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EUROPEAN ATOMIC ENERGY COMMUNITY — EURATOM

A ONE-GROUP COLLISION PROBABILITY CODE FOR CYLINDERS AND SLABS

by

B. QUIQUEMELLE

1966

Joint Nuclear Research Center
Ispra Establishment — Italy

Reactor Physics Department
Reactor Theory and Analysis

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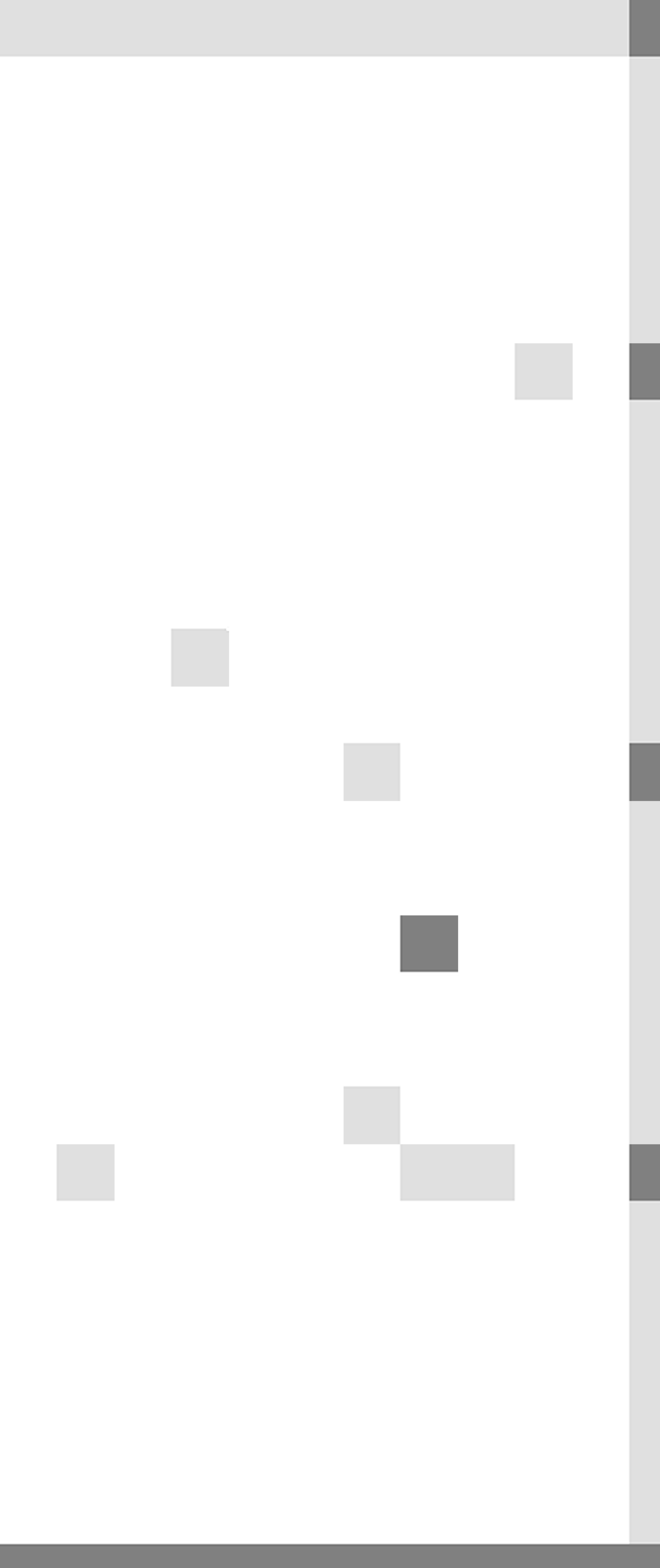

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Summary

The Code [redacted] forms the numerical evaluation of the collision probabilities in concentric [redacted] or slabs. For cell calculations several boundary conditions can be [redacted] including a black inner region. Escape probabilities and Dancoff [redacted] calculations are compared with other methods. The complete list of the FORTRAN programme is given.

C O N T E N T S

A one-group collision probability code for cylinders and slabs

Part I : Description of the method

Introduction (°)

In solving practical problems of neutron transport, the first flight collision probability theory has been proved successful since already some years. This theory provides a link between the most powerful methods for calculating the slowing down and the spatial distribution of neutrons.

Several works have dealt the analytical evaluation of collision probabilities in the simplest geometries. It has been thought interesting to solve the problem in using a straightforward numerical technique. Useful conclusions can then be drawn on the validity of such numerical techniques by comparison with the exact analytical evaluation

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(°) Manuscript received on November 5, 1965

Method of Calculation

We will consider now a reactor or a lattice cell which can be represented by a one-dimensional geometry. Those geometries are formed of concentric cylinders or side by side slabs; also if we consider a regular lattice, the periodic structure will be taken into account by a suitable boundary condition.

We want to calculate the probability $P_{R_i \rightarrow R_j}$ that a neutron born in a region "R_i" - with a given space-angle distribution - collides in a region "R_j". In case of a regular lattice, R_i refers to a well defined region of the cell together with the homolog region in the other cells (through a suitable cell boundary condition).

Considering a normalized source of neutron in region "R_i" and the corresponding first flight collision flux ϕ, the quantity to be calculated is just

$$P_{R_i \rightarrow R_j} = \int_{R_j} \phi(\underline{r}) \Sigma_t(\underline{r}) \, d\underline{r}$$

where Σ_t is the total cross section at space point r.

Such a problem is easily solved by the numerical integration of the inhomogeneous Boltzmann equation using the so-called "S_n approximation". This approximation consists in the discretisation of the angular and space variables. A mesh cell is then specified by an index i for the space variable and two indices l,m for the direction of flight vector. One then considers[1] the value of the flux on each boundary of the mesh cell such as ϕ_i which is the value at space point r_i (or x_i) when the direction of flight is an averaged direction inside the mesh cell. Similar definitions[1] exist for ϕ_m and ϕ_l. A set of difference type equations is written between those values ϕ_i, ϕ_m and ϕ_ℓ by representing the flux with an approximate shape inside the mesh cell.

In usual S_n calculations, this set is solved from mesh cell to mesh cell by starting with known conditions on the boundary of the system, then solving the equations by recursion and iterating until a convergence criterium is reached. In our case we are interested in the collision probabilities for which the medium is considered to be absorbing for all types of collisions. Then no iteration is needed which avoid the most time consuming operations of the usual S_n.

Without going in any more details the main equations solved by the code have been gathered in appendix I.

If the calculation is done inside one cell of a lattice, the contributions from other cells are introduced through a balance equation at the external boundary

$$\vec{\Phi}_I = R \cdot (\vec{g}_I + T \cdot \vec{\Phi}_I)$$

The vectors have for components the flux along the discrete directions chosen for the mechanical quadrature. It is really this balance equation which avoids the iteration over the space mesh and which suppresses the need for the inner iteration of the usual S_n codes.

- $\vec{g}_I$ represents the neutrons coming directly from the source and leaving the lattice cell without having collided.
- $\vec{\Phi}_I$ represents the neutrons coming from the other cells in the lattice.
- T is the transmission matrix of the lattice cell for incoming neutrons. When the set of discrete directions is symmetric for inward and outward directions this matrix is diagonal. In this case the elements of the matrix T are found in solving the system of equations of appendix I for an isotropic boundary source of unit intensity and collecting the number of neutrons leaving the cell along discrete outward directions.

The elements of the matrix R represent the coefficients of transfer from one outward direction to one inward direction.

The result of the calculation is just a square matrix of the $P_{R_i \rightarrow R_j}$ which we will write more simply P_{ij}. The elements of this matrix must satisfy the reciprocity relations

$$V_i \lambda_j P_{ij} = V_j \lambda_i P_{ji}$$

and also the conservation relations (in an infinite lattice)

$$\sum_{j} P_{ij} = 1$$

where V and λ are the volume and mean free path inside the region designated by the subscript. It should be noted that those relations are already a very good check for the accuracy of the numerical method.

Conclusion

This method for calculating the collision probabilities is fast and accurate. When used for a lattice geometry, rather complicated boundary laws are simply introduced through the specification of the R matrix. In the present code the neutrons are started uniformly and isotropically in each region but an extension has been done for dealing with anisotropic sources[14]. This code can also be used like a subroutine for calculating transport kernels with a flux calculation method similar to the THERMOS method[12]. It is thought that rather accurate kernels are found in a short time even for large size regions. The advantage of this method over the DSN method is that the S_n approximation is used only for calculating accurate transport kernels with a minimum effort, then well developed techniques for accelerating convergence are used to solve the linear flux equations[12].

List of Symbols

i	index for designation of a space mesh boundary
l,m	two indices for designation of an angular mesh boundary
ϕ_k	($k = i,l$ or m) value of the flux on the boundary labelled by index k when the variables which varies over other boundaries have a mean value[3]
Σ_i	total cross section inside space mesh r_i, r_{i+1}
w	weight associated to the discrete direction inside the mesh cell and used for mechanical quadrature (half value indices are generally omitted for clarity)
μ	direction cosine
r_i, r_{i+1}	inner and outer radius of mesh i in cylindrical geometry
x_i, x_{i+1}	abscissa defining the mesh i in slab geometry
$P_{R_i \rightarrow R_j}$	probability that a neutron born uniformly and isotropically in region R_i suffers his first collision in region R_j
δ_R	is 1 inside the region R and 0 outside
I	number of space mesh
n	order of approximation for the discrete angular representation In cylindrical geometry there exist $\frac{n(n+4)}{4}$ discrete directio[ns] and in slab geometry there exist n discrete directions.

Part 2: Some applications of the code

The code has been applied to a variety of problems and results were compared with exact methods.

a) calculation of escape probabilities:

We consider, by example, a two-media cell in a lattice consisting of a fuel rod surrounded by a moderator. The probability of escaping the rod is just

$$P_o = P_{f \to m}$$

where $P_{f \to m}$ is calculated using the code TIJ with two regions (fuel + moderator). Such a calculation is reported in table II and compared with other analytical methods. It should be noted that the best boundary condition is given by an isotropic return along directions which have the same azimuth that the incident neutron direction (although the difference with a purely isotropic return is negligible). In this case the results compared very closely with the analytic calculations of Pennington[4]. We can also state that there exists no simple specification for finding the exact results of Fukai[5] with any combination of two or three boundary laws.

In table III a similar calculation was performed and shows a very good agreement with Monte Carlo calculations reported by Rothenstein[7].

