Title

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Publication Date

1970-05-01

UCRL-19823
UC-32 Math. and Comp.
TID-4500 (56th Ed.)

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May 12, 1970

AEC Contract No. W-7405-eng-48

UCRL-19823

LAWRENCE RADIATION LABORATORY
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ABSTRACT

A CDC 6600, FORTRAN IV program SOTRM is described. SOTRM generates first and second order transformation elements by integrating numerically through a specified magnetic field. It can also be used for ray tracing. Data input is described and an illustrative example is presented. The results obtained can be used in a matrix beam transport program.

I. INTRODUCTION

Program SOTRM is a CDC 6600, FORTRAN IV program that generates first and second order transformation elements by integrating numerically through a specified magnetic field a specific set of rays which are then used in an appropriate elimination scheme [1]. It can also ray trace up to 30 nearby rays while integrating for the central orbit. For the purpose of evaluating the significance of the generated elements, it has the ability to apply a previously generated set of elements to the initial conditions of the nearby rays currently being obtained by integration and thus compare the integrated values of the solution with those obtained by applying the transformation.

This program consists of a number of subroutines and should be easily adaptable to various physical problems. We shall give in the following sections brief descriptions of these routines that should help in understanding the program and its subroutines, an explanation of the necessary data input, and a simple test example. It is assumed that the reader is familiar with the development given in [1]; however, the program is easy to use and if the 'black box' approach is taken, it should be possible to set up problems and run the program without consulting [1].

The necessary data input is given in Table III, sample test data is given in Table IV, the resultant output in Table V, and the program listing in Table VI.

II. PROGRAM AND SUBPROGRAM DESCRIPTIONS

The main program is

```
PROGRAM SOTRM(INPUT,OUTPUT,TAPE1)
```

and it is a driving program for subroutine SOTRM1 which actually generates the desired quantities. The sole purpose of SOTRM is to input data that is used in SOTRM1 and to call and execute that subroutine under user control. If it is desired to incorporate SOTRM1 into some user written program, then SOTRM may be discarded.

The main program is built in the style:

control:= read; <u>if</u> control= -1 <u>then</u> STOP <u>else</u>

<u>if</u> control=1 <u>then</u>

<u>begin</u> <u>comment</u> whatever happens when control=1. See the input section;

<u>end</u> <u>else</u>

<u>if</u> control=2 <u>then</u>

<u>begin</u> whatever happens when control=2;

.
.
.

<u>end</u> <u>else</u>

.
.
.

The main program is, essentially, described by the data input so we shall describe it no further here.

```
SUBROUTINE SOTRM1(SØ1,Z1,P1,V,W,PR,PI)
REAL SØ1,Z1(1),P1(1),V(5,5),W(5,5,5),PR(1)
INTEGER PI(1)
```

This subroutine generates a first order matrix V, and a second order matrix W.

It can also ray trace one reference ray and up to 30 nearby rays. All necessary values are supplied and returned in the argument list; the variables appearing there are described in Table I.

There are a number of labled commons in SOTRM1 that are used for communicating with the subprograms and their names and associated variables are given in Table II.

Once it sets all the initial conditions, SOTRM1 is basically a calling routine for the integration routines. Presently, the Lawrence Radiation Laboratory library routine ZAM [2] is used to carry out this integration. The integration loop will be executed until the program is shut off. The three variables in the common block LIMIT allow the user to control this shut off. The integration loop is exited from and the final values calculated whenever SØ ≧ SØMAX or the number of passes through the loop is greater than MAX. Thus, any criteria can be used to delimit the integration range and then one of the variables in LIMIT may be used to actually exit from the loop.

The action taken with regard to matrix generation and printout while integrating will depend on the values of the variables appearing in the integer parameter vector PI. These are explained in the section giving the data input to the driving program SOTRM.

SOTRM1 is built so that upon entry, the values in SØ, Z1, P1 are the initial values and upon exit, all arguments have their final value. In general, successive calls to SOTRM1 will generate cumulative results valid over the range of a particular call. The exact effect can be ascertained by consulting Table I.

Subroutines ZINIT and ZFINAL are used to establish respectively the initial values of the solution vector upon entry into SOTRM1 and the current, or final, values of the solution vector corresponding to SØ, or to SØ1 upon exit from SOTRM1. It should be remembered that the nearby rays have coordinates (δx_1, $\delta\theta_1$, δx_2, $\delta\theta_2$, $\delta P/P$) external to SOTRM1, but we are integrating (δx_1, δP_1, δx_2, δP_2), thus these two routines perform the necessary transformations.

Subroutine SF generates second order elements using either equation (20) or equation (21) of [1]. The initial values chosen for this elimination are as given in subroutine SETZ which actually sets the initial conditions when generating matrix elements. This subroutine uses the values (A(1), ... A(5)) located in common YAFS. If we use the dimension less coordinates ($\delta x_1/\rho$, $\delta\theta_1$, $\delta x_2/\rho$, $\delta\theta_2$, $\delta P/P_o$) where ρ is the radius of curvature of the reference particle, then for a uniform field, we have an optimum choice of (.01, .1, .01, .1, .0001) for the value of the vector A.

Subroutine FIELD is expected to set the magnetic field values in the common block FIELD corresponding to the current value of the integration variable SØ. The units are MKS.

Subroutine GAUSS takes a position vector R corresponding to SØ and returns the value in gauss of the three field components g_1, g_2, g_3. For the reference particle, these are in the global coordinate system; for the nearby particle, they are in the local coordinate system; that is, the moving trihedral.

Subroutine FUNC(SØ,Z,F) evaluates the right hand side of the differential equation DZ = F(Z(sØ)). See [1], equations (2) and (10).

The purpose of the remaining subroutines used in SOTRM1 can be ascertained from the program source listing. In practice, it should be possible to treat a variety of cases by making appropriate changes to the two field routines FIELD and GAUSS. The integration routines can be changed by substituting another integration package for ZAM [2].

III. PROGRAM CONTROL AND DATA INPUT FOR SOTRM

PROGRAM SOTRM (INPUT,OUTPUT,TAPE1)

This program drives SOTRM1 and can be used to ray trace or to generate transfer matrix elements or a combination of these tasks.

The program is controlled by inputing a quantity S that determines what the program will do. In Table III are given the values of S and the corresponding card, or cards, read and the action taken. S = - 1.0 stops the program and S = 99.0 calls the subroutine SOTRM1.

The program always reads S and after executing the selected section it will again read S. Thus, one can do as many cases as desired. Schematically, we have

```
L1:    S := read;
       execute the appropriate section;
       go to L1;
```

A few comments about SOTRM1 are in order here. The vector Z contains the values of the solution corresponding to SØ. Before calling SOTRM1, S = 99, the user must be sure that these values are properly set. Upon exit from SOTRM1, the values in Z will correspond to the value of SØ which existed at the time of exit. Thus, two consecutive calls to SOTRM1 will be cumulative unless the user resets the values in the Z vector. This feature, while possibly annoying in some cases, allows one to have some control when integrating through a series of elements.

However, when generating matrix elements, the subroutine SETZ will store the perturbations in Z upon each entry into SOTRM1. Thus, the generation of the matrices is not cumulative, but correspond instead to the range of integration within one call to SOTRM1. The final value of the solution vector used to generate the matrix elements does, however, reside in Z upon exit from SOTRM1. The initial values used to start the integration loop in SOTRM1 are stored in the common block ZSAVE, should they be desired. When checking the integrated values against those obtained from the generated transformation elements, subroutine APTRAN applies the transformation to the values in ZSAVE.

IV. SAMPLE DATA INPUT AND CORRESPONDING OUTPUT

To illustrate the program data input and output, we use as an example a 510.72 MeV proton reference particle which moves in a circle in a uniform field of one meter. The data for these examples are given in Table IV.

In Example 1, we generate a transfer matrix corresponding to a 45° bend. Example 2 traces a reference ray and two nearby rays through a 45° bend. Example 3 generates a matrix correspond to a 45° bend, saves the matrix and subsequently applies it to three nearby rays to check against the integrated values. The output of the program SOTRM for these three examples is presented in Table V.

In Example 3, the values ZTRAN represent the values (δx_1, $\delta\theta_1$, δx_2, $\delta\theta_2$, $\delta P/P$) obtained by applying the transformation to the initial values. Whereas, ZSOLN gives the values obtained by integration. In the first case, the solution was used to obtain the transformation, thus the two columns are essentially identical. However, the next pass applies the transformation to an arbitrary nearby ray and the results are seen to be somewhat different which is, of course, expected.

Table I

SOTRM1 Argument List

Variable	Comment
SØ1	The intial value of the independent variable at the time SOTRM1 is called. The final value of the independent variable upon exit from SOTRM1.
Z1	This vector contains the values of the coordinates of the reference ray and the nearby rays corresponding to the value of SØ1 upon entry and exit. It is the same as Z in SOTRM and must be set as indicated on the card C4 input to SOTRM. Note: When generating matrix elements, SOTRM1 will place the initial conditions in Z1, thus, destroying any previously set values. The matrix is, therefore, not cumulative for successive calls to SOTRM1.
P1	This vector contains the momentum perturbation $\delta P/P_{\emptyset}$ of the nearby particles. It is the same as P in SOTRM and must be set as indicated on the card C2 input to SOTRM. The dimensions of P1 and Z1 must be large enough to hold the required information. Presently P1 has up to 30 elements and Z1 up to $4 \times 31 = 124$ elements.
V(5,5)	Upon exit from SOTRM1, the first order elements of the transfer matrix corresponding to the value of SØ1 are stored here if these values have been asked for.
W(5,5,5)	Upon exit from SOTRM1, the second order elements of the transfer matrix corresponding to the value of SØ1 are stored here if those values have been asked for. The

Table I - contd.

Variable	Comment
	nearby rays are assumed to be a vector $y = (\delta x_1[\mathrm{cm}], \delta\theta_1[\mathrm{mr}], \delta x_2[\mathrm{cm}], \delta\theta_2[\mathrm{mr}], \delta P/P_o)$ and these arrays can be applied directly as $$y_i = \sum_j V_{ij}\, y_j^{(o)} + \sum_{j,k} W_{ijk}\, y_j^{(o)}\, y_k^{(o)} .$$
PR	This is a real parameter vector the values of which are param (1), ..., param (4) of SOTRM. See the card A2 input to SOTRM.
PI	This is an integer parameter vector the values of which are param (5), ..., param (8) of SOTRM. See the card A2 input of SOTRM.

Table II

SOTRM1 Tabled Common Blocks

Common Block	Variable	Comment
CASES	NUM	The number of rays, including the reference ray, that are being tracked. Present limit 31.
	L	Global counter
	K	Global counter
CHARGE	Q	Charge [MKS] of the reference particle and of nearby particles.
MOM	PØ	Momentum [MKS] of the reference particle.
	P(40)	Momentum, $1 + \delta P/P_o$, of the nearby particles.
FIELD	BBØ2	Field $B_2(r_1, 0, r_2)$ [Webers] on the reference orbit. It is assumed that the field is only in the two direction [1]. See the figure for the card B input to SOTRM to obtain the axis orientation.
	BB1(40)	The B_1 component of the field on the nearby orbit at the current value of the independent variable SØ.
	BB2(40)	The B_2 component of the field on the nearby orbit.
	BB3(40)	The B_3 component of the field on the nearby orbit.
SOLN	Z(164)	The current value of the solution vector. It's value corresponds to equations (3) and (9) of [1]. The units are [MKS].
DER	F(164)	The righthand side of the equation DZ = F(Z). These values are defined by equations (2) and (10) of [1]

Table II - contd.

Common Block	Variable	Comment
PARAM	CONST(8)	Contains the conversion factors from external units to internal [MKS] units.
LIMIT	SØ	Current value of the independent variable.
	SØMAX	The maximum allowed value of SØ.
	MAX	The maximum total number of steps allowed in the integration process.
YAFS	YP(5)	The current $y(+\ t^{(j)})$ vector for the elimination process [1].
	YM(5)	The current $y(-\ t^{(j)})$ vector for the elimination process [1].
	A(5)	The perturbation values (δx_1 [cm], $\delta\theta_1$ [mr], δx_2 [cm], $\delta\theta_2$ [mr], $\delta P/P_o$) used when constructing the first and second order matrix elements.
	U(5,5)	The first order matrix correspond to the current value of SØ.
	S(5,5,5)	The second order matrix corresponding to the current value of SØ.
WORK	COUNT	The number of function evaluations used in the integration process to move from SØ1 to the current value of SØ.
	STEP	The current number of maximum step sizes taken.
INIT	ZSAVE(15Ø)	Saves the initial values (δx_1, $\delta\theta_1$, δx_2, $\delta\theta_2$, $\delta P/P_o$) if all nearby rays corresponding to SØ1 upon entry into SOTRM1.

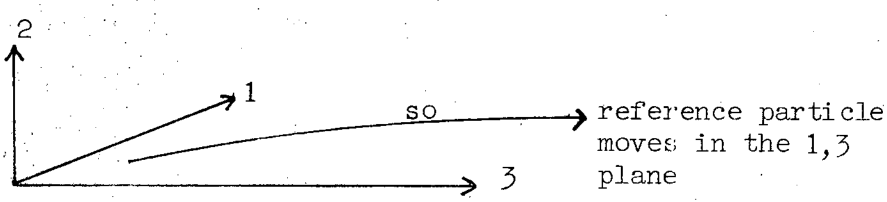
Table III

Data Input to SOTRM
May 10, 1970

Value of S	Card	Parameters Read	Format
1	A1	K	E10.Ø
	A2	(I, PARAM(I),I =1,K)	(I5,5X,E15.Ø)
		param(1) = Q = signed number of charges	
		param(2) = delsin = max. step size [cm]	
		param(3) = sØ max = max. arc length [m]	
		param(4) = SØ1 = initial arc length [m]	
		param(5) = option 0 ray trace. 1 first order matrix. - 1 first order matrix, second order trace. 2 first order and second order matrices, asymmetric. 3 first order and second order matrices, symmetric.	
		param(6) = num = number of rays including the center reference ray. May be set to 1 if generating matrix elements. Value ≤ 31.	
		param(7) = max = maximum number of steps that can be taken, includes all step adjustments of the variable step size integrator.	
		param(8) = nprint = 0 No print out of ray trace or of matrix generation.	

