
      U(7)+U(24)*U
      (9)
1890: B(24)=U(23)*
      U(9)+U(24)*U
      (8)
1900: U(19)=B(19),
      U(20)=B(20),
      U(21)=B(21),
      U(23)=B(23),
      U(24)=B(24)
2300: O=U(19)-U(20
      )
2310: IF O=0 AND U(
      21)>0 THEN 23
      30
2315: IF O=0 AND U(
      21)<0 THEN 23
      35
2320: U(13)=(ATN (
      2*U(21)/(U(1
      9)-U(20)))//
      2:GOTO 2340
2330: U(13)=45:
      GOTO 2340
2335: U(13)=-45
2340: U(14)=U(19)*
      (COS U(13))^
      2+2*U(21)*
      COS U(13)*
      SIN U(13)+U(
      20)*(SIN U(1
      3))^2
2350: U(15)=U(19)*
      (SIN U(13))^
      2-2*U(21)*
      SIN U(13)*
      COS U(13)+U(
      20)*(COS U(1
      3))^2
2360: U(16)=U(23)*
      COS U(13)+U(
      24)*SIN U(13
      )
2370: U(17)=-U(23)
      *SIN U(13)+U
      (24)*COS U(1
      3)
2380: U(18)=1+U(16
      )^2/U(14)/4+
      U(17)^2/U(15
      )/4
2390: X=ABS (U(18
      )/U(14)), Y=
      ABS (U(18)/U
      (15))
2400: U=-U(16)/U(1
      4)/2, V=-U(17
      )/U(15)/2
2410: H=U*COS U(13
      )-V*SIN U(13
      ), M=U*SIN U(
      13)+V*COS U(
      13)
2420: U=H, V=M
2430: X=X*W, Y=Y*W,
      U=U*W, V=V*W
2480: A(0)=X*COS U
      (13)+U, B(0)=
      X*SIN U(13)+
      V
2490: FOR J=1 TO 31
2500: A(J)=X*COS (
      12*J), B(J)=Y
      *SIN (12*J)
2510: M=A(J)*COS U
      (13)-B(J)*
      SIN U(13), H=
      A(J)*SIN U(1
      3)+B(J)*COS
      U(13)
2520: A(J)=M+U, B(J
      )=H+U
2540: LINE (B(J-1)
      , -A(J-1))-B(
      J), -A(J)), 0
      , 2: NEXT J:
      GOTO 1725
2570: LINE (-4, -60
      )-(-4, -60), 0,
      1
2572: LINE (-4, 60)
      -(-4, 60), 0, 1
2573: LINE (60, -4)
      -(-60, 4), 0, 1
2574: LINE (-60, -4
      )-(-60, 4), 0,
      1
2585: GLCURSOR (-6
      0, 90): SORGN
2590: LPRINT K; U$:
      RETURN
2600: XX=X(10): N=1
      : U$="MPa":
      INPUT "FAIL.
      ENU. IN STRES
      S-Y/N?": G$:
      IF G$="N"
      THEN 2640
2610: GOSUB 190:
      GOSUB LL: W=1
      6
2615: LPRINT " S
      TRESS SPACE"
2620: GOSUB 1700:
      GLCURSOR (13
      0, 230): SORGN
      : KK=2: GOSUB
      PP
2640: N=2: U$="N":
      INPUT "FAIL.
      ENU. IN STRAI
      N -Y/N?": G$:
      IF G$="N"
      THEN 2700
2650: GOSUB 190: W=
      2700
2655: LPRINT " S
      TRAIN SPACE"
2660: GOSUB 1700:
      GLCURSOR (13
      0, 230): SORGN
      : KK=2: GOSUB
      PP
2700: GOSUB 190:
      INPUT "FLEXU
      RAL STIFFNES

```