Table II

Escape Probabilities

(a (radius of rod) = 0.183 inch, V_m/V_f = 1.0, Σ_m = 1.49170 cm^{-1})

$\Sigma_{fuel} a$	Takahashi[6]	TIJ			Pennington[4]	exact[5]
		IBVL = 1	IBVL = 3	IBVL = 2		
0.1	0.76875	0.7723	0.8160	0.8157	0.81364	0.80745
0.3	0.52590	0.5295	0.5908	0.5898	0.58855	0.57988
0.5	0.39776	0.4014	0.4589	0.4575	0.45695	0.44745
0.8	0.28918	0.2927	0.3400	0.3383	0.33839	0.32973
1.0	0.24372	0.2471	0.2884	0.2866	0.28694	0.27918
2.0	0.12393	0.1358	0.1603	0.1588	0.15912	0.15490
4.0	0.068981	0.07047	0.08281	0.08196	0.082044	0.080363

* approximation S_{16}

IBVL = 1 (mirror reflection)
IBVL = 3 (white boundary)
IBVL = 2 (isotropic return along same azimuth)

Table III

Escape Probabilities

$(V_m/V_f = 1.0,\ \Sigma_m = 1.4916\ cm^{-1})$

$\Sigma_{fuel}a$	TIJ*		Monte Carlo[7]		TIJ*		Monte Carlo[7]	
0.5	0.5750	(0.5631)	0.572	(0.553)	0.6950		0.691	
1.0	0.3988		0.397		0.5243	(0.5159)	0.522	(0.513)
1.458	-		-		0.4237		0.422	
1.5	0.3026	(0.2909)	0.304	(0.291)	-		-	
2.0	0.2424		0.248		0.3422	(0.3343)	0.346	(0.335)
3.0	0.1718	(0.1636)	0.173	(0.163)	0.2491		0.250	
4.0	0.1324		0.133		0.1939	(0.1883)	0.194	(0.190)
6.0	0.09017	(0.0851)	0.088	(0.082)	0.1330		0.133	
8.0	-		-		0.1007	(0.0976)	0.100	(0.099)
	a = 0.25 inch				a = 0.60 inch			

* approximation S_{16} with isotropic return
(values between parenthesis include the effect of a .033 in. cladding)

b) Dancoff factor calculations

It is possible to specify a black inner region in the cylindrical geometry. In this case TIJ code prints the current J^-_{in} of neutrons entering the black region. If we perform a two region calculation with a cell boundary condition (IBVL different of 0) we can calculate the shadowing factor of Dancoff:

$$C = J^-_{in} \times 4\Sigma_m$$

where $1/4\,\Sigma_m$ is the current in the infinite moderator.

Such a calculation is reported on table IV and compared to exact Monte Carlo[8] calculations. There is a maximum discrepancy of 3.5% which can well be explained by the inadequacy of the linear approximation near the inner black boundary. It should be also necessary to use more discrete directions near the discontinuity of the angular flux at the black boundary. Those calculations compare well with some analytical results[9] but they are not as accurate as the Sauer[10] approximation.

Table IV

Dancoff coefficient

$(\Sigma_m = 1.4916)$

Rod size (inch)	V_m/V_f	IBVL = 1	TIJ IBVL = 2	IBVL = 3	Monte Carlo[8]
0.250	1.0	0.4532	0.5507	0.5400	0.52690
	1.5	0.5637	0.6797	0.6718	0.64627
	2.0	0.6342	0.7551	0.7472	0.73077
	3.0	0.7366	0.8514	0.8445	0.82361
	4.0	0.8026	0.9040	0.8983	0.88566
0.387	1.0	0.5960	0.6898	0.6820	0.66169
	1.5	0.7071	0.8023	0.7949	0.77261
	2.0	0.7751	0.8678	0.8619	0.84533
	3.0	0.8670	0.9357	0.9309	0.90732
	4.0	0.9252	0.9729	0.9697	0.95422
0.600	1.0	0.7446	0.8186	0.8113	0.78285
	1.5	0.8434	-	0.8992	-
	2.0	0.9005	0.9487	0.9444	0.92802
	3.0	0.9567	0.9854	0.9829	0.95930
	4.0	0.9817	0.9989	0.9975	0.99876

All previous calculations have been done with the S_{16} approximation. This is a rather high approximation which is not necessary in most cases. On table V the escape probabilities of table II have been evaluated as a function of the order of approximation. For practical purpose it is concluded that the approximation S_4 would be sufficient in this case.

It is anticipated that when used with a multigroup thermalization code TIJ would compute the 30-group transport kernels in a time of about one minute (IBM 7094) for a two region cell as above with the approximation S_4.

Table V

Escape Probabilities Against Order of Approximation
(see table II)

$\Sigma_g a$	S_2	S_4	S_6	S_8	S_{12}	S_{16}
0.1	0.8334	0.8204	0.8189	0.8178	0.8166	0.8160
0.3	0.6184	0.5965	0.5946	0.5932	0.5916	0.5908
0.5	0.4869	0.4641	0.4624	0.4611	0.4597	0.4589
0.8	0.3650	0.3446	0.3431	0.3420	0.3407	0.3400
1.0	0.3113	0.2927	0.2913	0.2902	0.2890	0.2884

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Appendix 1

Summary of main equations

1) Cylindrical geometry

difference equation for boundary values

$$\mu (r_{i+1}\phi_{i+1} - r_i \phi_i) - \frac{r_{i+1}-r_i}{\ell} (\gamma_{m+1}\phi_{m+1} - \gamma_m \phi_m) +$$

$$\frac{r_{i+1}-r_i}{6} \Sigma_i \left[(\ell r_{i+1} + r_i)\phi_i + (\ell r_i + r_{i+1})\phi_{i+1} \right] = \delta_R \frac{r_{i+1}^2 - r_i^2}{\ell}$$

recursion relation for the coefficients of streaming between rays

$$\gamma_{m+1} - \gamma_m = \ell \mu w \quad (\gamma_0 = 0)$$

linear approximation for the shape of the flux inside a mesh cell

$$\phi_{i+1} + \phi_i = \phi_{m+1} + \phi_m = \ell \bar{\Phi}_i$$

i = 1,2,3 .... I+1
m = 1,2 .... n-2(ℓ-1)
ℓ = 1,2 .... $\frac{n}{2}$

for m = o the following difference equation is used:

$$\mu (r_{i+1} + r_i)(\phi_{i+1} - \phi_i) +$$

$$\frac{r_{i+1}-r_i}{6} \Sigma_i \left[(\ell r_{i+1} + r_i)\phi_i + (\ell r_i + r_{i+1})\phi_{i+1} \right] = \delta_R \frac{r_{i+1}^2 - r_i^2}{\ell}$$

and

$$\phi_i + \phi_{i+1} = \ell \phi_{m=0}$$

2) Slab geometry

difference equation

$$\mu(\phi_{i+1}-\phi_i)+\frac{\Sigma_i}{\ell}(x_{i+1}-x_i)(\phi_{i+1}+\phi_i)=\delta_R(x_{i+1}-x_i)$$

approximation (same as in cylindrical geometry)

i = 1,2 .... I+1
m = 1,2 .... n

3) Both geometries

$$\phi(i)=\sum_{m,\ell} w\,\Phi \qquad \text{(total flux)}$$

$$P_{R\to R'}=\frac{1}{V_R}\sum_{i\in R'}(\phi\,\Sigma_t\,V)_i \qquad \text{(collision probability)}$$

Appendix 2

Input data format

card 1

col 2-72	identification of the problem

card 2 (FØRMAT 24I3)

col 1-3 (ISN) n = 2,4,6,8,12 or 16

col 4-6 (IGEØM)
- o slab geometry
- 1 cylindrical geometry

col 7-9 (ICVL) condition at r (or x) = o

- cylindrical geometry
  - o the inner region is a black region
  - 1 reflective condition
- slab geometry
  - 1 reflective condition
  - 2 periodicity condition

col 10-12 (IBVL) condition at the outer boundary

- cylindrical geometry ($r = r_I$)
  - o the system is in void
  - 1 mirror reflection condition
  - 2 isotropic return along directions of same azimuth
  - 3 isotropic return along all directions
  - 4 arbitrary input law of reflection
- slab geometry
  - 1 mirror reflection (if ICVL = 2 then the periodicity condition is applied)

```
col 13-15  IAFPT
    16-18  ITSNPT
    19-21  IBVLPT       printing options
    22-24  ICVLPT       (see list of symbols in appendix 4)
    25-27  ITPT
    28-30  ISNPT
```

card 3 (FØRMAT 2I3)

```
col  1-3   (NR)     nb of regions
col  4-6   (NMAT)   nb of cross sections
```

card 4 (FØRMAT 24I3)

```
col  1-3  etc...   nb of cross section inside each consecutive region
```

card 5 (FØRMAT 6E12.5)

```
col  1-12 etc...       1     cross section nb 1
                       2           "         2
                       NMAT        "         NMAT
```

(as much card as necessary)

card 6 (FØRMAT 6E12.5)

```
col  1-12 etc...    t1    thickness of region 1
                    t2          "             2
                    tNR         "             NR
```

(as much card as necessary)

card 7 (FØRMAT 6E12.5)

```
col  1-12           a = 10.0
     13-124         b = 2.0      (see subroutine MESH)
     25-36          c = 1.0
```

next problem follows

Appendix 3

Sample Problem

The sample problem corresponds to the case calculated by Jonsson[13]
We consider a three-region system with radii of 1, 2 and 3 mean free path. Results are given in following table.

P_{ij} i j	TIJ (IBVL = 2)	Theseus[13]
1 1	0.5915	0.5929
1 2	0.3012	0.3005
1 3	0.0740	0.0732
2 1	0.1002	0.1002
2 2	0.6190	0.6239
2 3	0.2122	0.2112
3 1	0.0148	0.0147
3 2	0.1271	0.1267
3 3	0.6112	0.6168

SAMPLE PROBLEM FOR

TIJ

(A ONE [redacted] SION PR[redacted]BILITY
CODE F[redacted]CAL ØR [redacted]B
GEOMETRIES)

					CARD
SAMPLE PROBLEM (JONSSON J. OF NUC. EN. VOL 17 P.515)					1
16	1	1	0	1	2
3	1				3
1	1	1			4
1.0					5
1.0		1.0	1.0		6
10.0		2.0	1.0		7

```
*      XEQ
ENTRY POINTS TO SUBROUTINES REQUESTED FROM LIBRARY,
     (FPT)          (TSHM)          (RTN)          (STHM)          (FIL)          EXIT          SQRT

        EXECUTION
SAMPLE PROBLEM OF TIJ(A ONE-DIMENSIONNAL COLLISION PROBABILITY CODE)

APPROXIMATION S 16

IGEOM=  1

ICVL =  1

IBVL =  0

           THICKNESS      MATERIAL      SIGMA-TOT

               1              2              3
    1    0.10000E 01              1    0.10000E 01
    2    0.10000E 01              1
    3    0.10000E 01              1

MATRIX PIJ*LAMDAJ*VI

               1              2              3
    1    0.29574E-00    0.15061E-00    0.37004E-01
    2    0.15031E-00    0.92854E 00    0.31837E-00
    3    0.37126E-01    0.31785E-00    0.15279E 01

VOLUME OF REGIONS

               1
    1    0.50000E 00
    2    0.15000E 01
    3    0.25000E 01

COLLISION PROBABILITY MATRIX

               1              2              3
    1    0.59148E 00    0.30123E-00    0.74008E-01
    2    0.10021E-00    0.61903E 00    0.21224E-00
    3    0.14850E-01    0.12714E-00    0.61118E 00

          32 LINES OUTPUT THIS JOB.

JOB START AT         20.50
COMP./LOAD    TIME 00.008
EXECUTION     TIME 00.003
TOTAL JOB     TIME 00.011
```