Table III - contd.

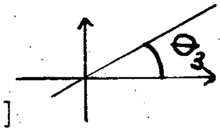
Value of S	Card	Parameters Read	Format
	A2 (continued)	param(8) = nprint (continued) > 0 Print out every nprint steps, will also print initial and final values. < 0 Same as > 0 except that the matrix elements will be stored on Tape 1 if generating elements or will be read from Tape 1 and applied to the initial conditions if ray tracing.	
2	B	(low lim(i), uplim(i),I = 1, 3)	(8E10.0)

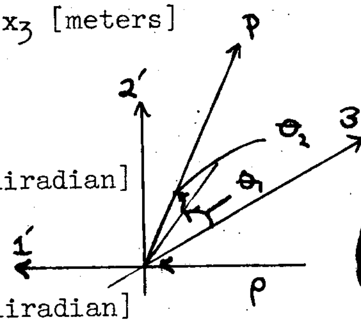


		low lim (i) The lower limit of the reference particle [m].	
		up lim (i) The upper limit of the reference particle [m].	
3	C		
(3V3.1)	C1	K	(I5)
	C2	(I,P(i),I = 1,K)	(I5,5X,E15.0)
		P(i) = momentum of the <u>nearby particle</u> $\delta P/P_o$. We have to have read in (num -1) of these at least once.	

Table III -contd.

Value of S	Card	Parameters Read	Format
(3V3.2)	C3	L	I5
	C4	(I, Z(i), i = 1,L)	(I5,5X,E15.0)
		Z(1) = reference ray Pc [mev]	always present
		Z(2) = angle [deg]	
		Z(3) = starting x_1 [meters]	
		Z(4) = starting x_3 [meters]	
		Z(5) = δx_1 [cm]	there are num - 1 of these when ray tracing
		Z(6) = θ_1 [milliradian]	
		Z(7) = δx_2 [cm]	
		Z(8) = θ_2 [milliradian]	





Value of S	Card	Parameters Read	Format
4	D	(A1(I, J), J = 1,10), I = 1,10)	(5E10.0)
		(A2(I, J), J = 1,10), I = 1,10)	
		Input row wise 5 items / card the matrix A1 and then the matrix A2. These can be used as one wishes, but are presently used with F. Selph field	
5	E		
(5V5.1)	E1	K	(I5)
	E2	(I,J,A1(I,J),L=1,K)	(J5,I5,E15.0)
(5V5.2)	E3	K	(I5)
	E4	(I,J,A2(I,J),L=1,K)	(I5,I5,E15.0)
		Allows one to change values of the individual elements of A1 or A2 or both.	

Table III - contd.

Value of S	Card	Parameters Read		Format
6	F1	K		(I5)
	F2	(I,A(I),L = 1,K)		(I5,5X,E15.0)
		$A(1) = \delta x_1$ [cm]	These are the magnitude of the perturbation for the derivative calculation. They are nominally set by data statements as	.01 [cm]
		$A(2) = \delta x_1'$ [mr]		.1 [mr]
		$A(3) = \delta x_2$ [cm]		.01 [cm]
		$A(4) = \delta x_2'$ [mr]		.1 [mr]
		$A(5) = \delta p/_p$		.0001

Table IV

SAMPLE INPUT DATA

EXAMPLE 1

```
1.0
    8
    1    1.0
    2    1.5707963267949
    3    30.0
    4    0.0
    5    3.0
    6    1.0
    7    50.0
    8    50.0
3.2
    4
    1    510.72
    2    90.0
    3    2.0
    4    1.0
99.0
-1.
```

EXAMPLE 2

```
1.0
    8
    1    1.0
    2    1.5707963267949
    3    30.0
    4    0.0
    5    0.0
    6    3.0
    7    50.0
    8    50.0
3.2
   12
    1    510.72
    2    90.0
    3    2.0
    4    1.0
    5    1.0
    6    0.0
    7    0.0
    8    0.0
    9    0.0
   10    0.
   11    1.0
   12    5.0
3.1
    2
    1    .01
    2    .01
99.0
-1.0
```

EXAMPLE 3

```
1.0
    8
    1    1.0
    2    1.5707963267949
    3    30.0
    4    0.0
    5    3.0
    6    1.0
    7    50.0
    8    -50.0
3.2
    4
    1    510.72
    2    90.0
    3    2.0
    4    1.0
99.0
1.0
    2
    5    0.0
    6    4.0
3.1
    3
    1    .01
    2    .05
    3    .10
3.2
   16
    1    510.72
    2    90.0
    3    2.0
    4    1.0
    5    .5
    6    5.0
    7    .5
    8    5.0
    9    1.0
   10    10.0
   11    1.0
   12    10.0
   13    5.0
   14    20.0
   15    5.0
   16    20.0
99.0
-1.0
```

TABLE V

PROGRAM OUTPUT EXAMPLES 1 - 3

EXAMPLE 1

```
1

 CONTROL=  1.000
 NUMBER OF PARAMETERS READ =    8

 C=             1.00000000
 DELSIN=        1.57079633 (CM)
 SOMAX=        30.00000000 (M)
 SO1=           0.00000000 (M)
 OPTION=        3.00000000
 NUM=           1.00000000
 MAX=          50.00000000
 NPRINT=       50.00000000

 CONTROL=  3.200
 NUMBER OF PARAMETERS READ =    4

 Z(  1)=   510.72000000(MEV) Z(  2)=    90.00000000(DEG) Z(  3)=     2.00000000( M)  Z(  4)=     1.00000000( M)
 Z(

 CONTROL= 99.000

START OF SOTRM1

1 THE FOLLOWING HEADINGS ARE TO BE USED FOR COL. 1-7

                   K= 0            PX(MEV/C)    PY(MEV/C)        X(M)         Y(M)     THETA(DEG)    FUNC CALLS
                   K=(1,NUM-1)      X(CM)          X (MR)        Y(CM)         Y (MR)     DP/PO           DPX/PO        DPY/PO
                    U(I,J)   / J=    1              2             3             4           5
                    S(I,J,K) / K=    1              2             3             4           5

     I   SO(METER)  K              1              2              3              4              5              6              7

     0    0.00000    0  5.1072000E+02 -8.7594838E-13  2.0000000E+00  1.0000000E+00  9.0000000E+01                1
                   U(1,J)      1.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
                   U(2,J)      0.0000000E+00  1.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
                   U(3,J)      0.0000000E+00  0.0000000E+00  1.0000000E+00  0.0000000E+00  0.0000000E+00
                   U(4,J)      0.0000000E+00  0.0000000E+00  0.0000000E+00  1.0000000E+00  0.0000000E+00
                   U(5,J)      0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  1.0000000E+00

                   S(1,1,K)    0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
                   S(1,2,K)    0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
                   S(1,3,K)    0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
                   S(1,4,K)    0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
                   S(1,5,K)    0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
                   S(2,1,K)    0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
                   S(2,2,K)    0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
                   S(2,3,K)    0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
                   S(2,4,K)    0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
                   S(2,5,K)    0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
                   S(3,1,K)    0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
                   S(3,2,K)    0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
```

TABLE V - contd.

Example 1 - contd.

```
          S(3,3,K)     0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
          S(3,4,K)     0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
          S(3,5,K)     0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
          S(4,1,K)     0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
          S(4,2,K)     0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
          S(4,3,K)     0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
          S(4,4,K)     0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
          S(4,5,K)     0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
          S(5,1,K)     0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
          S(5,2,K)     0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
          S(5,3,K)     0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
          S(5,4,K)     0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
          S(5,5,K)     0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
 50   .78540    0  3.6113357E+02  3.6113358E+02  2.7071068E+00  1.2928932E+00  4.5000000E+01        110
          U(1,J)       7.0710678E-01  7.0710678E-02  0.0000000E+00  0.0000000E+00  2.9289322E+01
          U(2,J)      -7.0710678E+00  7.0710678E-01  0.0000000E+00  0.0000000E+00  7.0710679E+02
          U(3,J)       0.0000000E+00  0.0000000E+00  1.0000000E+00  7.8539817E-02  0.0000000E+00
          U(4,J)       0.0000000E+00  0.0000000E+00  0.0000000E+00  1.0000000E+00  0.0000000E+00
          U(5,J)       0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  1.0000000E+00

          S(1,1,K)    -2.4999979E-03  2.4999991E-04 -8.4703295E-18 -4.3512594E-11  2.4999991E-01
          S(1,2,K)     2.4999991E-04  1.0355356E-05  4.2351647E-19 -2.4701251E-12  1.0355328E-02
          S(1,3,K)    -8.4703295E-18  4.2351647E-19  0.0000000E+00 -4.2351647E-19 -8.4703295E-16
          S(1,4,K)    -4.3512594E-11 -2.4701251E-12 -4.2351647E-19 -1.4644658E-05 -3.0758907E-09
          S(1,5,K)     2.4999991E-01  1.0355328E-02 -8.4703295E-16 -3.0758907E-09 -2.5000013E+01
          S(2,1,K)     4.6447290E-08 -1.7405893E-09  1.2924697E-22 -8.8496523E-10  3.5355317E+00
          S(2,2,K)    -1.7405893E-09 -3.5355301E-04 -1.3552527E-17 -7.5073929E-11 -2.2711833E-07
          S(2,3,K)     1.2924697E-22 -1.3552527E-17  0.0000000E+00 -6.7762636E-18 -2.7105054E-14
          S(2,4,K)    -8.8496523E-10 -7.5073929E-11 -6.7762636E-18 -3.5355329E-04 -8.5854197E-08
          S(2,5,K)     3.5355317E+00 -2.2711833E-07 -2.7105054E-14 -8.5854197E-08 -7.0710708E+02
          S(3,1,K)     0.0000000E+00  0.0000000E+00  0.0000000E+00  3.5355339E-04  0.0000000E+00
          S(3,2,K)     0.0000000E+00  0.0000000E+00  0.0000000E+00  1.4644661E-05  0.0000000E+00
          S(3,3,K)     0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
          S(3,4,K)     3.5355339E-04  1.4644661E-05  0.0000000E+00  0.0000000E+00  3.9145690E-03
          S(3,5,K)     0.0000000E+00  0.0000000E+00  0.0000000E+00  3.9145690E-03  0.0000000E+00
          S(4,1,K)     0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
          S(4,2,K)     0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
          S(4,3,K)     0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
          S(4,4,K)     0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
          S(4,5,K)     0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
          S(5,1,K)     0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00 -1.2621774E-23
          S(5,2,K)     0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00 -1.2621774E-24
          S(5,3,K)     0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00 -1.2621774E-23
          S(5,4,K)     0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00 -1.2621774E-24
          S(5,5,K)    -1.2621774E-23 -1.2621774E-24 -1.2621774E-23 -1.2621774E-24 -3.5527137E-07

END OF SOTRM1

CONTROL= -1.000

...END OF CONPUTATIONS...
```

TABLE V - contd.

EXAMPLE 2

```
1
 CONTROL=  1.000
 NUMBER OF PARAMETERS READ =     8

 Q=             1.00000000
 DELSIN=        1.57079633 (CM)
 SOMAX=        30.00000000 (M)
 SO1=           0.00000000 (M)
 OPTION=        0.00000000
 NUM=           3.00000000
 MAX=          50.00000000
 NPRINT=       50.00000000

 CONTROL=  3.200
 NUMBER OF PARAMETERS READ =    12

 Z(  1)=   510.72000000(MEV) Z(  2)=    90.00000000(DEG) Z(  3)=     2.00000000( M)  Z(  4)=     1.00000000( M)
 Z(  5)=     1.00000000(CM)  Z(  6)=     0.00000000(MR)  Z(  7)=     0.00000000(CM)  Z(  8)=     0.00000000(MR)
 Z(  9)=     0.00000000(CM)  Z( 10)=     0.00000000(MR)  Z( 11)=     1.00000000(CM)  Z( 12)=     5.00000000(MR)

 CONTROL=  3.100
 NUMBER OF PARAMETERS READ =     2

 P( 1)=      .01000000 DELTA P/PO
 P( 2)=      .01000000 DELTA P/PO

 CONTROL= 99.000

START OF SCTRM1

1 THE FOLLOWING HEADINGS ARE TO BE USED FOR COL. 1-7
                         K= 0            PX(MEV/C)     PY(MEV/C)          X(M)          Y(M)       THETA(DEG)     FUNC CALLS
                         K=(1,NUM-1)       X(CM)         X (MR)           Y(CM)         Y (MR)       DP/PO           DPX/PO          DPY/PO
                          U(I,J)   / J=    1               2                3             4            5
                          S(I,J,K) / K=    1               2                3             4            5

    I   SC(METER)  K          1              2              3              4              5              6              7

    0    0.00000   0  5.1072000E+02 -8.7594838E-13  2.0000000E+00  1.0000000E+00  9.0000000E+01        1
                   1  1.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  1.0000000E-02  0.0000000E+00  0.0000000E+00
                   2  0.0000000E+00  0.0000000E+00  1.0000000E+00  5.0000000E+00  1.0000000E-02  0.0000000E+00  5.0499790E-03
   50     .78540   0  3.6113357E+02  3.6113358E+02  2.7071068E+00  1.2928932E+00  4.5000000E+01       110
                   1  1.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  1.0000000E-02  0.0000000E+00  0.0000000E+00
                   2  2.9005438E-01  6.9923628E+00  1.3930933E+00  5.0000000E+00  1.0000000E-02  7.0621406E-03  5.0499790E-03

 END OF SCTRM1

 CONTROL= -1.000
```