```

S -Y/N?";G$:
X$="FLEX. ST
IFE. T. N=1
2745:GOSUB 670
2750:GOSUB 680
2765:X(10)=Z(0)*E
2770:FOR I=1 TO 4
2780:GOSUB 700
2785:X(10)=X(10)+
E*Z(1)
2790:U(1)=2/3*(X(
10)+3-(X(10)
Z(1)*E)+3)
2800:GOSUB 1100
2820:NEXT I
2830:GOSUB 800
2840:IF G$="Y"
GOSUB 620:
GOSUB 2880
2860:GOTO 2940
2880:Z=68:W=19:TT
=0:U$="N.m":
XX=1E6:GOSUB
630
2890:Z=100:W=20:TT
=6:U$="kN.
m":TT=1:XX=1E
3:GOSUB 630
2900:KK=2:GOSUB P
P
2940:X(10)=2*X(10)
+3/3
2950:GOSUB 1200
2960:Z=102:INPUT
"ENGIN. FLEX.
CST Y/N?";G
$
2970:IF G$="N"
GOTO 3000
2975:GOSUB 497
3000:INPUT "NORM.
FLEX. CST Y/
N?";G$:N=2:X
$="NORMALIZE
D FLEX."
3010:IF G$="N"
GOTO 3120
3020:GOSUB 670
3022:Z=68:W=19:U$
="GPa":TT=12
:XX=1E-3:
GOSUB 630
3025:Z=100:W=20:U
$="TPa-1":TT
=18:XX=1E6:
GOSUB 630
3030:KK=2:GOSUB P
P
3120:KK=1.05:
INPUT " FLE
XURAL STRENG
TH -Y/N? ";
G$
3130:IF G$="N"
GOTO 3330
3170:Z=77:U$="MN"
:GOSUB 1390
3200:X(17)=U(7)*K
+U(9)*L+U(11
)*M
3210:X(18)=U(9)*K
+U(8)*L+U(12
)*M
3220:X(19)=U(11)*
K+U(12)*L+U(
10)*M
3230:A(0)=Z(0)*E
3232:W=X(10)
3235:X(10)=1/6*
EXP (2/3*LN
(X(10)*12))
3240:FOR I=1 TO 6
3250:A(1)=A(1-1)+
Z(1)*E
3275:GOSUB 1555
3277:Y(1)=-Y(1)
3280:GOSUB 1000
3285:X(20)=X(20)*
A(1),X(21)=X
(21)*A(1),X(
22)=X(22)*A(
1)
3300:GOSUB 1600:
GOSUB 1650:
GOSUB PP:
NEXT I
3330:GOTO 322
4000:GLCURSOR (0,
-230*KK):
SORGN :LINE
(0,10)-(-200
,10),0:
GLCURSOR (0,
0)
4010:II=0:RETURN
5000:GLCURSOR (-2
0*II,0):II=I
I+1:RETURN

```

3. SYM - LAM 3