Appendix 4

List of symbols with printing option

Fortran name	Variable name* or description	Printing option
DMU (M,L)	(direction cosine)	ISNPT
W (M,L)	w (weight for quadrature)	ISNPT
F(M,L)	Diagonal elements of matrix T (boundary transparence coefficients)	ISNPT
CVL(M,L)	Angular flux at center	ICVLPT
BVL(M,L)	Angular flux at boundary and $\vec{g}_L$ vector components	IBVLPT
PTTP(ML,ML)	Elements of reflection matrix R (directions are ordered like in ref. 2 p. 13)	ISNPT
BVLZW(L)	Angular flux at boundary along m = o directions (zero weight directions)	IBVLPT
TH(I)	thickness of regions) see input data specifications	always printed
SGT(I)	cross section) see input data specifications	always printed
IMAT(I)	material table) see input data specifications	always printed
T(I,J)	$P_{R_i \rightarrow R_j}$	ITPT
R(I)	r_i, x_i	ITSNPT

* refer to text

DR(I)	$r_{i+1} - r_i$, $x_{i+1} - x_i$	ITSNPT
RM(I)	$\frac{r_{i+1} + r_i}{2}$, $\frac{x_{i+1} + x_i}{2}$	ITSNPT
V(I)	$\frac{r_{i+1}^2 - r_i^2}{2}$, $x_{i+1} - x_i$	ITSNPT
VNR(I)	volume of regions	ITSNPT
FMT(I)	Φ_i	IAFPT
BM(I)	Φ_m	IAFPT
TSN(I)	[illegible]	ISNPT

Appendix 5

Description of the subroutines

1) TIJ (main routine)

- read input data
- set up the elements of the R matrix if IBVL $\neq$ O, 1, 4
- monitor the complete calculation

2) Subroutine CYL (ARG1, ARG2, ARG3)

This routine solves the equations of table I and has two calling sequences:

a) CALL CYL (IR, ISL, ISR) then an uniform and isotropic source is placed in region IR which means between mesh points r_{ISL+1} (or x_{ISL+1}) and r_{ISR} (or x_{ISR}). The flux is stored in vector TSN (direct transfer) and components of vector g are collected.

b) CALL CYL (O, IMAXI, IMAXI) then no source is introduced but the boundary flux found in the data block BVL is imposed at the external surface. The flux value are cumulated in TSN (total transfer).

3) Subroutine DMND

From appendix I this subroutine calculates:

- ϕ_i function of ϕ_m, ϕ_{i+1} for inward directions
- ϕ_{i+1} function of ϕ_m, ϕ_i for outward directions

4) Subroutine ZWGHT (Y)

is used in cylindrical geometry for the directions (m=o) which cross the axis of the cylinder.

$$2\,Y = (\phi_i + \phi_{i+1})_{m=o}$$

5) Subroutine BVLCYL

solves the balance equation at the boundary of the lattice cell in cylindrical geometry.
When IBVL is different of 0 or 1, the equation is solved after a fixed number (11) of successive substitutions.

6) Subroutine SLABBC

applies boundary condition on each discrete direction in a slab geometry

7) Subroutine TKRNL(IR)

sets up the collision probability matrix elements when the source region is IR. Also it computes $\sum_j P_{ij}$ which must sum to one if the boundary la conserves neutrons and is symmetrical.

8) Subroutine SNWGT

prepares μ and w for each discrete directions. The three direction cosines are taken from the set of n/2 values.

$$\mu_m^2 = \frac{6m - 5}{3(n-1)} \qquad m = 1, 2 \ldots \frac{n}{2}$$

The weights are those calculated by Lee[2] using the area method.

9) Subroutine MESH

A fine mesh is automatically prepared. In each region i, the mesh size is λ_i/A with a minimum of B mesh interval in each region (A and B are input data). C is used to modify the mesh size within C mean free path of a boundary.

10) Subroutine MATPT (A, IDIM, JDIM, KDIM, I, J, K)

prints automatically in a suitable form a matrix A with one, two or three dimension (see code for use).

11) <u>Subroutine VCTRPT</u> (N, V1, I1, F1,..., VN, IN, FN)

pri[redacted] vect[redacted]f dir[redacted]n I with v[redacted]le format

F = 2 (floating point format)

F = 1 ([redacted] point format)