TABLE V - contd.

```
...END OF CONPUTATIONS...
1

CONTROL=  1.000                                          EXAMPLE 3
NUMBER OF PARAMETERS READ =    8

Q=              1.00000000
DELSIN=         1.57079633 (CM)
SOMAX=         30.00000000 (M)
SO1=            0.00000000 (M)
OPTION=         3.00000000
NUM=            1.00000000
MAX=           50.00000000
NPRINT=       -50.00000000

CONTROL=  3.200
NUMBER OF PARAMETERS READ =    4

Z(  1)=   510.72000000(MEV) Z(  2)=    90.00000000(DEG) Z(  3)=     2.00000000( M)  Z(  4)=     1.00000000( M)
Z(

CONTROL= 99.000

START OF SOTRM1

1 THE FOLLOWING HEADINGS ARE TO BE USED FOR COL. 1-7

               K= 0          PX(MEV/C)     PY(MEV/C)       X(M)         Y(M)     THETA(DEG)    FUNC CALLS
               K=(1,NUM-1)    X(CM)          X (MR)        Y(CM)         Y (MR)    DP/PO          DPX/PO          DPY/PO
                U(I,J)   / J=   1              2             3             4          5
                S(I,J,K) / K=   1              2             3             4          5

   I   SO(METER)  K              1             2             3             4             5             6             7

   0    0.00000    0  5.1072000E+02 -8.7594838E-13  2.0000000E+00  1.0000000E+00  9.0000000E+01              1
                 U(1,J)      1.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
                 U(2,J)      0.0000000E+00  1.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
                 U(3,J)      0.0000000E+00  0.0000000E+00  1.0000000E+00  0.0000000E+00  0.0000000E+00
                 U(4,J)      0.0000000E+00  0.0000000E+00  0.0000000E+00  1.0000000E+00  0.0000000E+00
                 U(5,J)      0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  1.0000000E+00

                 S(1,1,K)    0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
                 S(1,2,K)    0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
                 S(1,3,K)    0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
                 S(1,4,K)    0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
                 S(1,5,K)    0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
                 S(2,1,K)    0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
                 S(2,2,K)    0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
                 S(2,3,K)    0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
                 S(2,4,K)    0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
```

TABLE V - contd.

EXAMPLE 3 - contd.

S(2,5,K)	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
S(3,1,K)	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
S(3,2,K)	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
S(3,3,K)	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
S(3,4,K)	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
S(3,5,K)	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
S(4,1,K)	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
S(4,2,K)	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
S(4,3,K)	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
S(4,4,K)	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
S(4,5,K)	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
S(5,1,K)	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
S(5,2,K)	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
S(5,3,K)	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
S(5,4,K)	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
S(5,5,K)	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00

ZTRAN	ZSOLN	ZTRAN	ZSOLN	ZTRAN	ZSOLN
1.0000000E-02	1.0000000E-02	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
0.0000000E+00	0.0000000E+00	1.0000000E-01	1.0000000E-01	0.0000000E+00	0.0000000E+00
0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	1.0000000E-02	1.0000000E-02
0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	-1.0000000E-02	-1.0000000E-02
0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
1.0000000E-01	1.0000000E-01	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
0.0000000E+00	0.0000000E+00	1.0000000E-04	1.0000000E-04	0.0000000E+00	0.0000000E+00
0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
-1.0000000E-01	-1.0000000E-01	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
0.0000000E+00	0.0000000E+00	-1.0000000E-02	-1.0000000E-02	0.0000000E+00	0.0000000E+00
0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	-1.0000000E-01	-1.0000000E-01
0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
0.0000000E+00	0.0000000E+00	1.0000000E-02	1.0000000E-02	1.0000000E-02	1.0000000E-02
0.0000000E+00	0.0000000E+00	1.0000000E-01	1.0000000E-01	0.0000000E+00	0.0000000E+00
0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	1.0000000E-02	1.0000000E-02
0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
-1.0000000E-04	-1.0000000E-04	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
1.0000000E-02	1.0000000E-02	1.0000000E-02	1.0000000E-02	0.0000000E+00	0.0000000E+00
0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	1.0000000E-01	1.0000000E-01
0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	1.0000000E-02	1.0000000E-02
1.0000000E-01	1.0000000E-01	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
0.0000000E+00	0.0000000E+00	1.0000000E-04	1.0000000E-04	0.0000000E+00	0.0000000E+00
0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
1.0000000E-01	1.0000000E-01	1.0000000E-01	1.0000000E-01	0.0000000E+00	0.0000000E+00
0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	1.0000000E-02	1.0000000E-02
1.0000000E-01	1.0000000E-01	0.0000000E+00	0.0000000E+00	1.0000000E-01	1.0000000E-01

TABLE V - contd.

EXAMPLE 3 - contd.

```
     0.0000000E+00  0.0000000E+00      1.0000000E-04  1.0000000E-04      0.0000000E+00  0.0000000E+00
0
     0.0000000E+00  0.0000000E+00      0.0000000E+00  0.0000000E+00     -1.0000000E-02 -1.0000000E-02
     0.0000000E+00  0.0000000E+00      0.0000000E+00  0.0000000E+00     -1.0000000E-01 -1.0000000E-01
     1.0000000E-02  1.0000000E-02      0.0000000E+00  0.0000000E+00      0.0000000E+00  0.0000000E+00
     0.0000000E+00  0.0000000E+00      1.0000000E-01  1.0000000E-01      0.0000000E+00  0.0000000E+00
     1.0000000E-04  1.0000000E-04      1.0000000E-04  1.0000000E-04      0.0000000E+00  0.0000000E+00
0
    -1.0000000E-02 -1.0000000E-02     -1.0000000E-02 -1.0000000E-02     -1.0000000E-02 -1.0000000E-02
     0.0000000E+00  0.0000000E+00      0.0000000E+00  0.0000000E+00      0.0000000E+00  0.0000000E+00
    -1.0000000E-02 -1.0000000E-02      0.0000000E+00  0.0000000E+00      0.0000000E+00  0.0000000E+00
     0.0000000E+00  0.0000000E+00     -1.0000000E-01 -1.0000000E-01      0.0000000E+00  0.0000000E+00
     0.0000000E+00  0.0000000E+00      0.0000000E+00  0.0000000E+00     -1.0000000E-04 -1.0000000E-04
0
     0.0000000E+00  0.0000000E+00      0.0000000E+00  0.0000000E+00      0.0000000E+00  0.0000000E+00
    -1.0000000E-01 -1.0000000E-01     -1.0000000E-01 -1.0000000E-01     -1.0000000E-01 -1.0000000E-01
    -1.0000000E-02 -1.0000000E-02      0.0000000E+00  0.0000000E+00      0.0000000E+00  0.0000000E+00
     0.0000000E+00  0.0000000E+00     -1.0000000E-01 -1.0000000E-01      0.0000000E+00  0.0000000E+00
     0.0000000E+00  0.0000000E+00      0.0000000E+00  0.0000000E+00     -1.0000000E-04 -1.0000000E-04
0
     0.0000000E+00  0.0000000E+00      0.0000000E+00  0.0000000E+00      0.0000000E+00  0.0000000E+00
     0.0000000E+00  0.0000000E+00      0.0000000E+00  0.0000000E+00      0.0000000E+00  0.0000000E+00
    -1.0000000E-02 -1.0000000E-02     -1.0000000E-02 -1.0000000E-02      0.0000000E+00  0.0000000E+00
    -1.0000000E-01 -1.0000000E-01      0.0000000E+00  0.0000000E+00     -1.0000000E-01 -1.0000000E-01
     0.0000000E+00  0.0000000E+00     -1.0000000E-04 -1.0000000E-04     -1.0000000E-04 -1.0000000E-04
0
 50     .78540    0  3.6113357E+02  3.6113358E+02  2.7071068E+00  1.2928932E+00  4.5000000E+01        110
                 U(1,J)      7.0710678E-01  7.0710678E-02  0.0000000E+00  0.0000000E+00  2.9289322E+01
                 U(2,J)     -7.0710678E+00  7.0710678E-01  0.0000000E+00  0.0000000E+00  7.0710679E+02
                 U(3,J)      0.0000000E+00  0.0000000E+00  1.0000000E+00  7.8539817E-02  0.0000000E+00
                 U(4,J)      0.0000000E+00  0.0000000E+00  0.0000000E+00  1.0000000E+00  0.0000000E+00
                 U(5,J)      0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  1.0000000E+00

                 S(1,1,K)   -2.4999979E-03  2.4999991E-04 -8.4703295E-18 -4.3512594E-11  2.4999991E-01
                 S(1,2,K)    2.4999991E-04  1.0355356E-05  4.2351647E-19 -2.4701251E-12  1.0355328E-02
                 S(1,3,K)   -8.4703295E-18  4.2351647E-19  0.0000000E+00 -4.2351647E-19 -8.4703295E-16
                 S(1,4,K)   -4.3512594E-11 -2.4701251E-12 -4.2351647E-19 -1.4644658E-05 -3.0758907E-09
                 S(1,5,K)    2.4999991E-01  1.0355328E-02 -8.4703295E-16 -3.0758907E-09 -2.5000013E+01
                 S(2,1,K)    4.6447290E-08 -1.7405893E-09  1.2924697E-22 -8.8496523E-10  3.5355317E+00
                 S(2,2,K)   -1.7405893E-09 -3.5355301E-04 -1.3552527E-17 -7.5073929E-11 -2.2711833E-07
                 S(2,3,K)    1.2924697E-22 -1.3552527E-17  0.0000000E+00 -6.7762636E-18 -2.7105054E-14
                 S(2,4,K)   -8.8496523E-10 -7.5073929E-11 -6.7762636E-18 -3.5355329E-04 -8.5854197E-08
                 S(2,5,K)    3.5355317E+00 -2.2711833E-07 -2.7105054E-14 -8.5854197E-08 -7.0710708E+02
                 S(3,1,K)    0.0000000E+00  0.0000000E+00  0.0000000E+00  3.5355339E-04  0.0000000E+00
                 S(3,2,K)    0.0000000E+00  0.0000000E+00  0.0000000E+00  1.4644661E-05  0.0000000E+00
                 S(3,3,K)    0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
                 S(3,4,K)    3.5355339E-04  1.4644661E-05  0.0000000E+00  0.0000000E+00  3.9145690E-03
                 S(3,5,K)    0.0000000E+00  0.0000000E+00  0.0000000E+00  3.9145690E-03  0.0000000E+00
                 S(4,1,K)    0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
                 S(4,2,K)    0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
                 S(4,3,K)    0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
                 S(4,4,K)    0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
                 S(4,5,K)    0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00
                 S(5,1,K)    0.0000000E+00  0.0000000E+00  0.0000000E+00  0.0000000E+00 -1.2621774E-23
```

TABLE V - contd.

EXAMPLE 3 - contd.

S(5,2,K)	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	-1.2621774E-24
S(5,3,K)	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	-1.2621774E-23
S(5,4,K)	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	-1.2621774E-24
S(5,5,K)	-1.2621774E-23	-1.2621774E-24	-1.2621774E-23	-1.2621774E-24	-3.5527137E-07

	ZTRAN	ZSOLN	ZTRAN	ZSCLN	ZTRAN	ZSOLN
	7.0708178E-03	7.0708178E-03	7.0711714E-03	7.0711714E-03	0.0000000E+00	0.0000000E+00
	-7.0710678E-02	-7.0710678E-02	7.0707142E-02	7.0707142E-02	0.0000000E+00	0.0000000E+00
	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	1.0000000E-02	1.0000000E-02
	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
0						
	-1.4644658E-07	-1.4644658E-07	2.9286822E-03	2.9286822E-03	-7.0713178E-03	-7.0713178E-03
	-3.5355329E-06	-3.5355329E-06	7.0703608E-02	7.0703608E-02	7.0710678E-02	7.0710678E-02
	7.8539817E-03	7.8539817E-03	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
	1.0000000E-01	1.0000000E-01	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
	0.0000000E+00	0.0000000E+00	1.0000000E-04	1.0000000E-04	0.0000000E+00	0.0000000E+00
0						
	-7.0709643E-03	-7.0709643E-03	0.0000000E+00	0.0000000E+00	-1.4644658E-07	-1.4644658E-07
	-7.0714214E-02	-7.0714214E-02	0.0000000E+00	0.0000000E+00	-3.5355329E-06	-3.5355329E-06
	0.0000000E+00	0.0000000E+00	-1.0000000E-02	-1.0000000E-02	-7.8539817E-03	-7.8539817E-03
	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	-1.0000000E-01	-1.0000000E-01
	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
0						
	-2.9291822E-03	-2.9291822E-03	1.4142489E-02	1.4142489E-02	7.0708178E-03	7.0708178E-03
	-7.0717750E-02	-7.0717750E-02	-3.5358064E-06	-3.5358089E-06	-7.0710678E-02	-7.0710678E-02
	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	1.0000000E-02	1.0000000E-02
	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
	-1.0000000E-04	-1.0000000E-04	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
0						
	7.0706714E-03	7.0706713E-03	1.0000000E-02	1.0000000E-02	7.0711714E-03	7.0711714E-03
	-7.0714214E-02	-7.0714214E-02	7.0294368E-10	-5.5800316E-12	7.0707142E-02	7.0707142E-02
	7.8546886E-03	7.8546880E-03	0.0000000E+00	0.0000000E+00	1.0000000E-02	1.0000000E-02
	1.0000000E-01	1.0000000E-01	0.0000000E+00	0.0000000E+00	0.0000000E+00	0.0000000E+00
	0.0000000E+00	0.0000000E+00	1.0000000E-04	1.0000000E-04	0.0000000E+00	0.0000000E+00
0						
	7.0710249E-03	7.0710249E-03	1.0000061E-02	1.0000061E-02	-1.4644658E-07	-1.4644658E-07
	7.0703607E-02	7.0703607E-02	1.4141075E-01	1.4141075E-01	-3.5355329E-06	-3.5355329E-06
	7.8542745E-03	7.8542746E-03	0.0000000E+00	0.0000000E+00	1.7853982E-02	1.7853982E-02
	1.0000000E-01	1.0000000E-01	0.0000000E+00	0.0000000E+00	1.0000000E-01	1.0000000E-01
	0.0000000E+00	0.0000000E+00	1.0000000E-04	1.0000000E-04	0.0000000E+00	0.0000000E+00
0						
	2.9286822E-03	2.9286822E-03	2.9285358E-03	2.9285358E-03	-1.4141782E-02	-1.4141782E-02
	7.0703608E-02	7.0703600E-02	7.0700072E-02	7.0700073E-02	-3.5352515E-06	-3.5352490E-06
	1.0000000E-02	1.0000000E-02	7.8540599E-03	7.8540599E-03	0.0000000E+00	0.0000000E+00
	0.0000000E+00	0.0000000E+00	1.0000000E-01	1.0000000E-01	0.0000000E+00	0.0000000E+00
	1.0000000E-04	1.0000000E-04	1.0000000E-04	1.0000000E-04	0.0000000E+00	0.0000000E+00
0						
	-7.0713178E-03	-7.0713178E-03	-7.0714643E-03	-7.0714642E-03	-1.0000000E-02	-1.0000000E-02
	7.0710678E-02	7.0710678E-02	7.0707143E-02	7.0707143E-02	-7.0852371E-10	0.0000000E+00
	-1.0000000E-02	-1.0000000E-02	-7.8532745E-03	-7.8532745E-03	0.0000000E+00	0.0000000E+00
	0.0000000E+00	0.0000000E+00	-1.0000000E-01	-1.0000000E-01	0.0000000E+00	0.0000000E+00

TABLE V - contd.

