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DEVELOPMENT REPORT

HERD 1, 2, AND 3 — IBM-704 CODES USED TO SOLVE THE ONE-DIMENSIONAL, ONE-VELOCITY TRANSPORT EQUATION WITH ISOTROPIC SCATTERING

JANUARY 1959

CONTRACT AT-11-1-GEN-14

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HERD 1, 2, AND 3 — IBM-704 CODES USED TO SOLVE THE ONE-DIMENSIONAL, ONE-VELOCITY TRANSPORT EQUATION WITH ISOTROPIC SCATTERING

Louis A. Hageman

Contract AT-11-1-GEN-14

January 1959

Price \$.75

**Available from the Office of Technical Services,
Department of Commerce,
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The HERD codes furnish a numerical approximation to the one-dimensional, single energy transport equation in slab geometry. The primary purpose of HERD 2 and 3 is to compute blackness coefficients. The limitations of the codes are given and the preparation of input described.

HERD 1, 2, AND 3-IBM 704 CODES USED TO SOLVE THE ONE-DIMENSIONAL, ONE-VELOCITY NEUTRON TRANSPORT EQUATION WITH ISOTROPIC SCATTERING

Louis A. Hageman

INTRODUCTION

The HERD codes furnish a numerical approximation to the solution of the one-dimensional, one-velocity neutron transport equation (scattering and sources assumed to be isotropic) using the method of discrete ordinates. The equation solved by the HERD codes is

$$\mu \frac{\partial F(x, \mu)}{\partial x} + \Sigma^t(x) F(x, \mu) - \frac{\Sigma^s(x)}{2} \int_{-1}^1 F(x, \mu') d\mu' = \frac{S(x)}{2} \quad (1)$$

where

- $\mu = \cos \theta$,
- θ = the angular distance from the x axis,
- F = the vector flux,
- Σ^t = the total cross section,
- Σ^s = the scattering cross section,
- S = the source density.

Figure 1

All HERD codes solve the same integro-differential equation [Eq (1)], but with different boundary conditions. The boundary conditions imposed on the solutions are given below.

- HERD 1 $F(0, \mu) = F(0, -\mu)$, and A is an axis of symmetry (see Fig. 1).
- HERD 2 $F(0, \mu)$ is specified for $0 < \mu < 1$ and A is an axis of symmetry.
- HERD 3 $F(0, \mu)$ is specified for $0 < \mu < 1$ and $F(A, \mu) = 0$ for $-1 < \mu < 0$.

The primary purpose of HERD 2 and 3 is to compute blackness coefficients. A table of blackness coefficients is available in Ref 1.

The average running time for most problems is between 0.5-5 min.

GENERAL RESTRICTIONS OF THE HERD CODES

The HERD codes are governed by the following general restrictions:

1. The HERD codes require core storage units with capacities of either 16,384 or 32,768 core storage registers. The other equipment required is included in the "SHARE minimum 704".
2. There are 18 regions (or less) between the left boundary, Γ_0 , and the right boundary, A.
3. The mesh intervals, Σ^t , and Σ^s are region-wise constant. Σ^a must be non-zero in at least one region.
4. The source density, S, may either be specified by regions or by points.
5. The sources and scattering are isotropic.
6. The number of angles at which the vector fluxes are calculated may either be 6, 8, 10, or 12. The angles for which the vector fluxes are calculated are determined by the double Gauss quadrature formula.
7. The maximum number of mesh points, including both end points, depends on the number of angles and the capacity of the core storage unit and is as follows:

Total Angles	6	8	10	12
Mesh Points (16K core)	128	73	47	34
Mesh Points (32K core)	293	201	129	90

8. The juncture of two regions must be a mesh point.
9. At least five mesh points, including the juncture points, are required per region. Also, the number of mesh points per region must be an odd number.
10. To ensure the existence of a non-negative solution, it is recommended that the following bounds on $(\Delta x)\Sigma^t$ be followed for each region:
 - 6 angles $(\Delta x)\Sigma^t < 0.2254$
 - 8 angles $(\Delta x)\Sigma^t < 0.1388$
 - 10 angles $(\Delta x)\Sigma^t < 0.0938$
 - 12 angles $(\Delta x)\Sigma^t < 0.0675$

DERIVATION OF THE DIFFERENCE EQUATIONS AND SOLUTION OF THE MATRIX PROBLEM

Derivation of the Difference Equations

The derivation of the difference equations is given in Ref 2 and will not be given here. Briefly, Eq (1) is reduced to a system of coupled ordinary differential equations by replacing

$$\int_{-1}^1 F(x, \mu') d\mu'$$

with the double Gauss quadrature formula,

$$\sum_{\lambda'=1}^{2L} F(x, \mu_{\lambda'}) R_{\lambda'}$$

Then, the integration of each of these differential equations over a certain mesh interval by the trapezoidal method gives the final numerical approximation to Eq (1). $R_{\lambda'}$ and $\mu_{\lambda'}$ are the double Gaussian weights and abscissas, respectively.