12) <u>Subroutine RLINK</u>

13[redacted]routine PRINT

```
*     LABEL
CTIJ000
      DIMENSION DMU(17,8),W(17,8),F(17,8),CVL(17,8),BVL(17,8),PTTP(36,36
     1),BVLZW(8)
      DIMENSION TH(20),SGT(20),IMAT(20),NMSH(20),T(20,20)
      DIMENSION R(500),DR(500),V(500),RM(500),SGTHV(500),BM(500),FMT(500
     1),TSN(500)
      COMMONIGEOM,ISN,ISNH,MC,LC,NR,IMAX,IMAX1,NTIN,NTOUT
      COMMONK1,K2,K3,K4,J1,J2,J3,J4,I1,I2,I3,I4
      COMMONWRK1,WRK2,WRK3,WRK4,DMUML,WML,GMP,GMP1,B1,S
      COMMONDMU,W,F,CVL,BVL,PTTP
      COMMONTH,SGT,IMAT,NMSH,T
      COMMONR,DR,V,RM,SGTHV,BM,FMT,TSN,BVLZW
      COMMONISNH1G,ISNH1,ISN1,ISN1G,ICVL,IBVL,IBLCK,NRINIT,PI
      COMMONIAFPT,ITSNPT,IBVLPT,ICVLPT,ITPT,ISNPT
      NTIN=5
      NTOUT=6
      PI=3.1415927
   10 ISNO=ISN
      READ INPUT TAPE NTIN,6
      WRITE OUTPUT TAPE NTOUT,6
      READINPUTTAPENTIN ,1,ISN,IGEOM,ICVL,IBVL,IAFPT,ITSNPT,IBVLPT,ICVLP
     1T,ITPT,ISNPT
      WRITE OUTPUT TAPE NTOUT,5,ISN,IGEOM,ICVL,IBVL
      IF(ISNO-ISN)15,20,15
   15 ISNH=ISN/2
      ISNH1G=ISNH+1+IGEOM
      ISNH1=ISNH+1
      ISN1=ISN+1
      ISN1G=ISN+1+IGEOM
      ISNHG=ISNH+IGEOM
      ISNG=ISN+IGEOM
      CALLSNWGT
   20 READ INPUT TAPE NTIN,1,NR,NMAT
      READ INPUT TAPE NTIN,1,(IMAT(I),I=1,NR)
      READ INPUT TAPE NTIN,3,(SGT(I),I=1,NMAT)
      READ INPUT TAPE NTIN,3,(TH(I),I=1,NR)
      WRITE OUTPUT TAPE NTOUT,4
      CALLVCTRPT(3,TH,NR,2,IMAT,NR,1,SGT,NMAT,2)
      CALLMESH
      DO50LC=1,ISNH
      DO50MC=1,ISN1
   50 F(MC,LC)=0.0
      IF(IGEOM)300,300,100
C     CALCULATION OF TRANSPARENCE COEFFICIENTS FOR CYLINDER
  100 DO 150 I=1,IMAX1
  150 TSN(I)=0.0
      DO8000LC=1,ISNH
      J1=ISNH1G-LC
      DO8000MC=1,J1
 8000 BVL(MC,LC)=1.0
      CALLCYL(0,IMAX1,IMAX1)
      IF(IBVLPT)8200,8200,8100
 8100 WRITEOUTPUTTAPENTOUT,2001
      CALL MATPT(BVL,17,8,1,ISN1,ISNH,1)
 8200 DO8500LC=1,ISNH
      F(1,LC)=BVLZW(LC)
      J1=ISNH1G-LC
      DO8500MC=2,J1
      MP=2*J1+1-MC
 8500 F(MC,LC)=BVL(MP,LC)
      IF(ISNPT)8600,8600,8550
 8550 WRITEOUTPUTTAPENTOUT,3000
      CALL MATPT(F,17,8,1,ISNHG,ISNH,1)
 8600 K1=ISN*(ISN+2)
      K1=K1/8
      IF(IBVL-4)154,152,154
  154 IF(IBVL-1)370,370,175
  152 DO 153 K2=1,K1
  153 READ INPUT TAPE NTIN,3,(PTTP(K2,K),K=1,K1)
  170 IF(ISNPT)370,370,171
  171 WRITEOUTPUTTAPENTOUT,5000
      CALLMATPT(PTTP,36,36,1,K1,K1,1)
      GOTO370
  175 IF(IBVL-2)999,176,185
  176 MCLC=0
      DO180LC=1,ISNH
      J2=ISNH1G-LC+1
      J3=ISNG-2(LC-1)
      WRK1=0.0
      DO178MC=J2,J3
  178 WRK1=WRK1+W(MC,LC)* DMU(MC,LC)
      K2=MCLC+1
      K3=MCLC+ISNH1 -LC
```

```
      DO180 MC=J2,J3
      MCLC=MCLC+1
      WML=W(MC,LC)
      DMUML=DMU(MC,LC)
      DO180K=K2,K3
  180 PTTP(K,MCLC)=DMUML*WML/WRK1
      GOTO170
  185 MCLC=0
      WRK1=0.0
      DO188LC=1,ISNH
      J1=ISNH1G-LC
      DO188MC=1,J1
  188 WRK1=WRK1+W(MC,LC)*DMU(MC,LC)
      DO190LC=1,ISNH
      J2=ISNH1G-LC+1
      J3=ISNG-2*(LC-1)
      DO190MC=J2,J3
      MCLC=MCLC+1
      WML=W(MC,LC)
      DMUML=DMU(MC,LC)
      DO190K=1,K1
  190 PTTP(K,MCLC)=DMUML*WML/ABSF(WRK1)
      GOTO170
C     CALCULATION OF TRANSPARENCE COEFFICIENTS FOR SLAB
  300 DO355MC=1,ISNH
      DMUML=DMU(MC,1)
      BI=1.0
      DO350I=1,IMAX
      I1=IMAX1-I
  350 CALLDMNC
  355 F(MC,1)=BI
  360 IF(ISNPT)370,370,365
  365 WRITEOUTPUTTAPENOUT,3000
      CALLVCTRPT(1,F,ISNH1G,2)
  370 DO400I=1,NR
      DO400J=1,NR
  400 T(I,J)=0.0
      ISR=0
      ISL=0
      IF(ICVL)410,410,415
  410 IF(IGEOM)415,415,412
  412 NRINIT=2
      GOTO420
  415 NRINIT=1
  420 DO600IR=NRINIT,NR
      DO450LC=1,ISNH
      DO450MC=1,ISN1
      CVL(MC,LC)=0.0
  450 BVL(MC,LC)=0.0
      DO460I=1,IMAX1
  460 TSN(I)=0.0
      CTIM=0.0
      ISR=ISR+NMSH(IR)
      ISL=ISR-NMSH(IR)
      CALLCYL(IR,ISL,ISR)
  462 DO463LC=1,ISNH
      J1=ISNH1G-LC
      DO4620MC=1,J1
 4620 CTIM=CTIM+CVL(MC,LC)*W(MC,LC)*DMU(MC,LC)
      J2=J1+1
      J3=2*J1-IGEOM
  463 CONTINUE
  464 ISL1=ISL+1
      IF(ITSNPT)470,470,465
  465 WRITEOUTPUTTAPENOUT,2000,ISL1,ISR
      WRITEOUTPUTTAPENOUT,2002
      CALLVCTRPT(1,TSN,IMAX1,2)
  470 IF(IBVLPT)480,480,475
  475 WRITEOUTPUTTAPENOUT,2001
      CALL MATPT(BVL,17,8,1,ISNG,ISNH,1)
  480 IF(IGEOM)500,500,520
  500 CALLSLABBC
      GOTO560
  520 IF(IBVL)550,2563,550
  550 CALLBVLCYL
  560 CALLCYL(0,IMAX1,IMAX1)
  562 DO563LC=1,ISNH
      J1=ISNH1G-LC
      DO1562MC=1,J1
 1562 CTIM=CTIM+CVL(MC,LC)*W(MC,LC)*DMU(MC,LC)
      J2=J1+1
      J3=2*J1-IGEOM
  563 CONTINUE
 2563 IF(ICVL)564,1563,564
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 1563 WRITE CLTPUT TAPE 6,5001,CTIM                                         TIJ00167
  564 IF(ITSNFT)570,570,565                                                 TIJ00168
  565 WRITECUTPUTTAPENTOUT,2000,ISL1,ISR                                    TIJ00169
      WRITECUTPUTTAPENTOUT,2003                                             TIJ00170
      CALLVCTRPT(1,TSN,IMAX1,2)                                             TIJ00171
  570 IF(IBVLPT)580,580,575                                                 TIJ00172
  575 WRITECUTPUTTAPENTOUT,2001                                             TIJ00173
      CALLMATFT(BVL,17, 8,1,ISNG,ISNH,1)                                    TIJ00174
  580 CALLTKRNL(IR)                                                         TIJ00175
  600 CCNTINUE                                                              TIJ00176
  999 GCTO10                                                                TIJ00177
    1 FCRMAT(24I3)                                                          TIJ00178
    3 FCRMAT(6E12.5)                                                        TIJ00179
    4 FCRMAT( 1H09X37HTHICKNESS      MATERIAL       SIGMA-TOT)              TIJ00180
    5 FCRMAT (16H0APPROXIMATION S,I3/7H0IGECM=I3/7H0ICVL =I3/7H0IBVL =I3TIJ00181
     1)                                                                     TIJ00182
    6 FCRMAT (72H                                                           TIJ00183
     1                    )                                                 TIJ00184
 2000 FCRMAT( 1H08X11HSOURCE(I)=1/10X3H(I=I2,1H,I2,1H))                     TIJ00185
 2002 FCRMAT( 1H07X15HDIRECT TR.COEF.)                                      TIJ00186
 2001 FCRMAT(23H0BOUNDARY VALUES MATRIX)                                    TIJ00187
 2003 FCRMAT( 1H07X14HTOTAL TR.COEF.)                                       TIJ00188
 3000 FCRMAT(35H0BOUNDARY TRANSPARENCE COEFFICIENTS)                        TIJ00189
 4001 FCRMAT( 1H0)                                                          TIJ00190
 5000 FCRMAT( 18H0REFLECTICN MATRIX)                                        TIJ00191
 5001 FCRMAT (27HCCURRENT AT BLACK BCUNDARY=E12.5)                          TIJ00192
      ENC                                                                   TIJ00193
*     LABEL
CCYL000                                                                     CYL00000
      SLBROUTINECYL(IR,ISL,ISR)                                             CYL00001
      CIMENSICN CMU(17,8),W(17,8),F(17,8),CVL(17,8),BVL(17,8),PTTP(36,36CYL00002
     1),BVLZW(8)                                                            CYL00003
      DIMENSICN TH(20),SGT(20),IMAT(20),NMSH(20),T(20,20)                   CYL00004
      DIMENSICN R(500),CR(500),V(500),RM(500),SGTHV(500),BM(500),FMT(500CYL00005
     1),TSN(500)                                                            CYL00006
      CCMMONICEOM,ISN,ISNH,MC,LC,NR,IMAX,IMAX1,NTIN,NTOUT                   CYL00007
      CCMMONK1,K2,K3,K4,J1,J2,J3,J4,I1,I2,I3,I4                             CYL00008
      CCMMONWRK1,WRK2,WRK3,WRK4,DMUML,WML,GMP,GMP1,BI,S                     CYL00009
      CCMMONCMU,W,F,CVL,BVL,PTTP                                            CYL00010
      CCMMONTH,SGT,IMAT,NMSH,T                                              CYL00011
      CCMMCNR,DR,V,RM,SGTHV,BM,FMT,TSN,BVLZW                                CYL00012
      CCMMONISNH1G,ISNH1,ISN1,ISN1G,ICVL,IBVL,IBLCK,NRINIT,PI               CYL00013
      CCMMONIAFPT,ITSNPT,IBVLPT,ICVLPT,ITPT,ISNPT                           CYL00014
      DC4COLC=1,ISNH                                                        CYL00015
      CC20I=1,IMAX1                                                         CYL00016
      BM(I)=0.0                                                             CYL00017
   20 FMT(I)=C.0                                                            CYL00018
      GMP=0.0                                                               CYL00019
      GMP1=0.C                                                              CYL00020
C     INWARC CIRECTIONS MESH SWEEP                                          CYL00021
      J1=ISNH1G-LC                                                          CYL00022
      DC200MC=1,J1                                                          CYL00023
      WML=W(MC,LC)                                                          CYL00024
      CMUML=CMU(MC,LC)                                                      CYL00025
   75 IF(IGECM)85,85,80                                                     CYL00026
   80 GMP=GMP1                                                              CYL00027
      GMP1=GMP1-2.0*WML*DMLML                                               CYL00028
   85 IF(IR)9C,90,99                                                        CYL00029
   90 BI=BVL(MC,LC)                                                         CYL00030
      IM=IMAX                                                               CYL00031
      GCTC100                                                               CYL00032
   99 BI=C.C                                                                CYL00033
      IM=IMAX                                                               CYL00034
  100 TSN(IM+1)=TSN(IM+1)+WML*BI                                            CYL00035
      FMT(IM+1)=BI                                                          CYL00036
      CC150I=1,IM                                                           CYL00037
      I1=IM-I+1                                                             CYL00038
      I2=I1                                                                 CYL00039
      IF(I1-ISL)110,110,113                                                 CYL00040
  113 IF(I1-ISR)112,112,110                                                 CYL00041
  112 S=1.0                                                                 CYL00042
      GCTC115                                                               CYL00043
  110 S=0.0                                                                 CYL00044
  115 IF(WML)120,120,130                                                    CYL00045
  120 CALLZWGHT(Y)                                                          CYL00046
      BM(I1)=Y                                                              CYL00047
      GCTC150                                                               CYL00048
  130 CALLCMNC                                                              CYL00049
      TSN(I2)=TSN(I2)+WML*FMT(I2)                                           CYL00050
  150 CCNTINUE                                                              CYL00051
  152 IF(IAFPT)19C,190,155                                                  CYL00052
  155 WRITECUTPUTTAPENTOUT,1000,MC,LC                                       CYL00053
      CALLVCTRPT(2,FMT,IMAX1,2,BM,IMAX,2)                                   CYL00054
  190 CVL(MC,LC)=BI                                                         CYL00055
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```
  192 IF(WML)1920,1920,194                                                 CYL00056
 1920 IF(ICVL)1921,1921,1930                                               CYL00057
 1921 BI=0.0                                                               CYL00058
 1930 DO1960I1=1,IMAX                                                      CYL00059
      I2=I1+1                                                              CYL00060
      IF(I1-ISL)1950,1950,1935                                             CYL00061
 1935 IF(I1-ISR)1940,1940,1950                                             CYL00062
 1940 S=1.0                                                                CYL00063
      GOTO1955                                                             CYL00064
 1950 S=0.0                                                                CYL00065