EXAMPLE 3 - contd.

```
     0.0000000E+00  0.0000000E+00     0.0000000E+00  0.0000000E+00     -1.0000000E-04 -1.0000000E-04
0
    -7.0709643E-03 -7.0709643E-03    -7.0711107E-03 -7.0711107E-03     -9.9999394E-03 -9.9999394E-03
    -7.0714214E-02 -7.0714214E-02    -7.0717749E-02 -7.0717749E-02     -1.4143196E-01 -1.4143196E-01
    -1.0000000E-02 -1.0000000E-02    -7.8536888E-03 -7.8536888E-03      0.0000000E+00  0.0000000E+00
     0.0000000E+00  0.0000000E+00    -1.0000000E-01 -1.0000000E-01      0.0000000E+00  0.0000000E+00
     0.0000000E+00  0.0000000E+00     0.0000000E+00  0.0000000E+00     -1.0000000E-04 -1.0000000E-04
0
    -1.4644658E-07 -1.4644658E-07    -2.9291822E-03 -2.9291822E-03     -2.9293287E-03 -2.9293287E-03
    -3.5355329E-06 -3.5355329E-06    -7.0717750E-02 -7.0717750E-02     -7.0721286E-02 -7.0721286E-02
    -1.7853982E-02 -1.7853982E-02    -1.0000000E-02 -1.0000000E-02     -7.8539034E-03 -7.8539034E-03
    -1.0000000E-01 -1.0000000E-01     0.0000000E+00  0.0000000E+00     -1.0000000E-01 -1.0000000E-01
     0.0000000E+00  0.0000000E+00    -1.0000000E-04 -1.0000000E-04     -1.0000000E-04 -1.0000000E-04
0

 END OF SOTRM1

 CONTROL=  1.000
 NUMBER OF PARAMETERS READ =    2

 Q=             1.00000000
 DELSIN=        1.57079633 (CM)
 SOMAX=        30.00000000 (M)
 SO1=            .78539816 (M)
 OPTION=        0.00000000
 NUM=           4.00000000
 MAX=          50.00000000
 NPRINT=      -50.00000000

 CONTROL=  3.100
 NUMBER OF PARAMETERS READ =    3

 P( 1)=      .01000000 DELTA P/PO
 P( 2)=      .05000000 DELTA P/PO
 P( 3)=      .10000000 DELTA P/PO

 CONTROL=  3.200
 NUMBER OF PARAMETERS READ =   16

 Z(  1)=   510.72000000(MEV) Z(  2)=    90.00000000(DEG) Z(  3)=      2.00000000( M) Z(  4)=      1.00000000( M)
 Z(  5)=      .50000000(CM)  Z(  6)=     5.00000000(MR)  Z(  7)=       .50000000(CM) Z(  8)=      5.00000000(MR)
 Z(  9)=     1.00000000(CM)  Z( 10)=    10.00000000(MR)  Z( 11)=      1.00000000(CM) Z( 12)=     10.00000000(MR)
 Z( 13)=     5.00000000(CM)  Z( 14)=    20.00000000(MR)  Z( 15)=      5.00000000(CM) Z( 16)=     20.00000000(MR)

 CONTROL= 99.000

START OF SOTRM1

1 THE FOLLOWING HEADINGS ARE TO BE USED FOR COL. 1-7

              K= 0          PX(MEV/C)    PY(MEV/C)         X(M)          Y(M)      THETA(DEG)    FUNC CALLS
```

TABLE V - contd.

EXAMPLE 3 - contd.

```
                K=(1,NUM-1)      X(CM)          X (MR)         Y(CM)          Y (MR)      DP/PO            DPX/PO         DPY/PO
                 U(I,J)   / J=    1              2              3              4            5
                 S(I,J,K) / K=    1              2              3              4            5

    I   SO(METER)  K              1              2              3              4              5              6              7

    0     .78540   0  5.1072000E+02 -8.7594838E-13  2.0000000E+00  1.0000000E+00  9.0000000E+01              1
                   1  5.0000000E-01  5.0000000E+00  5.0000000E-01  5.0000000E+00  1.0000000E-02  5.0499158E-03  5.0499790E-03
01  1.0000000E+00  1.0000000E+010E5.0000000E-020E1.0499300E-02  1.0499825E-02
                   3  5.0000000E+00  2.0000000E+01  5.0000000E+00  2.0000000E+01  1.0000000E-01  2.1994134E-02  2.1998533E-02


         ZTRAN          ZSOLN                  ZTRAN          ZSOLN                  ZTRAN          ZSOLN
     5.0000000E-01  5.0000000E-01          1.0000000E+00  1.0000000E+00          5.0000000E+00  5.0000000E+00
     5.0000000E+00  5.0000000E+00          1.0000000E+01  1.0000000E+01          2.0000000E+01  2.0000000E+01
     5.0000000E-01  5.0000000E-01          1.0000000E+00  1.0000000E+00          5.0000000E+00  5.0000000E+00
     5.0000000E+00  5.0000000E+00          1.0000000E+01  1.0000000E+01          2.0000000E+01  2.0000000E+01
     1.0000000E-02  1.0000000E-02          5.0000000E-02  5.0000000E-02          1.0000000E-01  1.0000000E-01
0
   50    1.57080   0  3.6113357E+02  3.6113358E+02  2.7071068E+00  1.2928932E+00  4.5000000E+01            110
                   1  1.0015650E+00  7.0184714E+00  8.9560510E-01  5.0000000E+00  1.0000000E-02  7.0885093E-03  5.0499790E-03
                   2  2.8556731E+00  3.3945505E+01  1.7995120E+00  1.0000000E+01  5.0000000E-02  3.5634154E-02  1.0499825E-02
                   3  7.9123469E+00  4.6022222E+01  6.6705157E+00  2.0000000E+01  1.0000000E-01  5.0596455E-02  2.1998533E-02


         ZTRAN          ZSOLN                  ZTRAN          ZSOLN                  ZTRAN          ZSOLN
     1.0015533E+00  1.0015650E+00          2.8536060E+00  2.8556731E+00          7.9058851E+00  7.9123469E+00
     7.0180348E+00  7.0184714E+00          3.3870414E+01  3.3945505E+01          4.5679093E+01  4.6022222E+01
     8.9559054E-01  8.9560510E-01          1.7993127E+00  1.7995120E+00          6.6688810E+00  6.6705157E+00
     5.0000000E+00  5.0000000E+00          1.0000000E+01  1.0000000E+01          2.0000000E+01  2.0000000E+01
     1.0000000E-02  1.0000000E-02          4.9999999E-02  5.0000000E-02          9.9999996E-02  1.0000000E-01
0

 END OF SOTRM1

 CONTROL= -1.000

...END OF COMPUTATIONS...
```

TABLE VI

PROGRAM LISTING

```
      PROGRAM SOTRM(INPUT=300,OUTPUT=1000,TAPE1=1000,TAPE60=INPUT,TAPE61
     .                 = OUTPUT)
*     COMMENT THIS IS A CALLING PROGRAM FOR SOTRM1. SEE UCRL 19823.
*     BEGIN
            REAL    S
            INTEGER K,L,I,MAXRAY,NUM,N4,NUM1
            REAL    P(40),Z(164),PARAM(10),PR(4),LOW LIM,UP LIM,DUM,A,
     .              A1,A2,M1(5,5),M2(5,5,5),U,V
            INTEGER H1( 9),H2( 9),PI(5)
             INTEGER TEXT(13)
            LOGICAL START
            COMMON  /BOUND/ LOW LIM(3),UP LIM(3)
     .              /YAFS/  DUM(10),A(5),U(5,5),V(5,5,5)
     .              /TAME/ A1(10,10), A2(10,10)
     .             /PARAM/ CONST(8)
            DATA    START/.TRUE./,MAXRAY/31/,(H1(I),I=1,8)/3H Q=,
     .              8H DELSIN=,7H SOMAX=,5H SO1=,8H OPTION=,5H NUM=,
     .              5H MAX=,8H NPRINT=/,(H2(I),I=1,8)/1H ,5H (CM),
     .              2*4H (M),4*1H /
            PRINT 2998
    1       READ 4C01, S $ PRINT  12 ,S $ IF(S.EQ.-1.) 2,4
    2        PRINT 5000$ STOP
    4        IF(S.EQ.1.) 100,199
*            BEGIN
  100              READ 4002, K, (I,PARAM(I),L=1,K)
                   IF(PARAM(8).LT.0.0) REWIND 1
                   IF(START) 102,108
*                  BEGIN
  102                    IF(K.NE.8) 104,106
*                        BEGIN
  104                          PRINT 9000,K  $ STOP
 9000                          FORMAT (///*1  K=*I3* YOU HAVE NOT SET*,
     .                                * ALL THE INITIAL PARAMETERS*///)
  106                          CONTINUE
*                        END
                         START=.FALSE.
  108                    CONTINUE
*                  END
                   NUM=PARAM(6)
                   NUM1=NUM-1
                   N4=4*NUM
                   PRINT 2999,K
                   PRINT 3000 , ((H1(I),PARAM(I),H2(I)),I=1,8)
                   IF(PARAM(6).GT.MAXRAY) 110,112
*                  BEGIN
  110                    PRINT 9001,PARAM(7)$ STOP
 9001                    FORMAT(///* TOO MANY RAYS;NUM=*F10.6///)
  112                    CONTINUE
*                  END
                   DO 114 I=1,4,1
  114                 PR(I)= PARAM(I)
                   DO 116 I= 1,4,1
  116                 PI(I)= PARAM(I+4)+SIGN(0.0005,PARAM(I+4))
                   GO TO 1
```

TABLE VI - contd.

```
 199          CONTINUE                                                 SOTRM.56
*         END ELSE                                                     SOTRM.57
          IF(S.EQ.2.) 200,299                                          SOTRM.58
*         BEGIN                                                        SOTRM.59
 200          READ  4001, (LOW LIM(I),UP LIM(I),I=1,3)                 SOTRM.60
              PRINT 3004, (I,LOW LIM(I), I,UP LIM(I),I=1,3)            SOTRM.61
              GOTO 1                                                   SOTRM.62
 299          CONTINUE                                                 SOTRM.63
*         END ELSE                                                     SOTRM.64
          IF(S.GE.3..AND.S.LT.4.) 300, 399                             SOTRM.65
 300          IF(S.EQ.3.0.OR.S.EQ.3.1) 302,304                         SOTRM.66
*             BEGIN                                                    SOTRM.67
 302                READ 4002,K,(I,P(I),I=1,K,1)                       SOTRM.68
                    PRINT 2999,K                                       SOTRM.69
                    PRINT 3006,(I,P(I),I=1,NUM1,1)                     SOTRM.70
*             END                                                      SOTRM.71
 304          IF(S.EQ.3.0.OR.S.EQ.3.2) 306,308                         SOTRM.72
*             BEGIN                                                    SOTRM.73
 306                READ 4002,L,(I,Z(I),I=1,L,1)                       SOTRM.74
                    PRINT 2999,L                                       SOTRM.75
                    PRINT 3008, (I,Z(I),I=1,N4,1)                      SOTRM.76
*              END                                                     SOTRM.77
 308          GOTO1                                                    SOTRM.78
 399          CONTINUE                                                 SOTRM.79
*         END ELSE                                                     SOTRM.80
          IF(S.EQ.4.) 400,499                                          SOTRM.81
*         BEGIN COMMENT INPUT A1 AND A2,F.SELPH FIELD, 5 ITEMS/CARD    SOTRM.82
 400          READ  4008,((A1(I,J),J=1,10),I=1,10),                    SOTRM.83
                         ((A2(I,J),J=1,10),I=1,10)                     SOTRM.84
              PRINT 3010,((A1(I,J),J=1,10),I=1,10)                     SOTRM.85
              PRINT 3011,((A2(I,J),J=1,10),I=1,10)                     SOTRM.86
              GOTO 1                                                   SOTRM.87
 499          CONTINUE                                                 SOTRM.88
*         END ELSE                                                     SOTRM.89
          IF(S.GE.5..AND.S.LT.6.) 500,599                              SOTRM.90
*         BEGIN  COMMENT CHANGE A1 OR A2 OR BOTH                       SOTRM.91
 500          IF(S.EQ.5..OR.S.EQ.5.1)                                  SOTRM.92
              READ 4010, K,((I,J,A1(I,J)),L=1,K)$ PRINT 2999,K         SOTRM.93
              IF(S.EQ.5..OR.S.EQ.5.2)                                  SOTRM.94
              READ 4010, K,((I,J,A2(I,J)),L=1,K)$ PRINT 2999,K         SOTRM.95
              PRINT 3010,((A1(I,J),J=1,10),I=1,10)                     SOTRM.96
              PRINT 3011,((A2(I,J),J=1,10),I=1,10)                     SOTRM.97
              GOTO 1                                                   SOTRM.98
 599          CONTINUE                                                 SOTRM.99
*         END ELSE                                                     SOTRM.100
          IF(S.EQ.6.) 600,699                                          SOTRM.101
*         BEGIN COMMENT INPUT  INCREMENTS                              SOTRM.102
 600          READ  4002, K,((I,A(I)),L=1,K)$ PRINT 2999,K             SOTRM.103
              PRINT 3012,   ((L,A(L)),L=1,5)                           SOTRM.104
              GOTO 1                                                   SOTRM.105
 699          CONTINUE                                                 SOTRM.106
*         END ELSE                                                     SOTRM.107
          IF(S.EQ.7) 800,899                                           SOTRM.108
*         BEGIN COMMENT INPUT TEXT THAT IDENTIFIES THE TABLES AND      SOTRM.109
```