```

1: "SYM-LAM3"
3: DIM X(30), Y(20), Z(20), U(25), V(24), A$(2), A(10), B(31)
4: DATA "11", "22", "12", "66", "16", "26"
5: RESTORE 4: FOR I=1 TO 6: READ Q$(I): NEXT I
6: DATA "E1-", "E2-", "E6-", "U21-", "U12-", "U61-", "U16-", "U62-", "U26-"
7: RESTORE 6: FOR I=9 TO 17: READ Q$(I): NEXT I
8: INPUT "MATERIAL N.=(N FOR MENU)"; G$: IF G$="M" GOTO 195
9: I=VAL G$*10: GOSUB 1: RESTORE 1: READ W$, A, B, C, D, E, P, Q, R, S, T: PRINT W$: GOTO 200
10: DATA "T300/5208", 181E3, 10.3E3, .28, 7.17E3, .125E-3, 1500, 1500, 40, 246, 68: RETURN
20: DATA "B(4)/5505", 204E3, 18.5E3, .23, 5.59E3, .125E-3, 1260, 2500, 61, 202, 67: RETURN
30: DATA "AS/3501", 138E3, 8.96E3, .30, 7.10E3, .125E-3, 1447, 1447, 51.7, 206, 93: RETURN
40: DATA "SCOTCHPLY/1002", 38.6E3, 8.273, .26, 4.14E3, .125E-3, 1062, 610, 31, 118, 72: RETURN
50: DATA "KEULAR 49/EPOXY", 76E3, 5.5E3, .34, 2.30E3, .125E-3, 1400, 235, 12, 53, 34: RETURN
60: DATA ""
70: DATA ""
80: DATA ""
90: DATA ""
100: DATA ""
190: USING "#####": RETURN
191: USING "#####": RETURN
195: FOR I=1 TO 10: GOSUB 1*10: RESTORE 1*10: READ W$
197: PAUSE USING "#####"; I: W$: NEXT I: GOTO 8
200: A$(1)="MODULUS": A$(2)="COMPLIANCE": AA=190: BB=191
210: PAUSE "DEFINE THE LAMINATE"
220: F=1/(1-C*C*B/A)
230: X(1)=F*A, X(2)=F*B, X(3)=F*C*B, X(4)=D
260: INPUT "HOW MANY ANGLES="; G
270: FOR I=1 TO G
280: INPUT "ANGLE="; Y(I)
290: H$="ANGLE "+STR$(I)+"="
300: PRINT H$; Y(I)
310: INPUT "NO. OF PLIES="; Z(I)
315: PRINT "NO. OF PLIES = "; Z(I)
316: NEXT I
317: INPUT "N. OF CORE PLIES=(FLEX)"; Z(0)
318: PRINT USING "&#####&###"; "N. OF CORE PLIES"; Z(0)
320: PAUSE "ANSWER Y/N FOR LISTING"
323: INPUT "IN-PLAN STIFFNESS - Y/N?"; G$
327: GOSUB 670: GOSUB 680
329: FOR I=1 TO G
330: GOSUB 700
335: X(10)=X(10)+2*E*Z(I)
340: U(1)=2*Z(I)*E
350: GOSUB 1100
360: NEXT I
365: Z=65: TT=0: XX=1: U$="MN/m". IF G$="Y" GOSUB 380
375: GOTO 540
380: GOSUB BB: PRINT A$(TT/6+1)
400: GOSUB AA: FOR I=1 TO 6
405: PRINT CHR$(Z+Q$(I)); U(1+TT)*X; U$
410: NEXT I: RETURN
490: U$="GPa"
500: FOR I=1 TO 3
505: XX=1E-3: IF I>3 THEN LET XX=1, U$=""
510: GOSUB 190: PRINT Q$(I+8)+CHR$(Z); A(I)*XX; U$
515: NEXT I
518: RETURN
540: GOSUB 800
560: X$="": Z=97: TT=6: XX=1E3: U$="m/kN": IF G$="Y" GOSUB 380
580: GOSUB 1200
585: Z=111
590: INPUT "ENGINEERING CST - Y/N?"; G$

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      INPUT Q
      (1)
1400: GOSUB AA:
      PRINT X$(Q)
      )U$
1410: NEXT I
      RETURN
1420: X(17)=U(2)*K
      +U(9)*L+U(11)
      )*M
1430: X(18)=U(9)*K
      +U(8)*L+U(12)
      )*M
1440: X(19)=U(11)*
      K+U(12)*L+U(
      10)*M
1450: FOR I=1 TO G
1460: H$="ANGLE " +
      STR$(I)+": "
1480: USING "####&&
      &&&&####"
1490: IF G$="Y"
      PRINT H$;Y(I)
1500: GOSUB 1550
1501: GOSUB 1600
1502: GOSUB 1600
1510: GOSUB 1650
1520: NEXT I
1530: GOTO 2200
1550: Y(1)=Y(1)
1555: Y(23)=COS Y
      (1)^2/X(24)
      -(SIN Y(1))^2
      2/X(25)=COS
      Y(1)*SIN Y(1)
1560: X(20)=X(17)*
      X(23)+X(18)*
      X(24)+X(19)*
      X(25)
1570: X(21)=X(17)*
      X(24)+X(18)*
      X(23)+X(19)*
      X(25)
1580: X(22)=2*X(25)
      *(X(18)-X(1
      7))+X(19)*(X
      (23)-X(24))
1585: Y(1)=Y(1)
1590: RETURN
1600: U(13)=U(2)*X
      (20)^2+2*U(9)
      )*X(20)*X(21)
      +U(8)*X(21)
      ^2+U(14)*X(2
      2)^2

```