 1955 CALLZWCHT(Y)                                                         CYL00066
      FMT(I1)=Y                                                            CYL00067
 1960 CONTINUE                                                             CYL00068
      BVLZW(LC)=BI                                                         CYL00069
      IF(IAFPT)200 ,200 ,1961                                              CYL00070
 1961 WRITEOUTPUTTAPENTOUT,4000                                            CYL00071
      CALLVCTRPT(1,FMT,IMAX,2)                                             CYL00072
      GOTO200                                                              CYL00073
  194 IF(IGEOM)200,200,195                                                 CYL00074
  195 MP=2*J1+1-MC                                                         CYL00075
      IF(ICVL)196,196,197                                                  CYL00076
  196 CVL(MP,LC)=0.0                                                       CYL00077
      GOTO200                                                              CYL00078
  197 CVL(MP,LC)=BI                                                        CYL00079
  200 CONTINUE                                                             CYL00080
  260 J2=J1+1                                                              CYL00081
      J3=2*J1-IGEOM                                                        CYL00082
      DO390MC=J2,J3                                                        CYL00083
      WML=W(MC,LC)                                                         CYL00084
      DMUML=DMU(MC,LC)                                                     CYL00085
  264 IF(IGEOM)265,265,270                                                 CYL00086
  265 IF(IR)275,275,267                                                    CYL00087
  267 BI=0.0                                                               CYL00088
      IMIN=ISL+1                                                           CYL00089
      GOTO280                                                              CYL00090
  270 GMP=GMP1                                                             CYL00091
      GMP1=GMP1-2.0*WML*DMUML                                              CYL00092
  275 IMIN=1                                                               CYL00093
      BI=CVL(MC,LC)                                                        CYL00094
  280 TSN(IMIN)=TSN(IMIN)+WML*BI                                           CYL00095
      FMT(IMIN)=BI                                                         CYL00096
      DO350I1=IMIN,IMAX                                                    CYL00097
      I2=I1+1                                                              CYL00098
  304 IF(I1-ISL)320,320,305                                                CYL00099
  305 IF(I1-ISR)310,310,320                                                CYL00100
  310 S=1.0                                                                CYL00101
      GOTO330                                                              CYL00102
  320 S=0.0                                                                CYL00103
  330 CALLDMND                                                             CYL00104
  335 TSN(I2)=TSN(I2)+WML*FMT(I2)                                          CYL00105
  350 CONTINUE                                                             CYL00106
 356  IF(IAFPT)380,380,357                                                 CYL00107
  357 WRITEOUTPUTTAPENTOUT,1000,MC,LC                                      CYL00108
      CALLVCTRPT(2,FMT,IMAX1,2,BM,IMAX,2)                                  CYL00109
  380 BVL(MC,LC)=BI                                                        CYL00110
  390 CONTINUE                                                             CYL00111
      IF(IGEOM)410,410,400                                                 CYL00112
  400 CONTINUE                                                             CYL00113
      J1=ISNH                                                              CYL00114
      GOTO415                                                              CYL00115
  410 J1=1                                                                 CYL00116
  415 IF(ICVLFT)450,450,420                                                CYL00117
  420 WRITEOUTPUTTAPENTOUT,2000                                            CYL00118
      CALLMATPT(CVL,17,8 ,1,ISN1,J1,1)                                     CYL00119
  450 IF(IBVLFT)460,460,455                                                CYL00120
  455 WRITEOUTPUTTAPENTOUT,3000                                            CYL00121
      CALLVCTRPT(1,BVLZW,ISNH,2)                                           CYL00122
  460 RETURN                                                               CYL00123
 1000 FORMAT(1H013X12HANGULAR FLUX/14X4H (M=I2,4H,L= I2,1H)/1H011X3H NI1CYL00124
     11X4HNM+1)                                                            CYL00125
 2000 FORMAT(22H0CENTRAL VALUES MATRIX)                                    CYL00126
 3000 FORMAT(28H0ZERO WEIGHT BOUNDARY VALUES//)                            CYL00127
 4000 FORMAT(20H0RADIAL OUTWARD FLUX//)                                    CYL00128
      END                                                                  CYL00129
*     LABEL
CDMND00                                                                    DMND0000
      SUBROUTINEDMND                                                       DMND0001
      DIMENSION DMU(17,8),W(17,8),F(17,8),CVL(17,8),BVL(17,8),FTTP(36,36DMND0002
     1),BVLZW(8)                                                           DMND0003
      DIMENSION TM(20),SGT(20),IMAT(20),NMSH(20),T(20,20)                  DMND0004
      DIMENSION R(500),DR(500),V(500),RM(500),SGTHV(500),BM(500),FMT(500DMND0005
     1),TSN(500)                                                           DMND0006
      COMMONIGEOM,ISN,ISNH,MC,LC,NR,IMAX,IMAX1,NTIN,NTOUT                  DMND0007
      COMMONK1,K2,K3,K4,J1,J2,J3,J4,I1,I2,I3,I4                            DMND0008
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      COMMONWRK1,WRK2,WRK3,WRK4,DMUML,WML,GMP,GMP1,BI,S                 CMND0009
      COMMONDMU,W,F,CVL,BVL,PTTP                                        CMND0010
      COMMONTH,SGT,IMAT,NMSH,T                                          CMND0011
      COMMONR,DR,V,RM,SGTHV,BM,FMT,TSN,BVLZW                            CMND0012
      COMMONISNH1G,ISNH1,ISN1,ISN1G,ICVL,IBVL,IBLCK,NRINIT,PI           CMND0013
      COMMONIAFPT,ITSNPT,IBVLPT,ICVLPT,ITPT,ISNFT                       CMND0014
   50 IF(IGEOM)220,220,100                                              CMND0015
C     CALCULATES ANGULAR TERMS FOR CYLINDER                             CMND0016
  100 BMI1=BM(I1)                                                       CMND0017
      WRK3=DR(I1)/WML/2.0                                               CMND0018
      WRK2=GMP1*WRK3                                                    CMND0019
      WRK1=(GMP+GMP1)*WRK3*BMI1/2.0                                     CMND0020
      WRK4=SGTHV(I1)/(6.0*RM(I1))                                       CMND0021
  120 FM=(S*V(I1)/2.0+BI*(ABSF(DMUML)*RM(I1)+SIGNF(DR(I1),DMUML)*WRK4)  CMND0022
     1+WRK1)/(4.0*WRK4*RM(I1)+(ABSF(DMUML)+2.0*WRK4)*R(I2)+WRK2)        CMND0023
      BM(I1)=2.0*FM-BMI1                                                CMND0024
  200 BI=2.0*FM-BI                                                      CMND0025
      FMT(I2)=BI                                                        CMND0026
  210 RETURN                                                            CMND0027
  220 FM=(S*V(I1)/2.+ABSF(DMUML)*BI)/(SGTHV(I1)+ABSF(DMUML))            CMND0028
      GOTO200                                                           CMND0029
      END                                                               CMND0030
*     LABEL
CZWGHT0                                                                 ZWGHT000
      SUBROUTINEZWGHT(BMI1)                                             ZWGHT001
      DIMENSION DMU(17,8),W(17,8),F(17,8),CVL(17,8),BVL(17,8),PTTP(36,36ZWGHT002
     1),BVLZW(8)                                                        ZWGHT003
      DIMENSION TH(20),SGT(20),IMAT(20),NMSH(20),T(20,20)               ZWGHT004
      DIMENSION R(500),DR(500),V(500),RM(500),SGTHV(500),BM(500),FMT(500ZWGHT005
     1),TSN(500)                                                        ZWGHT006
      COMMONIGEOM,ISN,ISNH,MC,LC,NR,IMAX,IMAX1,NTIN,NTOUT               ZWGHT007
      COMMONK1,K2,K3,K4,J1,J2,J3,J4,I1,I2,I3,I4                         ZWGHT008
      COMMONWRK1,WRK2,WRK3,WRK4,DMUML,WML,GMP,GMP1,BI,S                 ZWGHT009
      COMMONDMU,W,F,CVL,BVL,PTTP                                        ZWGHT010
      COMMONTH,SGT,IMAT,NMSH,T                                          ZWGHT011
      COMMONR,DR,V,RM,SGTHV,BM,FMT,TSN,BVLZW                            ZWGHT012
      COMMONIAFPT,ITSNPT,IBVLPT,ICVLPT,ITPT,ISNFT                       ZWGHT013
      DMUML=DMU(MC,LC)                                                  ZWGHT014
      WRK1=     ABSF(DMUML)*RM(I1)                                      ZWGHT015
      WRK2=0.33333*SGTHV(I1)/RM(I1)                                     ZWGHT016
      WRK3=BI                                                           ZWGHT017
     0BI =(S*V(I1)+(WRK1-WRK2*(4.*RM(I1)-R(I2)))*BI)/                   ZWGHT018
     1(WRK1+WRK2*(2.0*RM(I1)+R(I2)))                                    ZWGHT019
      BMI1  =(WRK3+BI)/2.0                                              ZWGHT020
      RETURN                                                            ZWGHT021
      END                                                               ZWGHT022
*     LABEL
CBVLCY0                                                                 BVLCY000
      SUBROUTINEBVLCYL                                                  BVLCY001
      DIMENSION DMU(17,8),W(17,8),F(17,8),CVL(17,8),BVL(17,8),PTTP(36,36BVLCY002
     1),BVLZW(8)                                                        BVLCY003
      DIMENSION TH(20),SGT(20),IMAT(20),NMSH(20),T(20,20)               BVLCY004
      DIMENSION R(500),DR(500),V(500),RM(500),SGTHV(500),BM(500),FMT(500BVLCY005
     1),TSN(500)                                                        BVLCY006
      COMMONIGEOM,ISN,ISNH,MC,LC,NR,IMAX,IMAX1,NTIN,NTOUT               BVLCY007
      COMMONK1,K2,K3,K4,J1,J2,J3,J4,I1,I2,I3,I4                         BVLCY008
      COMMONWRK1,WRK2,WRK3,WRK4,DMUML,WML,GMP,GMP1,BI,S                 BVLCY009
      COMMONDMU,W,F,CVL,BVL,PTTP                                        BVLCY010
      COMMONTH,SGT,IMAT,NMSH,T                                          BVLCY011
      COMMONR,DR,V,RM,SGTHV,BM,FMT,TSN,BVLZW                            BVLCY012
      COMMONISNH1G,ISNH1,ISN1,ISN1G,ICVL,IBVL,IBLCK,NRINIT,PI           BVLCY013
      COMMONIAFPT,ITSNPT,IBVLPT,ICVLPT,ITPT,ISNFT                       BVLCY014
      ISN1=ISN+1                                                        BVLCY015
      DO100LC=1,ISNH                                                    BVLCY016
      J1=ISNH1G-LC                                                      BVLCY017
      DO100MC=1,J1                                                      BVLCY018
  100 CVL(MC,LC)=0.0                                                    BVLCY019
      IF(IBVL-1)145,110,145                                             BVLCY020
  110 DO135LC=1,ISNH                                                    BVLCY021
      J1=ISNH1G-LC                                                      BVLCY022
      DO130MC=2,J1                                                      BVLCY023
      MP=2*J1+1-MC                                                      BVLCY024
  130 BVL(MC,LC)=BVL(MP,LC)/(1.0-F(MC,LC))                              BVLCY025
  135 BVL(1,LC)=BVLZW(LC)/(1.0-F(1,LC))                                 BVLCY026
      GO TO 300                                                         BVLCY027
  145 K1=ISN*(ISN+2)                                                    BVLCY028
      K1=K1/8                                                           BVLCY029
      DO250NIT=1,10                                                     BVLCY030
      DO160LC=1,ISNH                                                    BVLCY031