TABLE VI - contd.

```
*              OUTPUT THE FIRST AND SECOND CRDER ELEMENTS.  THIS
*              SECTION REQUIRES CUTRT A SUBROUTINE TO OUTPUT THE
*              TABLES.
 800           READ 4014, TEXT
4014           FORMAT(13A10)
               CALL OUTRT(TEXT,M1,M2)
               GOTO 1
 899           CONTINUE
*          END ELSE
           IF(S.EQ.99) 700,799
*          BEGIN COMMENT EXECUTE SOTRM1
 700           PRINT 4012
               CALL SOTRM1(PARAM(4),Z,P,M1,M2,PR,PI)
               PRINT 4011
 799           CONTINUE
*          END
           GOTO 1
*
*          COMMENT ALL FORMAT STATEMENTS FOLLOW
  10       FORMAT(I2)
  12       FORMAT(/* CONTROL=*F7.3)
4000       FORMAT(I5/(5(I5,E10.0)))
4001       FORMAT(8E10.0)
4002       FORMAT(I5/(I5,5X,E15.0))
4008       FORMAT(5E10.0)
4010       FORMAT(I5/(I5,I5,E15.0))
4011       FORMAT(//* END OF SOTRM1 *//)
4012       FORMAT(//*START OF SOTRM1*//)
2998       FORMAT(*1*)
2999       FORMAT(* NUMBER OF PARAMETERS READ =*I5)
3000       FORMAT(/(A10,F15.8,A10/))
3004       FORMAT((* LOW LIM(*I2*)=*F15.8,*(M)  UP LIM(*I2*)=*F15.8
     .             *(M)*/))
3006       FORMAT(/(* P(*I2*)=*F15.8* DELTA P/P0*/))
3008       FORMAT(/ * Z(*I3*)=*F15.8*(MEV)*,* Z(*I3*)=*F15.8*(DEG)*,
     .            2(* Z(*I3*)=*F15.8*( M) *)/,
     .            (2(* Z(*I3*)=*F15.8*(CM) *
     .            * Z(*I3*)=*F15.8*(MR) *))
3010       FORMAT(//* A1(I,J)*/(10E12.6))
3011       FORMAT(//* A2(I,J)*/(10E12.6))
3012       FORMAT(/* DERIVATIVE INCREMENTS*/(* A(*I2*)=*E15.6))
5000       FORMAT(//*...END OF CONPUTATIONS...*)
      END

      SUBROUTINE SOTRM1(SO1,Z1,P1,V,W,PR,PI)$ REAL SO1$ REAL Z1(1),P1(1)
     .                                       ,V(5,5),W(5,5,5),PR(1)
                                             INTEGER PI(1)
*     BEGIN COMMENT SEE UCRL 19823.
           REAL Q,DELSO,SO,SOMAX,PO,SOOUT,BB02
           INTEGER NUM,NUM1,N,MAX,NPRINT,I,J,K,L,LOOP,FIN,NXTSTP,COUNT
     .            ,I1,STEP,PRTCNT,KK
           REAL Z,P0,P,BB1,BB2,BB3,F,CONST,YP,YM,A ,T(992),ZOUT(7)
     .     ,ZSAVE,EPS
```

TABLE VI - contd.

```
          LOGICAL  BOOL1,BOOL2,LAST,TEXT                                 SOTRM1.11
          COMMON  /CASES/ NUM,L,K                                        SOTRM1.12
     .              /CHARGE/ Q   /MOM/ PO,P(40)                          SOTRM1.13
     .              /FIELD/ BB02,BB1(40),BB2(40),BB3(40)                 SOTRM1.14
     .              /SOLN/ Z(164)  /DER/F(164)                           SOTRM1.15
     .              /PARAM/ CONST( 8)                                    SOTRM1.16
     .              /LIMIT/ SO,SOMAX,MAX                                 SOTRM1.17
     .              /YAFS/ YP( 5),YM( 5),A( 5),U(5,5),S(5,5,5)           SOTRM1.18
     .              /WORK/ COUNT,STEP                                    SOTRM1.19
          COMMON /INIT/ ZSAVE(150)                                       SOTRM1.20
          DATA    (CONST(I),I=1,7) /1.602072E-19,.5343922E-21,1.,1.E-2,  SOTRM1.21
     .              1.E-3,1.74532925199433E-2,1.E-4/,                    SOTRM1.22
     .          (A(I),I=1,5,1)/ .01,.1,.01,.1,.0001/                     SOTRM1.23
          DOUBLE PRECISION T,DELSO                                       SOTRM1.24
          EXTERNAL FUNC                                                  SOTRM1.25
          DIMENSION EPS(6)                                               SOTRM1.26
          ASSIGN 50 TO LOOP$ ASSIGN 10000 TO FIN                         SOTRM1.27
          ASSIGN 200TO NXTSTP                                            SOTRM1.28
          Q=PR(1)*CONST(1)$ DELSO= PR(2)*CONST(4)$ SO= SO1*CONST(3)      SOTRM1.29
          SOMAX= PR(3)*CONST(3)$ COUNT=0                                 SOTRM1.30
*         COMMENT SET THE INITIAL CONDITIONS OF THE REFERENCE RAY        SOTRM1.31
*                                                                        SOTRM1.32
          PO=Z1(1)*CONST(2)                                              SOTRM1.33
          Z(1)= SIN(Z1(2)*CONST(6))$  Z(2)= COS(Z1(2)*CONST(6))          SOTRM1.34
          Z(3)= Z1(3)*CONST(3)$ Z(4)= Z1(4)*CONST(3)                     SOTRM1.35
*                                                                        SOTRM1.36
          NPRINT= IABS(PI(4))                                            SOTRM1.37
          NUM=PI(2) $ NUM1=NUM-1 $ N=4*NUM $ MAX=PI(3)                   SOTRM1.38
    4     IF(PI(1).NE.0) 6,10                                            SOTRM1.39
*         BEGIN COMMENT SET THE INITIAL CONDITIONS OF THE NEAR BY RAYS   SOTRM1.40
*               FOR GENERATION OF U AND S                                SOTRM1.41
    6           IF(PI(1).EQ.1.OR.PI(1).EQ.-1) NUM=11                     SOTRM1.42
                IF(PI(1).EQ.2) NUM= 21                                   SOTRM1.43
                IF(PI(1).EQ.3) NUM= 31                                   SOTRM1.44
                NUM1=NUM-1$ N=4*NUM$ MAX=PI(3)                           SOTRM1.45
                CALL SETZ(Z1,P1)                                         SOTRM1.46
*         END                                                            SOTRM1.47
   10     IF(NUM1.GT.0) CALL ZINIT(P1,Z1)                                SOTRM1.48
          CALL SAVEZP(ZSAVE,Z1,P1,PI)                                    SOTRM1.49
*         COMMENT INTEGRATION AND PRINT LOOP                             SOTRM1.50
   16     STEP= 0$ PRTCNT= 0$ LAST= .FALSE.$ TEXT= .TRUE.                SOTRM1.51
                            IF(NPRINT.NE.0) PRINT 4000                   SOTRM1.52
          CALL INTO(4*NUM,SO,FUNC,Z,F,T,DELSO)                           SOTRM1.53
*     LOOP..                                                             SOTRM1.54
   50     DO 500 I1= 1,MAX                                               SOTRM1.55
*         BEGIN                                                          SOTRM1.56
                IF(SO.GE.SOMAX) 46,48                                    SOTRM1.57
*               BEGIN                                                    SOTRM1.58
   46                 MAX= I1-1$ GOTO 500                                SOTRM1.59
*               END                                                      SOTRM1.60
   48           IF(NPRINT.NE.0.OR.LAST) 52,200                           SOTRM1.61
*               BEGIN                                                    SOTRM1.62
   52                 IF(.NOT.LAST.AND..NOT.TEXT) GOTO NXTSTP            SOTRM1.63
                      SOOUT= SO/CONST(3)$ K=0.                           SOTRM1.64
```

TABLE VI - contd.

```
                  IF(TEXT) 54, 60                                 SOTRM1.65
*                 BEGIN COMMENT OUTPUT REFERENCE RAY              SOTRM1.66
   54                   IF(ABS(Z(1)).GT.1.) 55,56                 SOTRM1.67
   55                   ZOUT(5)= Z(1)+ 1000. $ GOTO 58            SOTRM1.68
   56                   ZOUT(5)= ASIN(Z(1))/CONST(6)              SOTRM1.69
   58                   CONTINUE                                  SOTRM1.70
                        ZOUT(1)= (Z(1)/CONST(2))* PO              SOTRM1.71
                        ZOUT(2)=(Z(2)/CONST(2))*PO                SOTRM1.72
                        ZOUT(3)= Z(3)/CONST(3)                    SOTRM1.73
                        ZOUT(4)= Z(4)/CONST(3)                    SOTRM1.74
                        PRINT 4002, STEP,SOOUT,K,(ZOUT(L),L=1,5), SOTRM1.75
                                    COUNT                         SOTRM1.76
*                 END                                             SOTRM1.77
   60             IF(LAST) 62,64                                  SOTRM1.78
*                 BEGIN COMMENT SET THE FINAL CONDITIONS OF THE   SOTRM1.79
*                       REFERENCE RAY                             SOTRM1.80
   62                   Z1(2)=ATAN2(Z(1),Z(2))/CONST(6)           SOTRM1.81
                        Z1(3)=Z(3)/CONST(3)                       SOTRM1.82
                        Z1(4)=Z(4)/CONST(3)                       SOTRM1.83
                        S01=SOOUT                                 SOTRM1.84
*                 END                                             SOTRM1.85
   64             IF(PI(1).EQ.0.A.NUM1.NE.0) 66,74                SOTRM1.86
*                 BEGIN                                           SOTRM1.87
   66             DO 72 K=1,NUM1                                  SOTRM1.88
*                 BEGIN                                           SOTRM1.89
                        L=4*K$ CALL ZFINAL(ZOUT,0)                SOTRM1.90
                        ZOUT(6)= Z(L+2)$ ZOUT(7)= Z(L+4)          SOTRM1.91
                        ZOUT(5)= P(K)-1.                          SOTRM1.92
                        IF(TEXT) PRINT 4004,K,(ZOUT(I),I=1,7)     SOTRM1.93
                        IF(LAST) 68,72                            SOTRM1.94
*                       COMMENT SET FINAL CONDITIONS OF THE NEARBY SOTRM1.95
*                               RAYS                              SOTRM1.96
   68                   DO 70 I= 1,4                              SOTRM1.97
   70                   Z1(L+1)= ZOUT(I)                          SOTRM1.98
   72                   CONTINUE                                  SOTRM1.99
*                 END                                             SOTRM1.100
                  IF(PI(4).LT.0.AND.TEXT) CALL APTRAN(0)          SOTRM1.101
   73             IF(LAST) GO TO FIN                              SOTRM1.102
                  GO TO NXTSTP                                    SOTRM1.103
*                 END                                             SOTRM1.104
   74             IF(ABS(PI(1)).GT.0)  76,100                     SOTRM1.105
*                 BEGIN                                           SOTRM1.106
   76                   DO 86 KK=1,5                              SOTRM1.107
*                       BEGIN                                     SOTRM1.108
                              L=4*KK                              SOTRM1.109
                              K=KK                                SOTRM1.110
                              CALL ZFINAL(YP,0)                   SOTRM1.111
                              K=KK+5                              SOTRM1.112
                              CALL ZFINAL(YM,20)                  SOTRM1.113
                              CALL YPYM5(KK,5,5)                  SOTRM1.114
   77                         DO 78 I=1,5                         SOTRM1.115
   78                         U(I,KK)=(YP(I)-YM(I))/(2.0*A(KK))   SOTRM1.116
                             IF(PI(1).NE.1)  80,84                SOTRM1.117
   80                         DO 82 I=1,5                         SOTRM1.118
```