If the distance between the left boundary, Γ_0 , and the reflected boundary, Γ_1 , (see Fig. 2) is divided into $2N$ intervals determined by the mesh points x_j , $j = 0, 1, \dots, 2N$, in such a way that $x_j - x_0 = x_{2N} - x_{2N-j}$, and if the value of $F(x, \mu)$ at $x = x_j$ and $\mu = \mu_{\lambda}$ is denoted by $F_{j, \lambda}$, then the difference equations are of the form

$$F_{j, \lambda} - b_{j, \lambda} F_{j-1, \lambda} - c_{j, \lambda} \left[\sum_{\substack{\lambda'=1 \\ \lambda' \neq \lambda}}^L F_{j, \lambda'} R_{\lambda'} + \sum_{\lambda'=1}^L F_{2N-j, \lambda'} R_{\lambda'} + \sum_{\lambda'=1}^L F_{j-1, \lambda'} R_{\lambda'} + \sum_{\lambda'=1}^L F_{2N+1-j, \lambda'} R_{\lambda'} \right] = e_{j, \lambda} [S_{j-1} + S_j] \quad (2)$$

where

$$b_{j, \lambda} = \frac{\left[2\mu_{\lambda} - \Delta x_j \Sigma_j^t + \frac{\Delta x_j \Sigma_j^s R_{\lambda}}{2} \right]}{\left[2\mu_{\lambda} + \Delta x_j \Sigma_j^t - \frac{\Delta x_j \Sigma_j^s R_{\lambda}}{2} \right]}$$

$$c_{j, \lambda} = \frac{\frac{\Delta x_j \Sigma_j^s}{2}}{\left[2\mu_{\lambda} + \Delta x_j \Sigma_j^t - \frac{\Delta x_j \Sigma_j^s R_{\lambda}}{2} \right]}$$

$$e_{j, \lambda} = \frac{\frac{\Delta x_j}{2}}{\left[2\mu_{\lambda} + \Delta x_j \Sigma_j^t - \frac{\Delta x_j \Sigma_j^s R_{\lambda}}{2} \right]}$$

$$j = 1, 2, \dots, 2N,$$

and

$$\lambda = 1, 2, \dots, L$$

Equation (2) has a slightly different form for $j = 1, N, N+1$, and $2N$, but these are easily obtained from Eq (2) and will not be given here. The coefficient of $F_{j, \lambda}$ is always normalized to one. It should be noted that, by reason of symmetry, $F_{j, \lambda} = F_{2N-j, 2L+1-\lambda}^*$

In matrix notation, Eq (2) may be written as

$$A \vec{F} = \vec{k} \quad (3)$$

where $\vec{F}$ is a vector whose components are the values of $F_{j, \lambda}$ at a certain point on the x axis and with a certain angular direction. The order of these components defining $\vec{F}$ is indicated in the following equation:

$$\vec{F} = \begin{pmatrix} F_{1,1} \\ F_{1,2} \\ \vdots \\ F_{1,L} \\ F_{2,1} \\ \vdots \\ F_{2N,L} \end{pmatrix}$$

* For the HERD 3 code, it is assumed that a very large absorbing region exists in the center so that a symmetric problem may still be assumed to exist.

The ordering of the matrix A is the same as the ordering of the components of $\vec{F}$. A is a 2NL x 2NL matrix.

It can be shown (Ref 2) that A is non-singular and the existence of a non-negative solution is assured if the bounds on $(\Delta x)\Sigma^{\dagger}$ as given under restriction 10 on page 2 are maintained for all regions.