      J1=ISNH1G-LC                                                      BVLCY032
      J2=2*J1-IGEOM                                                     BVLCY033
      J3=J1+1                                                           BVLCY034
      DO150MC=J3,J2                                                     BVLCY035
      MP=2*J1+1-MC                                                      BVLCY036
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  150 F(MC,LC)=BVL(MC,LC)+BVL(MP,LC)*F(MP,LC)                          BVLCY037
  160 CONTINUE                                                         BVLCY038
      MCLC=0                                                           BVLCY039
      DO220LC=1,ISNH                                                   BVLCY040
      J1=ISNH1G-LC                                                     BVLCY041
      DO210MC=2,J1                                                     BVLCY042
      MCLC=MCLC+1                                                      BVLCY043
      LP=1                                                             BVLCY044
      K2=0                                                             BVLCY045
      WRK1=0.0                                                         BVLCY046
      DO200K=1,K1                                                      BVLCY047
      K2=K2+1                                                          BVLCY048
      IF(ISNH-LP+1-K2)180,190,190                                      BVLCY049
  180 K2=1                                                             BVLCY050
      LP=LP+1                                                          BVLCY051
  190 MP=K2+ISNH1G-LP                                                  BVLCY052
  200 WRK1=WRK1+PTTP(MCLC,K)*F(MP,LP)                                  BVLCY053
  210 BVL(MC,LC)=WRK1                                                  BVLCY054
  220 BVL(1,LC)=BVL(2,LC)                                              BVLCY055
      IF(IBVLPT)250,250,225                                            BVLCY056
  225 WRITEOUTPUTTAPENTOUT,1000,NIT                                    BVLCY057
      CALL MATPT(BVL,17,8,1,ISN1,ISNH,1)                               BVLCY058
  250 CONTINUE                                                         BVLCY059
      IF(ITSNPT)255,300,255                                            BVLCY060
  255 WRITEOUTPUTTAPENTOUT,1000,NIT                                    BVLCY061
      CALL MATPT(BVL,17,8,1,ISN1,ISNH,1)                               BVLCY062
  300 RETURN                                                           BVLCY063
 1000 FORMAT(29HOBOUNDARY VALUES MATRIX ,NIT=I2)                       BVLCY064
      END                                                              BVLCY065
*     LABEL
CSLABBC                                                                SLABBC00
      SUBROUTINESLABBC                                                 SLABBC01
      DIMENSION DMU(17,8),W(17,8),F(17,8),CVL(17,8),BVL(17,8),PTTP(36,36SLABBC02
     1),BVLZW(8)                                                       SLABBC03
      DIMENSION TH(20),SGT(20),IMAT(20),NMSH(20),T(20,20)              SLABBC04
      DIMENSION R(500),DR(500),V(500),RM(500),SGTHV(500),BM(500),FMT(500SLABBC05
     1),TSN(500)                                                       SLABBC06
      COMMONIGEOM,ISN,ISNH,MC,LC,NR,IMAX,IMAX1,NTIN,NTOUT              SLABBC07
      COMMONK1,K2,K3,K4,J1,J2,J3,J4,I1,I2,I3,I4                        SLABBC08
      COMMONWRK1,WRK2,WRK3,WRK4,DMUML,WML,GMP,GMP1,BI,S                SLABBC09
      COMMONDMU,W,F,CVL,BVL,PTTP                                       SLABBC10
      COMMONTH,SGT,IMAT,NMSH,T                                         SLABBC11
      COMMONR,DR,V,RM,SGTHV,BM,FMT,TSN,BVLZW                           SLABBC12
      COMMONISNH1G,ISNH1,ISN1,ISN1G,ICVL,IBVL,IBLCK,NRINIT,PI          SLABBC13
      COMMONIAFPT,ITSNPT,IBVLPT,ICVLPT,ITPT,ISNPT                      SLABBC14
  500 IF(ICVL-1)530,520,505                                            SLABBC15
C     PERIODIC SLAB                                                    SLABBC16
  505 DO510MC=1,ISNH                                                   SLABBC17
      BVL(MC,1)=CVL(MC,1)/(1.0-F(MC,1))                                SLABBC18
      MP=ISN1-MC                                                       SLABBC19
  510 CVL(MP,1)=BVL(MP,1)/(1.0-F(MC,1))                                SLABBC20
      GOTO560                                                          SLABBC21
C     REFLECTIVE SLAB                                                  SLABBC22
  520 DO525MC=1,ISNH                                                   SLABBC23
      MP=ISN1-MC                                                       SLABBC24
      CVL(MP,1)=(CVL(MC,1)+F(MC,1)*BVL(MP,1))/(1.0-F(MC,1)**2)         SLABBC25
  525 BVL(MC,1)=(BVL(MP,1)+F(MC,1)*CVL(MC,1))/(1.0-F(MC,1)**2)         SLABBC26
      GOTO560                                                          SLABBC27
C     BLACK INNER CONDITION                                            SLABBC28
  530 DO535MC=1,ISNH                                                   SLABBC29
      MP=ISN1-MC                                                       SLABBC30
      CVL(MP,1)=0.0                                                    SLABBC31
  535 BVL(MC,1)=BVL(MP,1)                                              SLABBC32
  560 RETURN                                                           SLABBC33
      END                                                              SLABBC34
*     LABEL
CTKRNL0
      SUBROUTINETKRNL(IR)                                              TKRNL001
      DIMENSION DMU(17,8),W(17,8),F(17,8),CVL(17,8),BVL(17,8),PTTP(36,36TKRNL002
     1),BVLZW(8)                                                       TKRNL003
      DIMENSION TH(20),SGT(20),IMAT(20),NMSH(20),T(20,20)              TKRNL004
      DIMENSION R(500),DR(500),V(500),RM(500),SGTHV(500),BM(500),FMT(500TKRNL005
     1),TSN(500)                                                       TKRNL006
      COMMONIGEOM,ISN,ISNH,MC,LC,NR,IMAX,IMAX1,NTIN,NTOUT              TKRNL007
      COMMONK1,K2,K3,K4,J1,J2,J3,J4,I1,I2,I3,I4                        TKRNL008
      COMMONWRK1,WRK2,WRK3,WRK4,DMUML,WML,GMP,GMP1,BI,S                TKRNL009
      COMMONDMU,W,F,CVL,BVL,PTTP                                       TKRNL010
      COMMONTH,SGT,IMAT,NMSH,T                                         TKRNL011
      COMMONR,DR,V,RM,SGTHV,BM,FMT,TSN,BVLZW                           TKRNL012
      COMMONISNH1G,ISNH1,ISN1,ISN1G,ICVL,IBVL,IBLCK,NRINIT,PI          TKRNL013
      COMMONIAFPT,ITSNPT,IBVLPT,ICVLPT,ITPT,ISNPT                      TKRNL014
      DIMENSIONVNR(20)                                                 TKRNL015
      IF(ICVL)45,45,50                                                 TKRNL016
   45 NRINIT=2                                                         TKRNL017
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      GCTC55                                                            TKRNL018
   50 NRINIT=1                                                          TKRNL019
   55 K1=NRINIT                                                         TKRNL020
      K2=NMSH(K1)                                                       TKRNL021
      DC110I=1,IMAX                                                     TKRNL022
      IF(I-K2)100,100,90                                                TKRNL023
   90 K1=K1+1                                                           TKRNL024
      K2=K2+NMSH(K1)                                                    TKRNL025
  100 IF(IGECM)105,105,108                                              TKRNL026
  105 T(IR,K1)=T(IR,K1)+0.5*DR(I )*(TSN(I)+TSN(I+1))                    TKRNL027
      GCTC110                                                           TKRNL028
  108 T(IR,K1)=T(IR,K1)+DR(I )*(TSN(I+1)*(2.0*R(I+1)+R(I))+TSN(I)*(2.0* TKRNL029
     1R(I)+R(I+1)))/6.0                                                 TKRNL030
  11C CCNTINUE                                                          TKRNL031
  160 IF(IR-NR)20C,650,200                                              TKRNL032
  650 IF(ITPT)655,200,655                                               TKRNL033
  655 J2=0                                                              TKRNL034
      WRITE OLTPUT TAPE NTCUT,300C                                      TKRNL035
      CALLMATPT(T,20,20,1,NR,NR,1)                                      TKRNL036
      DC660I=NRINIT,NR                                                  TKRNL037
      J1=J2+1                                                           TKRNL038
      J2=J2+NMSH(I)                                                     TKRNL039
      VNR(I)=C.0                                                        TKRNL040
      DC660J=J1,J2                                                      TKRNL041
  660 VNR(I)=VNR(I)+V(J)                                                TKRNL042
      WRITECUTPUTTAPENTOUT,4000                                         TKRNL043
      CALLVCTRPT(1,VNR,NR,2)                                            TKRNL044
      DC680I=NRINIT,NR                                                  TKRNL045
      WRK1=0.C                                                          TKRNL046
      DC670J=NRINIT,NR                                                  TKRNL047
      K2=IMAT(J)                                                        TKRNL048
      T(I,J)=SGT(K2)*T(I,J)/VNR(I)                                      TKRNL049
  670 WRK1=WRK1+T(I,J)                                                  TKRNL050
      IF(IBVL)200,680,675                                               TKRNL051
  675 WRITE CLTPUT TAPE NTCUT,100C,I,WRK1                               TKRNL052
  68C CCNTINUE                                                          TKRNL053
      WRITECUTPUTTAPENTCUT,2000                                         TKRNL054
      CALLMATPT(T,20,20,1,NR,NR,1)                                      TKRNL055
  200 RETURN                                                            TKRNL056
 1000 FCRMAT (16HOSUM OVER J CF P,I3,4H  J=E12.5)                       TKRNL057
 2000 FCRMAT(29HOCOLLISION PROBABILITY MATRIX)                          TKRNL058
 3000 FCRMAT (21HOMATRIX PIJ*LAMDAJ*VI//)                               TKRNL059
 4000 FCRMAT(18HOVOLUME OF REGICNS)                                     TKRNL060
      END                                                               TKRNL061
*     LABEL
CMESHCO                                                                 MESH0000
      SUBROUTINEMESH                                                    MESH0001
      DIMENSICN DMU(17,8),W(17,8),F(17,8),CVL(17,8),BVL(17,8),PTTP(36,36MESH0002
     1),BVLZW(8)                                                        MESH0003
      DIMENSICN TH(20),SGT(20),IMAT(20),NMSH(20),T(20,20)               MESH0004
      DIMENSICN R(500),DR(500),V(500),RM(500),SGTHV(500),BM(500),FMT(500MESH0005
     1),TSN(5C0)                                                        MESH0006
      CCMMONIGEOM,ISN,ISNH,MC,LC,NR,IMAX,IMAX1,NTIN,NTOUT               MESH0007
      CCMMONK1,K2,K3,K4,J1,J2,J3,J4,I1,I2,I3,I4                         MESH0008
      CCMMONWRK1,WRK2,WRK3,WRK4,DMUML,WML,GMP,GMP1,BI,S                 MESH0009
      CCMMONDMU,W,F,CVL,BVL,PTTP                                        MESH0010
      CCMMONTH,SGT,IMAT,NMSH,T                                          MESH0011
      CCMMONR,DR,V,RM,SGTHV,BM,FMT,TSN,BVLZW                            MESH0012
      CCMMONISNH1C,ISNH1,ISN1,ISN1G,ICVL,IBVL,IBLCK,NRINIT,PI           MESH0013
      CCMMCNIAFPT,ITSNPT,IBVLPT,ICVLPT,ITPT,ISNPT                       MESH0014
      DIMENSICNBMSH(20),CMSH(20)                                        MESH0015
      READ INPUT TAPE 5,1C04,A,B,C                                      MESH0016
      MSHMX=5C0                                                         MESH0017
      IF(IGEOM)75,75,50                                                 MESH0018
   50 IF(ICVL)60,60,75                                                  MESH0019
   60 NRINIT=2                                                          MESH0020
      R(1)=TH(1)                                                        MESH0021
      GCTO8C                                                            MESH0022