TABLE VI - contd.

```
                               S(I,KK,KK)=(YP(I)+YM(I))/(2.0*A(KK)     SOTRM1.119
       .                       **2)                                    SOTRM1.120
   82                          CONTINUE                                SOTRM1.121
   84                          CONTINUE                                SOTRM1.122
   86                          CONTINUE                                SOTRM1.123
*                          END                                         SOTRM1.124
                           IF(TEXT.AND.PI(1).NE.0) 88,100              SOTRM1.125
*                          BEGIN                                       SOTRM1.126
   88                          PRINT 4006,((I,(U(I,K),K=1,5)),I=1,5)   SOTRM1.127
                               PRINT 4010                              SOTRM1.128
                               IF(PI(1).EQ.-1)                         SOTRM1.129
       .                       PRINT 4007,                             SOTRM1.130
       .                       ((I,(S(I,K,K),K=1,5)),I=1,5)            SOTRM1.131
       .                       IF(PI(4).LT.0.A.PI(1).LE.1)             SOTRM1.132
       .                       CALL APTRAN(1,PI(1))                    SOTRM1.133
*                          END                                         SOTRM1.134
*                      END                                             SOTRM1.135
  100                  IF(PI(1).GT.1) 102,104                          SOTRM1.136
*                      BEGIN                                           SOTRM1.137
  102                      CALL SF(4,44,10,1)$ CALL SF(3,60,14,2)      SOTRM1.138
                           CALL SF(2,72,17,3)$ CALL SF(1,80,19,4)      SOTRM1.139
                           IF(TEXT) 103,104                            SOTRM1.140
*                          BEGIN                                       SOTRM1.141
  103                          PRINT 4008,                             SOTRM1.142
       .                       ((((I,J,(S(I,J,K),K=1,5)),J=1,5),I=1,5  SOTRM1.143
       .                                                             ) SOTRM1.144
                               IF(PI(4).LT.0) CALL APTRAN(1,PI(1))     SOTRM1.145
*                          END                                         SOTRM1.146
*                      END                                             SOTRM1.147
  104                  IF(LAST) GOTO 509                               SOTRM1.148
*                  END                                                 SOTRM1.149
*              NXTSTP..                                                SOTRM1.150
  200              CALL INT(SO,FUNC,Z,F,T,BOOL1)$ TEXT= .FALSE.        SOTRM1.151
                   IF(BOOL1) 202,204                                   SOTRM1.152
*                  BEGIN                                               SOTRM1.153
  202                  STEP= STEP + 1                                  SOTRM1.154
                       PRTCNT= PRTCNT+1$ IF(PRTCNT.EQ.NPRINT) 203,204  SOTRM1.155
*                          BEGIN                                       SOTRM1.156
  203                          TEXT= .TRUE.$ PRTCNT= 0                 SOTRM1.157
*                          END                                         SOTRM1.158
*                  END                                                 SOTRM1.159
  204              CONTINUE                                            SOTRM1.160
  500              CONTINUE                                            SOTRM1.161
*              END OF LOOP                                             SOTRM1.162
               IF(.NOT.LAST) 501, 508                                  SOTRM1.163
*              BEGIN                                                   SOTRM1.164
  501              IF(NPRINT.EQ.0) 502,504                             SOTRM1.165
  502              TEXT=.FALSE.$ GOTO 506                              SOTRM1.166
  504              TEXT=.TRUE.                                         SOTRM1.167
  506              LAST= .TRUE.$   MAX=2$ SOMAX= SOMAX+.05             SOTRM1.168
                   GOTO LOOP                                           SOTRM1.169
  508              CONTINUE                                            SOTRM1.170
*              END                                                     SOTRM1.171
  509          IF(PI(1).NE.0) 510,512                                  SOTRM1.172
```

TABLE VI - contd.

```
*         BEGIN                                                                SOTRM1.173
 510            DO 511 I=1,5,1                                                 SOTRM1.174
                DO 511 J=1,5,1                                                 SOTRM1.175
                V(I,J)=U(I,J)                                                  SOTRM1.176
 511            IF(PI(1).EQ.-1) W(I,J,J)= S(I,J,J)                             SOTRM1.177
 512            CONTINUE                                                       SOTRM1.178
*         END                                                                  SOTRM1.179
          IF(PI(1).GT.1) 514,518                                               SOTRM1.180
 514      DO 516 I=1,5,1                                                       SOTRM1.181
          DO 516 J=1,5,1                                                       SOTRM1.182
          DO 516 K=1,5,1                                                       SOTRM1.183
 516      W(I,J,K)= S(I,J,K)                                                   SOTRM1.184
 518      CONTINUE                                                             SOTRM1.185
*     FIN..                                                                    SOTRM1.186
10000 RETURN                                                                   SOTRM1.187
*                                                                              SOTRM1.188
 4000 FORMAT(*1 THE FOLLOWING HEADINGS ARE TO BE USED FOR COL. 1-7*//          SOTRM1.189
     .     19X,*K= 0*,11X,*PX(MEV/C)*,4X,*PY(MEV/C)*,9X,*X(M)*,9X,             SOTRM1.190
     .     *Y(M)*,5X,*THETA(DEG)*,4X,*FUNC CALLS*/19X,*K=(1,NUM-1)*,           SOTRM1.191
     .     6X,*X(CM)*,10X,*X (MR)*,8X,*Y(CM)*,9X,*Y (MR)*,5X,*DP/PO*,          SOTRM1.192
     .     12X,*DPX/PO*,8X,*DPY/PO*/20X,*U(I,J)*,3X,*/ J=*,4X,*1*,13X,         SOTRM1.193
     .     *2*,13X,*3*,13X,*4*,13X,*5*/20X,*S(I,J,K) / K=*,4X,*1*,13X,         SOTRM1.194
     .     *2*,13X,*3*,13X,*4*,13X,*5*///5X,*I*,3X,*SO(METER)*                 SOTRM1.195
     .     ,2X,*K*,14X,                                                        SOTRM1.196
     .     *1*,13X,*2*,13X,*3*,13X,*4*,13X,*5*,13X,*6*,13X,*7*//)              SOTRM1.197
 4002 FORMAT(1X,I5,1X,F10.5,2X,I3,   5E15.7,I14)                               SOTRM1.198
 4004 FORMAT(19X,I3,7E15.7)                                                    SOTRM1.199
 4006 FORMAT(20X,*U(*I1*,J)*4X,5E15.7)                                         SOTRM1.200
 4007 FORMAT(20X,*S(*I1*,K,K)*,  2X,5E15.7)                                    SOTRM1.201
 4008 FORMAT(20X,*S(*I1*,*I1*,K)*2X,5E15.7)                                    SOTRM1.202
 4010 FORMAT(/)                                                                SOTRM1.203
      END                                                                      SOTRM1.204
                                                                               SOTRM1.205
                                                                               SOTRM1.206
      SUBROUTINE ZINIT(P1,Z1)                                                  ZINIT.2
      REAL P1(1),Z1(1)                                                         ZINIT.3
*     COMMENT ZINIT ESTABLISHES THE INITIAL VALUES                             ZINIT.4
*           OF THE NEAR BY RAYS. THESE ARE ORIGINALLY FURNISHED                ZINIT.5
*           AS Z1(L+1) CM, Z1(L+2) MR, Z1(L+3) CM, Z1(L+4) MR.                 ZINIT.6
*           THESE ARE CHANGED TO Z1(L+1) M, Z1(L+2) DELTA P(K)/PO,             ZINIT.7
*           Z1(L+3) M, Z1(L+4) DELTA P(K)/PO. THE INPUT MOMENTUM               ZINIT.8
*           P(K) IN UNITS OF DELTA P(K)/PO IS CHANGED TO 1+DELTA P(K)          ZINIT.9
*           /PO                                                                ZINIT.10
*     BEGIN                                                                    ZINIT.11
          INTEGER K,L,N,NUM1,NUM                                               ZINIT.12
          REAL P,PO,CONST                                                      ZINIT.13
          COMMON  /CASES/NUM,L,K                                               ZINIT.14
     .            /MOM/ PO,P(40 )                                              ZINIT.15
     .            /PARAM/ CONST(8)                                             ZINIT.16
     .            /SOLN/ Z(164)                                                ZINIT.17
          NUM1= NUM-1$ N= 4*NUM                                                ZINIT.18
          DO 10 K=1,NUM1,1                                                     ZINIT.19
*         BEGIN                                                                ZINIT.20
                P(K)= P1(K)+1.0                                                ZINIT.21
```

TABLE VI - contd.

```
                L=4*K
                Z(L+2)= Z1(L+2)* CONST(5)
                Z(L+4)= Z1(L+4)* CONST(5)
                Z(L+2)= P(K)*COS(Z(L+4))*SIN(Z(L+2))
                Z(L+4)= P(K)*SIN(Z(L+4))
                Z(L+1)= Z1(L+1)*CONST(4)
                Z(L+3)= Z1(L+3)*CONST(4)
   10           CONTINUE
*           END
      RETURN
      END


      SUBROUTINE ZFINAL(Y,M)$ REAL Y(1)$ INTEGER M
*     COMMENT  ZFINAL ESTABLISHES THE FINAL CONDITIONS OF ANY NEARBY RAY
*              IT IS THE INVERSE OF ZINIT EXCEPT THAT IT WORKS ONE
*              RAY AT A TIME.
*     BEGIN
            INTEGER N,NUM,L,K
            REAL PO,P,Z,CONST
            COMMON /CASES/NUM,L,K
    .              /MOM/ PO,P(40)
    .              /SOLN/ Z(164)
    .              /PARAM/ CONST(8)
           N=M
           Y(4)=ASIN(Z(L+N+4)/P(K))
           Y(2)=ASIN(Z(L+N+2) /(P(K)*COS(Y(4))))/CONST(5)
           Y(4)=Y(4)/CONST(5)
           Y(1)=Z(L+N+1)/CONST(4)
           Y(3)=Z(L+N+3)/CONST(4)
      RETURN
      END


      SUBROUTINE SF(N1,N2,N3,N4)$ INTEGER N1,N2,N3,N4
*     COMMENT SF OBTAINS THE OFF DIAGONAL ELEMENTS OF THE SECOND ORDER
*             TRANSFER MATRIX
*     BEGIN
            INTEGER M1,M2,M3,M4,K,K1,L,NUM,I,I1,KK
            REAL Z,PO,P,YP,YM,A,U,S
            COMMON  /CASES/ NUM,L,K
    .               /SOLN/  Z(164) /MOM/ PO,P(40)
    .               /YAFS/  YP(5),YM(5),A(5),U(5,5),S(5,5,5)
            M1=N1$ M2=N2$ M3= N3$ M4=N4
            IF(NUM.EQ.21) 2,20
*           COMMENT ASYMMETRIC SOLN
   2        DO 10 KK=1,M1,1
*           BEGIN
                L= 4*KK-4
                K= KK+M3
                CALL ZFINAL(YP,M2)
                CALL YPYM5(KK+M3,10,M1+M3)

       K1= KK+M4
                DO 10 I=1,5,1
```

TABLE VI - contd.

```
*                  BEGIN
                        S(I,M4,K1)=
     .                  (YP(I)-A(M4)*U(I,M4)- A(K1)*U(I,K1)
     .                  -S(I,M4,M4)*(A(M4)**2)-S(I,K1,K1)*(A(K1)**2))/
     .                  (2.*A(M4)*A(K1))
                        S(I,K1,M4)=S(I,M4,K1)
   10                   CONTINUE
*                  END
*            END
             RETURN
*            COMMENT  SYMMETRIC SOLUTION
   20        DO 30 KK=1,M1,1
*            BEGIN
                   L=4*KK-4
                   K=KK+M3
                   CALL ZFINAL(YP,M2)
                   K= K+10
                   CALL ZFINAL(YM,M2+40)
                   K1=KK+M4
                   CALL YPYM5(KK+M3,10,M1+M3)
                   DO 30 I=1,5,1
*                  BEGIN
                        S(I,M4,K1)=
     .                  (YP(I)+YM(I)-2.0*(S(I,M4,M4)*A(M4)**2
     .                  +S(I,K1,K1)*A(K1)**2))/(4.0*A(M4)*A(K1))
                         S(I,K1,M4)= S(I,M4,K1)
   30                    CONTINUE
*                  END
*            END
             RETURN
       END

       SUBROUTINE SETZ(Z,P)
       REAL Z(1),P(1)
*      COMMENT SETZ  SETS THE NEAR BY RAYS FOR  GENERATION OF THE FIRST
*              ORDER MATRIX F AND THE SECOND ORDER MATRIX S
*      BEGIN
             INTEGER NUM1,NUM,K,N,L
             REAL PO,YP,YM,A,U,S,CONST
             COMMON /CASES/ NUM,L,K
     .              /YAFS/  YP( 5 ),YM( 5 ),A( 5),U(5,5),S(5,5,5)
     .              /PARAM/ CONST(8)
             NUM1= NUM-1$ N= 4*NUM
             DO 10  K=5,N,1
   10        Z(K)= 0.
             DO 12  K=1,NUM1,1
   12        P(K)= 0.0
             Z(5)=A(1)
             Z(10)=A(2)
             Z(15)=A(3)
             Z(20)=A(4)
             Z(25)=-Z(5)$Z(30)=-Z(10)$Z(35)=-Z(15)$Z(40)=-Z(20)
             P(5)=P(5)+A(5)
```