The Iteration Process

The solution of the matrix Eq (3) is found using the Young-Frankel Successive Overrelaxation Method (Refs 3 and 4). If $B = I - A = (b_{i,m})$, where

$$b_{i,m} = \begin{cases} -a_{i,m} & \text{if } i \neq m \\ 0 & \text{if } i = m \end{cases},$$

then the Successive Overrelaxation Method is defined by

$$F_i^{(n+1)} = \omega \left[\sum_{m=1}^{i-1} b_{im} F_m^{(n+1)} + \sum_{m=i+1}^{2NL} b_{im} F_m^{(n)} + k_i \right] + [1-\omega] F_i^{(n)}, \quad (4)$$

where ω is the overrelaxation parameter and n is the iteration index. For $\omega = 1$, the Successive Overrelaxation Method reduces to the Gauss-Seidel Method.

The iteration cycle is terminated when $F_i^{(n+1)}$ and $F_i^{(n)}$ agree to ϵ significant octal digits for all i. Epsilon is an input parameter and must always be less than 9. The effective decimal agreement is given in Table I.

TABLE I

ϵ	Effective Decimal Agreement
3	4 parts in the third significant digit
4	5 parts in the fourth significant digit
5	7 parts in the fifth significant digit
6	8 parts in the sixth significant digit
7	1 part in the sixth significant digit
8	2 parts in the seventh significant digit

There is a program stop if the problem has not converged after 150 iterations. The problem may then be continued or a forced edit may be obtained.

Comments on the Choice of ω

The coefficient matrix A does not have the necessary properties to use the procedures developed by Young (Ref 4) and Varga (Refs 5 and 6) for calculating the optimum value of ω , ω_b . * An experimental code was written so that the optimum value of ω and the effect of ω on the rate of convergence could be determined for various types of problems. These results are given in Ref 2. For certain problems (namely those with a small amount of absorption), the number of iterations required for convergence of the Gauss-Seidel Method ($\omega = 1$) was reduced by at least a factor of 2 when the optimum value of ω was used. The number of iterations required for convergence depends very strongly on the choice of ω . The author very strongly recommends that a value of $\omega = 1.0000$ (Gauss-Seidel Method) be used unless Ref 2 is first consulted.

* Dr. Varga's p-cyclic theory (Ref 5) does apply to the matrix A for the special case of no scattering.

ACKNOWLEDGMENT

The author would like to thank Drs. C. Maynard and E. Gelbard for their help in the formulation of the problem solved by the HERD codes.

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APPENDIX I:

INPUT PREPARATION

The input deck for HERD 1, 2, and 3 consists of a title card, data cards, and a transfer card. The information on the data cards is either in decimal or integer (no decimal point) form. In the following description input data which should be in decimal form will be given in upper case letters and input data which should be in integer form will be given in lower case letters.

The number of digits that may be provided in input numbers is completely arbitrary, but no more than seven significant digits are used by the computer. Signs may be used, but only minus signs are necessary.

For all cards, columns 1, 2, 7, and 11 must be blank; columns 8-10 must contain DEC for all cards except the title and transfer cards. The input itself begins in column 12 and may extend through column 72. Successive numbers are separated by commas, but no comma is permitted following the last number on a card. The first blank column indicates the end of the information on a card, and any number punched beyond this blank is not used.

A transfer card must be the last card of the input deck for each problem. The transfer card has TRA in column 8-10, 1196 in columns 12-15, and the rest of the card must be blank.

HERD 1 Input and Output

Title Card for HERD 1

A title card must precede the input deck of each problem.

Columns 1-7 must be blank.

Columns 8-10 must contain BCD.

Columns 11-12 must be blank.

Columns 13-15 must contain 57H.

Columns 67-72 must contain HERD01 (HERD zero 1).

Columns 16-66 may be used for identification purposes. Any combination of alphabetic and numeric punching may be used and any of these columns may be left blank.

Data Cards and Transfer Card for HERD 1

Col

3

2451 DEC ϵ , alpha, gamma, OMEGA

ϵ - Convergence criterion used to terminate the iteration cycle ($\epsilon < 9$).

alpha - alpha = 0 if the sources are given pointwise,
alpha = 1 if the sources are given regionwise.

gamma - gamma = 0 if the vector fluxes are not to be printed,
gamma = 1 if the vector fluxes are to be printed.

OMEGA - Overrelaxation parameter, OMEGA, should be 1.0
unless Ref 2 is first consulted.

Col

3

2455 DEC $W_1, W_2, \dots, W_j$

DEC $W_{j+1}, \dots, W_{tr}$

W - Regionwise vector flux guess. tr is the total number of regions

Col

3

2475 DEC $S_1, S_2, \dots, S_j$

DEC $S_{j+1}, \dots, S_{tr}$

S - Regionwise sources. This card should be omitted if alpha = 0.