   75 NRINIT=1                                                          MESH0023
      R(1)=0.C                                                          MESH0024
   80 DC130K1=NRINIT,NR                                                 MESH0025
      WRK1=TH(K1)                                                       MESH0026
      K2=IMAT(K1)                                                       MESH0027
      WRK2=1./SGT(K2)                                                   MESH0028
      WRK3=WRK2/A                                                       MESH0029
      WRK4=WRK1/B                                                       MESH0030
      IF(WRK3-WRK4)100,11C,11C                                          MESH0031
  100 CMSH(K1)=WRK3                                                     MESH0032
      GCTO115                                                           MESH0033
  110 CMSH(K1)=WRK4                                                     MESH0034
  115 WRK3=WRK2/C                                                       MESH0035
      WRK4=WRK1/2.                                                      MESH0036
      IF(WRK3-WRK4)120,130,130                                          MESH0037
  120 BMSH(K1)=WRK3                                                     MESH0038
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      GOTO131
  130 BMSH(K1)=WRK4
  131 IMSH1=1
      XR2=R(1)
      YR2=CMSH(NRINIT)
      XR1=XR2
      YR1=YR2
      X=R(1)
      DRC=CMSH(NRINIT)
      DO260K=NRINIT,NR
      K2=0
      K3=IMAT(K)
      XL1=XR1
      XL2=XR2
      YL1=YR1
      YL2=YR2
      WRK1=R(IMSH1)
      WRK2=WRK1+TH(K)
      IF(K-NR)135,1352,1352
  135 YR1=YR2
      YR2=CMSH(K +1)
      IF(YR2-YR1)1351,1352,1353
 1351 XR1=WRK2-BMSH(K )
      XR2=WRK2
      GOTO137
 1352 XR1=WRK2
      XR2=WRK2
      GOTO137
 1353 XR1=WRK2
      XR2=WRK2+BMSH(K +1)
  137 K1=1
  140 IMSH=IMSH1
      IMSH1=IMSH+1
      IF(MSHMX-IMSH)270,270,145
  145 K2=K2+1
      IF(X-XL2)150,170,170
  150 DRC=RLINK(XL1,YL1,XL2,YL2,X)
      GOTO250
  170 IF(X-XR1)175,175,190
  175 IF(XR1-WRK2)180,176,190
  176 IF(X-XR1+0.2*DRC)180,210,210
  180 DRC=CMSH(K )
      GOTO250
  190 IF(X-WRK2+0.2*DRC)200,210,210
  200 DRC=RLINK(XR1,YR1,XR2,YR2,X)
      GOTO250
  210 X=WRK2
      IMSH1=IMSH
      IMSH=IMSH-1
      DRC=X-R(IMSH)
      K1=2
      K2=K2-1
      GOTO251
  250 X=X+DRC
  251 R(IMSH1)=X
      WRK3=(R(IMSH1)+R(IMSH))/2.0
      IF(IGEOM)253,253,254
  253 V(IMSH)=DRC
      GOTO255
  254 V(IMSH)=DRC*WRK3
  255 RM(IMSH)=WRK3
      SCTHV(IMSH)=SGT(K3)*V(IMSH)/2.
      DR(IMSH)=DRC
      GOTO(140,257),K1
  257 NMSH(K)=K2
  260 CONTINUE
      IMAX=IMSH
      IMAX1=IMSH1
      IF(ITSNFT)265,265,262
  262 WRITEOUTPUTTAPENTOUT,1002
      WRITEOUTPUTTAPENTOUT,1003
     0CALLPRINT(8,R,IMAX1,2,DR,IMAX,2,RM,IMAX,2,V,IMAX,2,NMSH,NR,1,CMSH,
     1NR,2,BMSH,NR,2,SCTHV,IMAX,2)
  265 RETURN
  270 WRITEOUTPUTTAPE6,1001
      CALLEXIT
 1001 FORMAT(21H TOO MUCH MESH POINTS)
 1002 FORMAT(1H151X16HGEOMETRICAL MESH//)
 1003 FORMAT(///11X6HRADIUS8X6HDELTAR8X6HR-MEAN8X6HVOLUME//)
 1004 FORMAT (3E12.5)
      END
*     LABEL
CRLINK0
      FUNCTIONRLINK(X1,Y1,X2,Y2,X)
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```
      WRK3=(Y1-Y2)/(X1-X2)                                              RLINK002
      RLINK=WRK3*(X-X1)+Y1                                              RLINK003
      RETURN                                                            RLINK004
      END                                                               RLINK005
*     LABEL
CMATPT0                                                                 MATPT000
      SUBROUTINEMATPT(A,IDIM,JDIM,KDIM,I,J,K)                           MATPT001
      DIMENSIONA(1)                                                     MATPT002
      NB=J/8                                                            MATPT003
      IF(8*NB-J)100,110,110                                             MATPT004
  100 NB=NB+1                                                           MATPT005
  110 DC170N=1,K                                                        MATPT006
      JS=IDIM*JDIM*(N-1)                                                MATPT007
      DC160M=1,NB                                                       MATPT008
      J1=JS+8*IDIM*(M-1)+1                                              MATPT009
      K1=8*(M-1)+1                                                      MATPT010
      J2=JS+8*IDIM*M                                                    MATPT011
      IF(M-NB)125,120,120                                               MATPT012
  120 J2=JS+ICIM*J                                                      MATPT013
      K2=J                                                              MATPT014
      GCTC130                                                           MATPT015
  125 K2=K1+7                                                           MATPT016
  130 WRITECUTPUTTAPE6,1000,(K3,K3=K1,K2)                               MATPT017
      DC150L=1,I                                                        MATPT018
      J3=J1+L-1                                                         MATPT019
      WRITECUTPUTTAPE6,1001,L,(A(IJK),IJK=J3,J2,ICIM)                   MATPT020
  150 CCNTINUE                                                          MATPT021
  160 CCNTINUE                                                          MATPT022
  170 CCNTINUE                                                          MATPT023
      RETURN                                                            MATPT024
 1000 FCRMAT(1H08I14/)                                                  MATPT025
 1001 FCRMAT(2XI4,8E14.5)                                               MATPT026
      END                                                               MATPT027
*     LABEL
*     FAP                                                               VCTRPT01
        ENTRY      VCTRPT                                               VCTRPT02
VCTRPT  SXA        VCTXR1,1                                             VCTRPT03
        SXA        VCTXR2,2                                             VCTRPT04
        CLA        1,4                                                  VCTRPT05
        STA        CALL+1                                               VCTRPT06
        LDQ*       1,4                                                  VCTRPT07
        MPY        =3                                                   VCTRPT08
        LLS        35                                                   VCTRPT09
        PDX        ,1                                                   VCTRPT10
        AXT        24,2                                                 VCTRPT11
 VCT10  CLA        2,4                                                  VCTRPT12
        STA        RETURN,2                                             VCTRPT13
        TIX        *+1,2,1                                              VCTRPT14
        TIX        *+1,4,1                                              VCTRPT15
        TIX        VCT10,1,1                                            VCTRPT16
        SXA        VCTXR4,4                                             VCTRPT17
 CALL   TSX        $PRINT,4                                             VCTRPT18
        PZE                                                             VCTRPT19
        PZE                                                             VCTRPT20
        PZE                                                             VCTRPT21
        PZE                                                             VCTRPT22
        PZE                                                             VCTRPT23
        PZE                                                             VCTRPT24
        PZE                                                             VCTRPT25
        PZE                                                             VCTRPT26
        PZE                                                             VCTRPT27
        PZE                                                             VCTRPT28
        PZE                                                             VCTRPT29
        PZE                                                             VCTRPT30
        PZE                                                             VCTRPT31
        PZE                                                             VCTRPT32
        PZE                                                             VCTRPT33
        PZE                                                             VCTRPT34
        PZE                                                             VCTRPT35
        PZE                                                             VCTRPT36
        PZE                                                             VCTRPT37
        PZE                                                             VCTRPT38
        PZE                                                             VCTRPT39
        PZE                                                             VCTRPT40
        PZE                                                             VCTRPT41
        PZE                                                             VCTRPT42
        PZE                                                             VCTRPT43
RETURN  NOP                                                             VCTRPT44
VCTXR1  AXT        **,1                                                 VCTRPT45
VCTXR2  AXT        **,2                                                 VCTRPT46
VCTXR4  AXT        **,4                                                 VCTRPT47
        TRA        2,4                                                  VCTRPT48
        END                                                             VCTRPT49
*       LABEL
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CSNWGT0                                                                 SNWGT000
      SUBROUTINESNWGT                                                   SNWGT001
C     SN DIRECTION MESH AND WEIGHTS FOR N=2,4,6,8,12OR16                SNWGT002
      DIMENSION DMU(17,8),W(17,8),F(17,8),CVL(17,8),BVL(17,8),PTTP(36,36SNWGT003
     1),BVLZW(8)                                                        SNWGT004
      DIMENSION TH(20),SGT(20),IMAT(20),NMSH(20),T(20,20)               SNWGT005
      DIMENSION R(500),DR(500),V(500),RM(500),SGTHV(500),BM(500),FMT(500SNWGT006
     1),TSN(500)                                                        SNWGT007
      COMMONIGEOM,ISN,ISNH,MC,LC,NR,IMAX,IMAX1,NTIN,NTOUT               SNWGT008
      COMMONK1,K2,K3,K4,J1,J2,J3,J4,I1,I2,I3,I4                         SNWGT009
      COMMONWRK1,WRK2,WRK3,WRK4,DMUML,WML,GMP,GMP1,BI,S                 SNWGT010
      COMMONDMU,W,F,CVL,BVL,PTTP                                        SNWGT011
      COMMONTH,SGT,IMAT,NMSH,T                                          SNWGT012
      COMMONR,DR,V,RM,SGTHV,BM,FMT,TSN,BVLZW                            SNWGT013
      COMMONISNH1G,ISNH1,ISN1,ISN1G,ICVL,IBVL,IBLCK,NRINIT,PI           SNWGT014
      COMMONIAFPT,ITSNPT,IBVLPT,ICVLPT,ITPT,ISNPT                       SNWGT015
      DIMENSIONP(8)                                                     SNWGT016
      XSABF(I)=2*K3+1-I+2*IGE                                           SNWGT017
      XSAMF(I)=K3+1-I+2*IGE                                             SNWGT018
      XTBCF(I)=K3+I                                                     SNWGT019
   15 IF(IGEOM)16,16,17                                                 SNWGT020
   16 IGE=0                                                             SNWGT021
      GOTO18                                                            SNWGT022
   17 IGE=1                                                             SNWGT023
   18 ISNH=ISN/2                                                        SNWGT024
      ISNH1=ISNH+1                                                      SNWGT025
      ISN1=ISN+1                                                        SNWGT026
      ISNH1G=ISNH+1+IGE                                                 SNWGT027
      ISN1G=ISN+1+IGE                                                   SNWGT028
      ISNHG=ISNH+IGE                                                    SNWGT029
      ISNG=ISN+IGE                                                      SNWGT030
      DO150J=1,ISNH                                                     SNWGT031