TABLE VI - contd.

```
            P(10)=P(10)-A(5)
            IF(NUM.GT.11) 14, 30
*           BEGIN
   14                DO 16 K=45,57,4
                     Z(K)= Z(5)
   16                Z(K+40)=-Z(5)
                     Z(46)= Z(10)$ Z(86)=-Z(10)
                     DO 18 K=62,70,4
                     Z(K)= Z(10)
   18                Z(K+40)= -Z(10)
                     DO 20 K= 51,75,12
                     Z(K)= Z(15)
   20                Z(K+40)=-Z(15)
                     Z(79)= Z(15)$ Z(119)=-Z(15)
                     DO 22 K= 68,84,8
                     Z(K)= Z(20)
   22                Z(K+40)= -Z(20)
                     Z(56)=Z(20)$ Z(96)=-Z(20)
                     DO 24 K= 14,20,3
                     P(K)= P(5)
   24                P(K+10)=P(10)
                     P(19)= P(5)
                     P(29)=P(10)
*           END
   30       CONTINUE
       RETURN
       END


       SUBROUTINE FUNC(SO,Z,F)$ REAL SO$ REAL Z(1),F(1)
*      COMMENT FUNC COMPUTES THE RIGHT HAND SIDE OF THE DIFFERENTIAL
*             EQUATION DZ(SO)=F(Z(SO)) WHERE Z IS IN R**(4*NUM).
*             Z(1) TO Z(4) ARE THE REFERENCE RAY AND Z(4*K+1) TO
*             Z(4*K+4),K IN (1,...,NUM-1),ARE THE NEARBY RAYS.
*      BEGIN
            INTEGER K,K1,NUM,L,COUNT
            REAL QBAR,ABAR,BB3K,WK,DELP3,QBARWK,Q,PO,P,BB02,BB1,BB2,BB3
            COMMON /CASES/ NUM,L,K
   .                /CHARGE/ Q
   .                /MOM/ PO,P(40)
   .                /FIELD/ BB02,BB1(40),BB2(40),BB3(40)
   .                /WORK/COUNT,STEP
*           COMMENT ESTABLISH THE FIELD AT THE CURRENT POSITION IN SPACE
            CALL FIELD $ COUNT= COUNT +1
            QBAR= Q/PO$ ABAR= QBAR * BB02
*           COMMENT REFERENCE RAY
            F(1)= -1.*ABAR*Z(2)$ F(2)= ABAR*Z(1)
            F(3)= Z(1)$ F(4)= Z(2)$ K1= NUM-1
            IF(K1.EQ.0) RETURN
            DO 10 K=1,K1,1
*           BEGIN
                 L=4*K$ DELP3= SQRT(P(K)**2-Z(L+2)**2-Z(L+4)**2)
                 WK= DELP3/(1+Z(L+1)*ABAR)$ QBARWK= QBAR/WK
                 F(L+2)=(QBARWK) *(Z(L+4)*BB3(K)-DELP3*BB2(K))
```

TABLE VI - contd.

```
                     +ABAR*DELP3
                F(L+4)=(QBARWK) *(DELP3*BB1(K)-Z(L+2)*BB3(K))
                F(L+1)=Z(L+2)/WK
                F(L+3)=Z(L+4)/WK
   10           CONTINUE
*           END
      RETURN
      END


      SUBROUTINE YPYM5(M,N,A5)
      INTEGER M,N,A5
*     BEGIN COMMENT YP(5) AND YM(5) ARE SET EXACTLY FOR THE FIRST
*                   STEP. ALL OTHER STEPS ARE SET USING THE CALCULATED
*                   VALUES OF THE MOMENTUM P.
            COMMON /CASES/ NUM,L,K
            COMMON /YAFS/ YP(5),YM(5),A(5),U(5,5),S(5,5,5)
            COMMON /WORK/ COUNT,STEP /MOM/ PO,P(40)
            REAL YP,YM,A,P
            INTEGER STEP,NUM
            IF(STEP.EQ.0 .A. M.EQ.A5) 2,4
*           BEGIN
    2             YP(5)= A(5)
                  YM(5)= -A(5)
                  RETURN
*           END ELSE
*           BEGIN
    4             YP(5)= P(M)-1.0
                  IF(M+N.GT.10 .A. NUM.EQ.21) RETURN
                  YM(5)=P(M+N)-1.0
                  RETURN
*           END
      END


      SUBROUTINE SAVEZP(ZSAVE,Z1,P1,PI)
      REAL ZSAVE(1),Z1(1),P1(1),PI(1)
*     BEGIN
*           COMMENT THE INITIAL VALUSE Z1,P1 THAT SOTRM1 WAS CALLED
*           WITH ARE SAVED
            INTEGER NUM,L,K,NUM1
            COMMON /CASES/ NUM,L,K
            NUM1= NUM-1
            DO 20 L= 1,NUM1,1
            DO 18 K= 1,4,1
*           BEGIN
   18             ZSAVE(5*L-5+K)= Z1(4*L+K)
   20       ZSAVE(5*L)= P1(L)
*           END
            RETURN
      END


      SUBROUTINE CUTRT(TEXT,R,T)
```

TABLE VI - contd.

```
         INTEGER TEXT
         REAL R(5,5),T(5,5,5)
*        BEGIN COMMENT THIS ROUTINE REQUIRES EXTENDED FORTRAN OUTPUT. SEE
*              UCRL 19463. IT OUTPUTS THE FIRST AND SECOND CRDER ELEMENTS
*              IN A TABLE LIKE THAT APPEARING IN UCRL 19182. IT CAN BE
*              DELETED CR REPLACED. IT IS CALLED FROM PROGRAM SOTRM
               INTEGER I,J,K,N
               CALL CUTMODE(1HS)
               CALL FLIM(10,130)
               CALL PAGE
               CALL S(TEXT) $ CALL LINES(1)
               CALL S(10H(*R(J,K)*)) $ CALL LINES(1)
               CALL S(14H(*  J   / K =*))
               DO 10 J=1,5,1
*              BEGIN
                     CALL SPACES(8)
                     CALL OUTI(J,1)
   10                CALL SPACES(8)
*              END
               CALL LINES(1)
               DO 22 I=1,5,1
               DO 20 J=1,5,1
                     IF(J.EQ.1) CALL SPACES(11)
                     IF(R(I,J).EQ.0)
     .               CALL S(21H(*    0.0000000E 00*))
                     IF(R(I,J).NE.0)
     .               CALL OUTR(R(I,J),.FALSE.,17,7)
   20                CONTINUE
   22                CALL LINES(1)
*              END
               CALL LINES(2)
               CALL S(12H(*T(I,J,K)*)) $ CALL LINES(1)
               CALL S(14H(* I/ J/ K =*))
               DO 30 I= 1,5,1
*              BEGIN
                     CALL SPACES(8)
                     CALL OUTI(I,1)
   30                CALL SPACES(8)
*              END
               CALL LINES(1)
               DO 44 I=1,5,1
               DO 42 J= 1,5,1
               DO 40 K= J,5,1
*              BEGIN
                     IF(J.EQ.K) 32,38
*                    BEGIN
   32                      CALL OUTI(I,2)
                           CALL OUTI(J,3)
                           CALL SPACES(5)
                           CALL SPACES(17*(J-1))
*                    END
   38                CONTINUE
                     IF(T(I,J,K).EQ.0.0)
     .               CALL S(21H(*    0.0000000E C0*))
```

TABLE VI - contd.

```
                    IF(T(I,J,K).NE.0.0)                                          OUTRT.57
                    CALL OUTR(T(I,J,K),.FALSE.,17,7)                             OUTRT.58
   40               CONTINUE                                                     OUTRT.59
   42               CALL LINES(1)                                                OUTRT.60
   44               CONTINUE                                                     OUTRT.61
*           END                                                                  OUTRT.62
            CALL PAGE                                                            OUTRT.63
            CALL S(13H(*END OUTRT*))                                             OUTRT.64
            CALL LINES(1)                                                        OUTRT.65
            RETURN                                                               OUTRT.66
      END                                                                        OUTRT.67
                                                                                 OUTRT.68
                                                                                 OUTRT.69
      SUBROUTINE APTRAN(II,KKEY)                                                 APTRAN.2
      INTEGER II,KKEY,STEP                                                       APTRAN.3
*                                                                                APTRAN.4
*  THIS ROUTINE APPLIES THE TRANSFER MATRIX CCRRESPONDING TO THE VALUE           APTRAN.5
*  OF KEY TO THE NEARBY RAYS.                                                    APTRAN.6
*                                                                                APTRAN.7
      COMMON /INIT/ ZSAVE(150)                                                   APTRAN.8
      COMMON /CASES/ NUM,L,K                                                     APTRAN.9
      COMMON /MOM/ PO,P(40)  /YAFS/ YP(5),YM(5),A(5),U(5,5),S(5,5,5)             APTRAN.10
      COMMON /WCRK/ COUNT,STEP                                                   APTRAN.11
      DIMENSION ZTRAN(150),ZSOLN(150),V(5)                                       APTRAN.12
      IF(II.EQ.0) 4,8                                                            APTRAN.13
    4 READ(1) LSTP,KEY,U,S                                                       APTRAN.14
      IF(STEP.NE.LSTP) 720,9                                                     APTRAN.15
  720 PRINT 731,STEP,LSTP                                                        APTRAN.16
  731 FORMAT(*OWRCNG STEP ON DISK. STEP =*I10,5X*LSTP =*I10)                     APTRAN.17
      RETURN                                                                     APTRAN.18
    8 KEY= KKEY                                                                  APTRAN.19
      WRITE(1) STEP,KEY,U,S                                                      APTRAN.20
    9 CCNTINUE                                                                   APTRAN.21
      NUM1=NUM-1                                                                 APTRAN.22
      DO 20 L=1,NUM1                                                             APTRAN.23
      M=5*L-5                                                                    APTRAN.24
      DO 20 I=1,5                                                                APTRAN.25
      SUM1=0.0                                                                   APTRAN.26
      SUM2=0.0                                                                   APTRAN.27
      DO 12 J=1,5                                                                APTRAN.28
      SUM1=SUM1+U(I,J)*ZSAVE(M+J)                                                APTRAN.29
      IF(KEY.EQ.1.OR.KEY.EQ.-1) GO TO 12                                         APTRAN.30
      DO 10 K=1,5                                                                APTRAN.31
      SUM2=SUM2+S(I,J,K)*ZSAVE(M+J)*ZSAVE(M+K)                                   APTRAN.32
   10 CONTINUE                                                                   APTRAN.33
   12 CCNTINUE                                                                   APTRAN.34
      IF(KEY.GT.0) GO TO 17                                                      APTRAN.35
      DC 15 J=1,5                                                                APTRAN.36
   15 SUM2=SUM2+S(I,J,J)*ZSAVE(M+J)*ZSAVE(M+J)                                   APTRAN.37
   17 ZTRAN(M+I)=SUM1+SUM2                                                       APTRAN.38
   20 CONTINUE                                                                   APTRAN.39
      V(5)=0.0                                                                   APTRAN.40
      DO 30 KK=1,NUM1                                                            APTRAN.41
      L=4*KK                                                                     APTRAN.42
```

TABLE VI - contd.

```
      K=KK                                                              APTRAN.43
      CALL ZFINAL(V,0)                                                  APTRAN.44
      DO 30 J=1,5                                                       APTRAN.45
      ZSOLN(5*KK+J-5)=V(J)                                              APTRAN.46
   30 CONTINUE                                                          APTRAN.47
      DO 40 I=1,NUM1                                                    APTRAN.48
   40 ZSOLN(5*I)=P(I)-1.0                                               APTRAN.49
      N=5*NUM1                                                          APTRAN.50
      IF(N.EQ.15*(N/15)) GO TO 45                                       APTRAN.51
      NN=15*(N/15)+1                                                    APTRAN.52
      GO TO 50                                                          APTRAN.53
   45 NN=N-14                                                           APTRAN.54
   50 PRINT 55                                                          APTRAN.55
   55 FORMAT(///11X5HZTRAN,10X5HZSOLN,15X5HZTRAN,10X5HZSOLN,15X5HZTRAN, APTRAN.56
     110X5HZSOLN)                                                       APTRAN.57
      DO 90 I=1,NN,15                                                   APTRAN.58
      DO 70 J=1,5                                                       APTRAN.59
      K=I-1+J                                                           APTRAN.60
      L=K+10                                                            APTRAN.61
      PRINT 60,(ZTRAN(M),ZSOLN(M),M=K,L,5)                              APTRAN.62
   60 FORMAT(5X2E15.7,5X2E15.7,5X2E15.7)                                APTRAN.63
   70 CONTINUE                                                          APTRAN.64
      PRINT 80                                                          APTRAN.65
   80 FORMAT(1H0)                                                       APTRAN.66
   90 CONTINUE                                                          APTRAN.67
      RETURN                                                            APTRAN.68
      END                                                               APTRAN.69
                                                                        APTRAN.70
                                                                        APTRAN.71
      FORTRAN IV SUBROUTINE INTC(NO,X,DERI ,Y,F,T,HPRO)                 ZAM.2
*     COMMENT THIS IS THE LRL INTEGRATOR ZAM. SEE LRL COMPUTER CENTER   ZAM.3
*             WRITE UP FOR ZAM D2 BKY ZAM.                              ZAM.4
      COMMON /INTC/ IPMX,AREF,EMAX,SSSR,HFAC,SWAM,SWEX                  ZAM.5
      COMMON /INTP/ HPR,XX,N,EUB,ELB,IP,IT,NRKS,SWIN                    ZAM.6
      DIMENSION Y(1),F(1),T(8,1)                                        ZAM.7
      LOGICAL SWAM,SWEX,SWIN                                            ZAM.8
      INTEGER HFAC                                                      ZAM.9
      DOUBLE PRECISION T,HPRO,HPR,XX                                    ZAM.10
      DATA IPMX,AREF,EMAX,SSSR,HFAC,SWAM,SWEX                           ZAM.11
     $  /16384 ,1.0,1.0E-8 ,100.0,2,.TRUE.,.TRUE./                      ZAM.12
*     COMMENT NOTE THAT EMAX= 10E-8 IS PROBABLY TOO SMALL FOR EXPERIMEN- ZAM.13
*             TAL DATA, EMAX= 10E-6 IS PROBABLY BETTER.                 ZAM.14
C                                                                       ZAM.15
      HPR=HPRO                                                          ZAM.16
      XX=DBLE(X)                                                        ZAM.17
      N=NO                                                              ZAM.18
      EUB=EMAX                                                          ZAM.19
      ELB=EMAX/SSSR                                                     ZAM.20
      IP=1                                                              ZAM.21
      IT=0                                                              ZAM.22
      NRKS=0                                                            ZAM.23
      SWIN=SWEX                                                         ZAM.24
      CALL DERI (X,Y,F)                                                 ZAM.25
      DO 9 I=1,N                                                        ZAM.26
```