```

1605: U(14)=U(11)*
      X(20)+U(12)*
      X(21)
1610: U(15)=U(14)/
      U(13)^2
1615: U(16)=-U(15)
      +J(U(15)^2+1
      /U(13))
1620: U(17)=U(15)+
      J(U(15)^2+1/
      U(13))
1625: B(1)=INT (X(
      10)/E/U(16)/
      2+1)*2, B(2)=
      INT (X(10)/E
      /U(17)/2+1)*
      2
1630: B(3)=U(16)/X
      (10), B(4)=U(
      17)/X(10)
1635: RETURN
1650: IF G$="N"
      THEN 1685
1653: USING "####&&
      #####.####"
1655: PRINT "R+ =
      ";U(16)
1657: IF U$="MN"
      THEN 1665
1660: PRINT "N+ =
      ";B(1)
1665: PRINT "Sgm+=
      ";B(3); "MPa"
1670: PRINT "R- =
      ";U(17)
1672: IF U$="MN"
      THEN 1680
1675: PRINT "N- =
      ";B(2)
1680: PRINT "Sgm-=
      ";B(4); "MPa"
1685: RETURN
2550: NEXT J
2680: INPUT "W= ?"
      :W: GOTO 2655
2700: GOSUB BB
2710: INPUT "FLEX.
      STIFFNESS -
      Y/N?";G$
2720: X$="FLEX. ST
      IFFNESS"
2740: GOSUB 670:
      GOSUB 680
2765: X(10)=Z(0)*E
2770: FOR I=1 TO G
2780: GOSUB 700
2785: X(10)=X(10)+
      E*Z(I)

```

```

2790: U(1)=2/3*(X(
      10)^3-(X(10)
      -Z(1)*E)^3)
2800: GOSUB 1100
2820: NEXT I
2850: Z=68: TT=0: XX
      =1E6: U$="N.m
      ": IF G$="Y"
      GOSUB 380
2910: GOSUB 800
2930: Z=100: TT=6: X
      =1E-3: U$=""
      : IF G$="Y"
      GOSUB 380
2934: USING "####&&
      &&&&&&&&&&&&&&&
      &"
2935: PRINT "
      (n (kN.m)-
      1"
2940: X(10)=2*X(10)
      ^3/3
2950: GOSUB 1200
2960: Z=102
2965: INPUT "ENGIN
      FLEX.CST -
      Y/N?";G$
2970: IF G$="Y"
      GOSUB 490
3000: INPUT "NORM.
      FLEX.CST - Y
      /N?";G$
3005: X$="NORMALIZ
      ED CONST"
3010: Z=68: W=1: TT=
      12: XX=1E-3: U
      $="GPa": IF G
      $="Y" GOSUB 6
      30
3050: Z=100: W=2: TT
      =18: XX=1E6: U
      $="TPa-1": IF
      G$="Y" GOSUB
      630
3160: INPUT " FLE
      XURAL STRENG
      TH - Y/N? ";
      G$
3170: IF G$="N"
      GOTO 3330
3180: Z=77: U$="MN"
      : GOSUB 1390
3200: X(17)=U(2)*K
      +U(9)*L+U(11)
      )*M
3210: X(18)=U(9)*K
      +U(8)*L+U(12)
      )*M

```

```

3220: USING #88888
      88888888###.
      PRINT H$;Y(1
      )
3225: GOSUB 1000
3227: X(10)=Y(1)
3280: GOSUB 1000
3285: X(20)=X(20)*
      A(1), X(21)=X
      (21)*A(1), X(
      22)=X(22)*A(
      1)
3290: GOSUB 1600
3300: GOSUB 1600
3310: NEXT I
3320: X(10)=W
3330: GOTO 123
3350: END

```

```

3220: X(19)=U(11)*
      K+U(12)*L+U(
      10)*M
3230: A(0)=Z(0)*E
3232: W=X(10)
3235: X(10)=1/6*
      EXP (2/3*LN
      (X(10)*12))
3240: FOR I=1 TO G
3250: A(1)=A(1-1)+
      Z(1)*E
3260: H$="ANGLE "+
      STR$ (1)+ "
      "
3268: IF G$="N"
      GOTO 3275

```

SECTION IV

CONCLUSIONS

The description and instruction of the use of Sharp PC-1500 Pocket Computer for the key calculations of the stiffness and strength of symmetric laminated composites are presented in this paper. With the computer packages that were programmed, instant calculations can be made for practical use.

END

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