      DO150I=1,ISN1                                                     SNWGT032
      W(I,J)=0.0                                                        SNWGT033
  150 DMU(I,J)=0.0                                                      SNWGT034
      IF(ISNH-9)200,555,555                                             SNWGT035
C     PREPARATION OF COSMU                                              SNWGT036
  200 DO260 L=1,ISNH                                                    SNWGT037
      J1=ISNH1-L                                                        SNWGT038
      DO250 M=1,J1                                                      SNWGT039
      K=J1+1-M                                                          SNWGT040
      MD=M+IGE                                                          SNWGT041
      X= (6.*FLOATF(K)-5.)/(3.*(FLOATF(ISN)-1.))                        SNWGT042
      X=-SQRTF(X)                                                       SNWGT043
      DMU(MD,L)=X                                                       SNWGT044
  210 K=2*J1+1-M+IGE                                                    SNWGT045
      DMU(K,L)=-X                                                       SNWGT046
  250 CONTINUE                                                          SNWGT047
      IF(IGEOM)260,270,255                                              SNWGT048
  255 DMU(1,L)=-SQRTF(1.-DMU(MD,1)**2)                                  SNWGT049
  260 CONTINUE                                                          SNWGT050
  270 GOTO(300,310,320,330,555 ,350,555 ,370),ISNH                      SNWGT051
C     S2 WEIGHTS                                                        SNWGT052
  300 P(1)=0.5                                                          SNWGT053
      GOTO500                                                           SNWGT054
C     S4 WEIGHTS                                                        SNWGT055
  310 P(1)=0.16666667                                                   SNWGT056
      GOTO500                                                           SNWGT057
C     S6 WEIGHTS                                                        SNWGT058
  320 P(1)=0.08043063                                                   SNWGT059
      P(2)=0.08623605                                                   SNWGT060
      GOTO500                                                           SNWGT061
C     S8 WEIGHTS                                                        SNWGT062
  330 P(1)=0.05330038                                                   SNWGT063
      P(2)=0.05058636                                                   SNWGT064
      P(3)=0.03658070                                                   SNWGT065
      GOTO500                                                           SNWGT066
C     S12WEIGHTS                                                        SNWGT067
  350 P(1)=0.03188428                                                   SNWGT068
      P(2)=0.02844993                                                   SNWGT069
      P(3)=0.02268799                                                   SNWGT070
      P(4)=0.01736872                                                   SNWGT071
      P(5)=0.01513782                                                   SNWGT072
      GOTO500                                                           SNWGT073
C     S16WEIGHTS                                                        SNWGT074
  370 P(1)=0.02275580                                                   SNWGT075
      P(2)=0.01988730                                                   SNWGT076
      P(3)=0.01502308                                                   SNWGT077
      P(4)=0.01366597                                                   SNWGT078
      P(5)=0.01164258                                                   SNWGT079
      P(6)=0.00931431                                                   SNWGT080
      P(7)=0.00881570                                                   SNWGT081
      P(8)=0.00767130                                                   SNWGT082
  500 J3=0                                                              SNWGT083
```

```
      DO520 L=1,ISNH                                                    SNWGT084
      J1=ISNH1-L                                                        SNWGT085
      J2=J1/2                                                           SNWGT086
      IF(J1-2*J2)503,503,502                                            SNWGT087
  502 J2=J2+1                                                           SNWGT088
  503 DO520 M=1,J2                                                      SNWGT089
      M=M                                                               SNWGT090
      MD=M+IGE                                                          SNWGT091
      IF(W(MD,L))520,510,520                                            SNWGT092
  510 J3=J3+1                                                           SNWGT093
      X=P(J3)                                                           SNWGT094
      K2=0                                                              SNWGT095
  511 K2=K2+1                                                           SNWGT096
      GOTO(5111,5113,5115,520),K2                                       SNWGT097
 5111 MP=M+IGE                                                          SNWGT098
      LP=L                                                              SNWGT099
      GOTO513                                                           SNWGT100
 5113 LP=M                                                              SNWGT101
      GOTO512                                                           SNWGT102
 5115 LP=J1+1-M                                                         SNWGT103
  512 MP=L+IGE                                                          SNWGT104
  513 K1=0                                                              SNWGT105
      MD=MP                                                             SNWGT106
      K3=ISNH1-LP                                                       SNWGT107
  514 K1=K1+1                                                           SNWGT108
      W(MP,LP)=X                                                        SNWGT109
      GOTO(515,516,517,511),K1                                          SNWGT110
  515 MP=XSABF(MD)                                                      SNWGT111
      GOTO514                                                           SNWGT112
  516 MP=XSAMF(MD)                                                      SNWGT113
      GOTO514                                                           SNWGT114
  517 MP=XTBCF(MD)                                                      SNWGT115
      GOTO514                                                           SNWGT116
  520 CONTINUE                                                          SNWGT117
  530 CONTINUE                                                          SNWGT118
      IF(IGEOM)540,531,540                                              SNWGT119
  531 DO538M=2,ISNH                                                     SNWGT120
      WRK1=0.0                                                          SNWGT121
      DO535L=2,M                                                        SNWGT122
      MD=M-L+1                                                          SNWGT123
      WRK1=WRK1 +W(MD,L)                                                SNWGT124
      W(MD,L)=0.0                                                       SNWGT125
      DMU(MD,L)=0.0                                                     SNWGT126
      K3=ISNH1-L                                                        SNWGT127
      MP=XSABF(MD)                                                      SNWGT128
      W(MP,L)=0.0                                                       SNWGT129
  535 DMU(MP,L)=0.0                                                     SNWGT130
      W(M,1)=W(M,1)+WRK1                                                SNWGT131
      MP=ISN1-M                                                         SNWGT132
  538 W(MP,1)=W(M,1)                                                    SNWGT133
  540 IF(ISNPT)543,543,542                                              SNWGT134
  542 WRITEOUTPUTTAPENTOUT,1000,ISN                                     SNWGT135
      DO545LC=1,ISNH                                                    SNWGT136
      J1=ISN-2*(LC-1)+IGE                                               SNWGT137
      WRITEOUTPUTTAPENTOUT,1001,(M,LC,DMU(M,LC),W(M,LC),M=1,J1)         SNWGT138
  543 IF(IGEOM)545,550,545                                              SNWGT139
  545 CONTINUE                                                          SNWGT140
  550 RETURN                                                            SNWGT141
  555 WRITEOUTPUTTAPENTOUT,1002,ISN                                     SNWGT142
      CALLEXIT                                                          SNWGT143
 1000 FORMAT(1H149X19HANGULAR SN MESH (N=I2,1H)//45X3HPML10X4HMUML11X3HWSNWGT144
     1ML//)                                                             SNWGT145
 1001 FORMAT(44X1HP2I2,3X2E14.5)                                        SNWGT146
 1002 FORMAT(35H SN WEIGHTS ARE NOT PROVIDED FOR N=I4)                  SNWGT147
      END                                                               SNWGT148
*     LABEL
CPRINTO                                                                 PRINT000
      SUBROUTINEPRINT(NITEM,V1,L1,IT1,V2,L2,IT2,V3,L3,IT3,V4,L4,IT4,V5,LPRINT001
     15,IT5,V6,L6,IT6,V7,L7,IT7,V8,L8,IT8)                              PRINT002
      DIMENSIONV1(1),V2(1),V3(1),V4(1),V5(1),V6(1),V7(1),V8(1)          PRINT003
      DIMENSIONFORMAT(9),VLINE(8)                                       PRINT004
C     BUILT-IN FORMATS                                                  PRINT005
      FORMAT(1)=6H(2XI4,                                                PRINT006
      FMTFX1=6H7X,I7,                                                   PRINT007
      FMTFX2=6H7X,I7)                                                   PRINT008
      FMTFL1=6HE14.5,                                                   PRINT009
      FMTFL2=6HE14.5)                                                   PRINT010
      FMTBK1=6H13XA1,                                                   PRINT011
      FMTBK2=6H13XA1)                                                   PRINT012
B     BLANK=606060606060                                                PRINT013
      WRITE OUTPUT TAPE 6,1000,(I,I=1,NITEM)                            PRINT014
      LINC=0                                                            PRINT015
    5 K=0                                                               PRINT016
C     FORMAT OF LINE                                                    PRINT017
```

```
      LINC=LINO+1
      CC250I=1,NITEM
      GCTC(10,20,30,40,50,60,70,8C),I
   10 ITYPE=IT1
      LENCTH=L1
B     VAR=V1(LINO)
      GCTO1CC
   20 ITYPE=IT2
      LENCTH=L2
B     VAR=V2(LINO)
      GCTO1CC
   30 ITYPE=IT3
      LENGTH=L3
B     VAR=V3(LINO)
      GCTO1CC
   40 ITYPE=IT4
      LENCTH=L4
B     VAR=V4(LINO)
      GCTO10C
   50 ITYPE=IT5
      LENCTH=L5
B     VAR=V5(LINO)
      GCTO1CC
   60 ITYPE=IT6
      LENGTH=L6
B     VAR=V6(LINO)
      GCTO1CC
   70 ITYPE=IT7
      LENGTH=L7
B     VAR=V7(LINO)
      GCTO1CC
   80 ITYPE=IT8
      LENCTH=L8
B     VAR=V8(LINO)
  100 IF(LINO-LENGTH)150,150,200
  150 GCTO(16C,17C),ITYPE
  160 IF(I-8)162,165,165
  162 FMT=FMTFX1
      GCTC208
  165 FMT=FMTFX2
      GCTC208
  170 IF(I-8)172,175,175
  172 FMT=FMTFL1
      GCTC208
  175 FMT=FMTFL2
      GCTO208
  200 K=K+1
      IF(I-8)202,205,205
  202 FMT=FMTBK1
      GCTC207
  205 FMT=FMTBK2
  207 VAR=BLANK
  208 FCRMAT(I+1)=FMT
      VLINE(I)=VAR
      MP=I
  250 CCNTINUE
      IF(MP-8)260,280,260
  260 MP=MP+1
      DC270I=MP,8
      FCRMAT(I+1)=FMTBK1
  270 VLINE(I)=BLANK
      FCRMAT(9)=FMTBK2
  280 IF(K-NITEM)300,290,290
  290 RETURN
  300 WRITEOUTPUTTAPE6,FORMAT,LINO,(VLINE(I),I=1,8)
      GCTO5
 1000 FCRMAT(1H013X11,7I14)
      END
```

To disseminate knowledge is to disseminate prosperity — I mean general prosperity and not individual riches — and with prosperity disappears the greater part of the evil which is our heritage from darker times.

Alfred Nobel

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