TABLE VI - contd.

```
      T(5,I)=DBLE(Y(I))
    9 CONTINUE
      RETURN
      END
        SUBROUTINE INT(X,DERI ,Y,F,T,SWPR
     X )
      COMMON /INTC/ IPMX,AREF,EMAX,SSSR,HFAC,SWAM,SWEX
      COMMON /INTP/ HPR,XX,N,EUB,ELB,IP,IT,NRKS,SWIN
C
        DIMENSION Y(1),F(1),T(8,1)
      LOGICAL SWAM,SWEX,SWIN
      LOGICAL SWPR
      INTEGER HFAC
        DOUBLE PRECISION T,HPR,XX
        DOUBLE PRECISION D,H
 6000   FORMAT (36H0 CANNOT DECREASE H BECAUSE OF HMIN.    ,1PE16.8,I20)
C
 1      CONTINUE
        SWPR=.FALSE.
        TEST=0.0
        H=HPR/DBLE(FLOAT(IP*24))
        IF ((NRKS .LT. 3) .OR. (.NOT. SWAM)) GO TO 200
C
C       ADAMS-MOULTON STEP.
 100    CONTINUE
        DO 109 I=1,N
        D=DBLE(F(I))
        T(4,I)=D
        Y(I)=SNGL(T(5,I)+H*(
     X  55.0D0*D-59.0D0*T(3,I)+37.0D0*T(2,I)- 9.0D0*T(1,I) ))
 109    CONTINUE
        X=SNGL(XX+24.0D0*H)
      CALL DERI (X,Y,F)
        DO 119 I=1,N
        D=DBLE(F(I))
        D=(     T(5,I)+H*(

     X   9.0D0*D+19.0D0*T(4,I)- 5.0D0*T(3,I)+        T(2,I) ))
        T(6,I)=D
        E=ABS(SNGL(D)-Y(I))/14.0
        TEST=AMAX1(E/AMAX1(AREF,ABS(SNGL(D))),TEST)
 119    CONTINUE
C
        GO TO 300
C
C       ZONNEVELD STEP.
 200    CONTINUE
        DO 209 I=1,N
        D=DBLE(F(I))
        T(4,I)=D
C       1
        Y(I)=SNGL(T(5,I)+H*(
     X  12.0D0*D                                             ))
 209    CONTINUE
```

TABLE VI - contd.

```
      X=SNGL(XX+12.0D0*H)
     CALL DERI (X,Y,F)
      DO 219 I=1,N
      D=DBLE(F(I))
      T(6,I)=D
C     2
      Y(I)=SNGL(T(5,I)+H*(
     X 12.0D0*D                                             ))
 219  CONTINUE
     CALL DERI (X,Y,F)
      DO 229 I=1,N
      D=DBLE(F(I))
      T(7,I)=D
C     3
      Y(I)=SNGL(T(5,I)+H*(
     X 24.0D0*D                                             ))
 229  CONTINUE
      X=SNGL(XX+24.0D0*H)
     CALL DERI (X,Y,F)
      DO 239 I=1,N
      D=DBLE(F(I))
      T(8,I)=D
C     4
      Y(I)=SNGL(T(5,I)+H*(
     X 3.75D0*T(4,I)+5.25D0*T(6,I)+9.75D0*T(7,I)-0.75D0*D ))
 239  CONTINUE
      X=SNGL(XX+18.0D0*H)
     CALL DERI (X,Y,F)
      DO 249 I=1,N
      D=DBLE(F(I))
      E=ABS(SNGL(H*(
     X -16.0D0*T(4,I)+48.0D0*T(6,I)+48.0D0*T(7,I)+48.0D0*T(8,I)
     X -128.0D0*D    )))
C     5
      D=(     T(5,I)+H*(
     X 4.0D0*T(4,I)+ 8.0D0*T(6,I)+ 8.0D0*T(7,I)+ 4.0D0*T(8,I)
     X ))
      T(6,I)=D
      TEST=AMAX1(E/AMAX1(AREF,ABS(SNGL(D))),TEST)
 249  CONTINUE
C
C     BOTH ADAMS-MOULTON AND ZONNEVELD METHODS CONTINUE FROM HERE.
 300  CONTINUE
     X=SNGL(XX+24.0D0*H)
      IF (TEST .LE. EUB) GO TO 310
      IF (IP*HFAC .GT. IPMX) GO TO 309
C
C     REPEAT STEP WITH SMALLER H.
      NRKS=0
      IP=IP*HFAC
[redacted]
      IT=IT*HFAC
      DO 305 I=1,N
      Y(I)=SNGL(T(5,I))
      F(I)=SNGL(T(4,I))
```

TABLE VI - contd.

```
  305   CONTINUE
        GO TO 1
C
C       CANNOT DECREASE H BECAUSE OF HMIN.
  309   CONTINUE
      IF (.NOT. SWIN) GO TO 310
        PRINT 6000, X,IPMX
      SWIN=.FALSE.
C
  310   CONTINUE
C
C
C       ACCEPT CURRENT STEP.
C
C       XX STILL HAS NOT BEEN CHANGED SINCE ENTRY.
C       YY(XX) IS STILL IN T(5, ).
C       F(YY) IS IN T(4, ).
C
        IT=IT+1
        XX=XX+HPR/DBLE(FLOAT(IP))
        NRKS=MIN0(NRKS+1,4)
        DO 319 I=1,N
        D=T(6,I)
        T(5,I)=D
        Y(I)=SNGL(D)
  319   CONTINUE
        X=SNGL(XX)
      CALL DERI (X,Y,F)
        IF (IT .LT. IP) GO TO 320
C
C       X IS A MULTIPLE OF HPRINT.
        SWPR=.TRUE.
        IT=IT-IP
C
  320   CONTINUE
        IF (TEST .GE. ELB) GO TO 330
        IF (MOD(IP,HFAC)+MOD(IT,HFAC) .NE. 0) GO TO 330
C
C       PROCEED TO NEXT STEP WITH LARGER H, USING ZONNEVELD METHOD.
        NRKS=0
        IP=IP/HFAC
        IT=IT/HFAC
        RETURN
C
C
C       PROCEED TO NEXT STEP WITH SAME H.
  330   CONTINUE
        DO 339 I=1,N
        T(1,I)=T(2,I)
        T(2,I)=T(3,I)
        T(3,I)=T(4,I)
  339   CONTINUE
        RETURN
        END
```

TABLE VI - contd.

```
      SUBROUTINE FIELD
*     COMMENT  THIS ROUTINE ESTABLISHES THE FIELD AT THE CURRENT
*              POSITION OF THE REFERENCE PARTICLE AND THE NEARBY
*              PARTICLES. THE ORIGIN IS THE ORIGIN OF THE REFERENCE
*              PARTICLE. THE ACTUAL FIELD IN GAUSS IS SUPPLIED BY THE
*              SUBROUTINE GAUSS.
*     BEGIN
            INTEGER K,K1,L,NUM
            REAL    Z4K,R,P0,P,BB02,BB1,BB2,BB3,Z,G,CONST
            DIMENSION R(3),G(3)
            COMMON  /CASES/ NUM,L,K
     .              /MOM/ P0,P(40)
     .              /FIELD/BB02,BB1(40),BB2(40),BB3(40)
     .              /SOLN/ Z(164)
     .              /PARAM/ CONST(8)
            K1=NUM-1
*           COMMENT THE POSITION OF THE REFERENCE ORBIT IN THE GLOBAL
*           COORDINATE SYSTEM IS R(1),R(2),R(3). SEE FIGURE 1 UCRL
*           19182.
            R(1)= Z(3)
            R(2)= 0.0
            R(3)= Z(4)
            CALL GAUSS(R,G)
            BB02= G(2) * CONST(7)
            IF(K1.EQ.0) RETURN
            DO 10 K=1,K1,1
*           BEGIN
                  L=4*K$ Z4K= Z(L+1)
*                 COMMENT SEE UCRL 19182 FIGURE 1. WE ARE TRANSFORMING
*                 FROM THE PRIMED TO THE GLOBAL UNPRIMED COORDINATE
*                 SYSTEM.
                  R(1)= Z(3)+Z4K * Z(2)
                  R(2)= Z(L+3)
                  R(3)= Z(4)- Z4K * Z(1)
                  CALL GAUSS(R,G)
*                 COMMENT NOTE THAT THE FIELD HERE, BB1(K)...BB3(K),
*                 REFERS TO THE FIELD COMPONENTS IN THE PRIMED
*                 COORDINATE SYSTEM. SEE UCRL 19182 FIGURE 1.
                  BB1(K)= G(1)* CONST(7)
                  BB2(K)= G(2)* CONST(7)
   10             BB3(K)= G(3)* CONST(7)
*           END
      RETURN
      END

      SUBROUTINE GAUSS(R,G)$ REAL R(1),G(1)
*      COMMENT
$          THIS VERSION OF GAUSS SETS A CONSTANT FIELD = 17.036E4 GAUSS
C           WHICH CORRESPONDS TO A RADIUS OF 1 METER FOR PC= 510.72
*          FOR A PROTON
```

TABLE VI - contd.

```
*       BEGIN
             REAL G,PO,P
             COMMON/CHARGE/ Q
      .              /MOM    / PO,P(40)
             G(1)=C.
             G(2)=(PO/Q)*1.E4
             G(3)=C.
        RETURN
        END


        SUBROUTINE FIELD
*       COMMENT  THIS ROUTINE ESTABLISHES THE FIELD AT THE CURRENT
*                POSITION OF THE REFERENCE PARTICLE AND THE NEARBY
*                PARTICLES. THE ORIGIN IS THE ORIGIN OF THE REFERENCE
*                PARTICLE. THE ACTUAL FIELD IN GAUSS IS SUPPLIED BY THE
*                SUBROUTINE GAUSS.
*       BEGIN COMMENT THIS VERSION OF FIELD CAN BE USED WITH AN IDEAL
*            SEXTUPOLE AND AN IDEAL QUADRUPOLE. IT ASSUMES THAT THE
*            REFERENCE ORBIT HAS FIELD ZERO.
             INTEGER K,K1,L,NUM
             REAL    Z4K,R,PO,P,BB02,BB1,BB2,BB3,Z,G,CONST
             DIMENSION R(3),G(3)
             COMMON  /CASES/ NUM,L,K
      .              /MOM/ PO,P(40)
      .              /FIELD/BB02,BB1(40),BB2(40),BB3(40)
      .              /SOLN/ Z(164)
      .              /PARAM/ CONST(8)
             K1=NUM-1
*            COMMENT THE REFERENCE ORBIT FIELD IS SET TO ZERO.
             BB02= 0.0
             IF(K1.EQ.0) RETURN
             DO 10 K=1,K1,1
*            BEGIN
                  L=4*K$ Z4K= Z(L+1)
*                 COMMENT R(1) AND R(2) GIVE THE DISPLACEMENT IN METERS
*                 IN THE PRIMED SYSTEM. SEE FIGURE 1 UCRL 19182.
                  R(1)=Z(L+1)
                  R(2)=Z(L+3)
                  CALL GAUSS(R,G)
                  BB1(K)= G(1)* CONST(7)
                  BB2(K)= G(2)* CONST(7)
   10             BB3(K)= G(3)* CONST(7)
*            END
        RETURN
        END


        SUBROUTINE GAUSS(R,G)$ REAL R(1),G(1)
*       BEGIN
*            COMMENT THIS ROUTINE FURNISHES THE IDEAL QUADRUPOLE FIELD
*            USED AS AN EXAMPLE IN UCRL 19182.
             REAL G,PC,P
             REAL PO
```

TABLE VI - contd.

```
        COMMON/CHARGE/ Q                                              GAUSS2.8
     .        /MOM     / PO,P(40)                                     GAUSS2.9
        BO=(PC/Q)*1.E4/2.0                                            GAUSS2.10
        G(1)= BO*R(2)/.0508                                           GAUSS2.11
        G(2)= BO*R(1)/.0508                                           GAUSS2.12
        G(3)=C.0                                                      GAUSS2.13
  RETURN                                                              GAUSS2.14
  END                                                                 GAUSS2.15
                                                                      GAUSS2.16
                                                                      GAUSS2.17
  SUBROUTINE GAUSS(R,G)$ REAL R(1),G(1)                               GAUSS3.2
*   BEGIN                                                             GAUSS3.3
*       COMMENT THIS ROUTINE FURNISHES THE IDEAL SEXTUPOLE FIELD      GAUSS3.4
*       USED AS AN EXAMPLE IN UCRL 19182.                             GAUSS3.5
        REAL C,PC,P                                                   GAUSS3.6
        REAL BO                                                       GAUSS3.7
        COMMON/CHARGE/ Q                                              GAUSS3.8
     .        /MOM     / PO,P(40)                                     GAUSS3.9
        BO= (PO/Q)*1.0E4/10.0                                         GAUSS3.10
        G(1)= (2.0*BO*R(1)*R(2))/(.0508**2)                           GAUSS3.11
        G(2)= (BO*(R(1)**2-R(2)**2))/(.0508**2)                       GAUSS3.12
        G(3)= 0.0                                                     GAUSS3.13
        RETURN                                                        GAUSS3.14
  END                                                                 GAUSS3.15
                                                                      GAUSS3.16
                                                                      GAUSS3.17
```

REFERENCES

[1] E. Close, Generation of First and Second Order Transformation Elements from a Given Magnetic Field, UCRL-~~19182~~ 19812, Lawrence Radiation Laboratory, Berkeley, Ca.

[2] D2 BKY ZAM, Computer Center Library, Lawrence Radiation Laboratory, Berkeley, Ca.