Col

3

2495 DEC tdx, tr, ang/2, problem number

tdx - Total number of mesh points including those on the boundary
and the axis of symmetry.

tr - Total number of regions.

ang/2 - The number of angles at which the vector fluxes are to be
calculated divided by 2. This number must be either 3, 4,
5, or 6.

Col

3

2499 DEC region number, tdxr, DELTA X, TCS, SCS

DEC tr, tdxr, DELTA X, TCS, SCS

region number - The number of the region, where the regions are numbered
consecutively starting at the boundary with 1. This set of
cards specifies the region constants and must be arranged
in the order of increasing region number.

tdxr - The total number of mesh points in the region, including those on both interfaces. This must be an odd number.
 DELTA X - The distance between mesh points in the region.
 TCS - The value of the total cross section in the region.
 SCS - The value of the scattering cross section in the region.

Col

3

2692 DEC $\bar{S}_1, \bar{S}_2, \dots, \bar{S}_j$
 DEC $\bar{S}_{j+1}, \dots, \bar{S}_{tdx + tr - 1}$

$\bar{S}$ - Pointwise sources. At interfaces, two sources must be specified; one for the region to the left and one for the region to the right.

This card should be omitted if alpha = 1.

TRA. 1196

Output for HERD 1

The scalar fluxes are printed by lines. Reading from left to right, the first number is the value at the boundary and the last number is the value at the axis of symmetry.

The vector fluxes are also printed by lines. Again reading from left to right, the first angles/2 numbers give the vector fluxes in the positive μ direction for the first point from the boundary. The next angles/2 numbers give the vector fluxes in the positive μ direction for the second point from the boundary, and so on, until the point on the axis of symmetry is reached. At this point the vector fluxes in the positive and negative directions are equal. The first angles/2 numbers beyond this give the vector fluxes in the negative μ direction for the first point from the axis of symmetry. The second set of angles/2 numbers from the symmetry point give the vector fluxes in the negative μ direction for the second point from the axis of symmetry, and so on, until the last angles/2 numbers give the vector fluxes for the boundary in both the positive and negative μ directions. For any set of angles/2 numbers, the first one given is for the largest μ .

The following integrals are also printed for each region:

- 1) $\int_R S dx$,
- 2) $\int_R \Sigma^a \phi dx$, where ϕ is the scalar flux ,
- 3) $\int_{-1}^1 \mu F d\mu$, where this integral is evaluated at the interface.

Omega, the number of iterations required for convergence, and DIFF are also printed for each problem. If DIFF is not equal to zero, then a "forced edit" was obtained and the problem was not completely converged.

HERD 2 Input and Output

Title Card for HERD 2

The title card is the same as for HERD 1 except columns 67-72 must now contain HERD02 (HERD zero 2).

Data Cards and Transfer Card for HERD 2

Symbols previously defined for HERD 1 will not be redefined in the description below.

Col

3

2615 DEC ϵ , alpha, gamma, zeta, g, OMEGA

zeta - zeta = 0 if the scalar fluxes are not to be printed.

zeta = 1 if the scalar fluxes are to be printed.

g - g = 0 if the incoming vector fluxes are to be specified by the input.

g = 1 if the incoming vector fluxes are to be furnished by the code.

The incoming vector fluxes which can be furnished by the code are unity or μ^y .

Col

3

2621 DEC h, x, y

h - h = 0 if the result from the last problem is to be used as a guess for this problem..

h = 1 if the result from the last problem is not to be used as a guess.

x - $\int_{-1}^0 |\mu|^x F dx$ is calculated and printed for $X = 0, 1, \dots, x$.

This integral is calculated at the boundary; $x \leq 5$.

y - μ^y is used as the incoming vector fluxes.

Col

3

2624 DEC $W_1, W_2, \dots, W_j$

DEC $W_{j+1}, \dots, W_{tr}$

If h = 0, omit the above card.

Col

3

2644 DEC $S_1, S_2, \dots, S_j$

DEC $S_{j+1}, \dots, S_{tr}$

If alpha = 0, omit the above card.

If the region sources are zero, this card must still be submitted and filled with the appropriate number of zeros.

Col

3

2664 DEC tdx, tr, ang/2, problem number

Col

3

2668 DEC region number, tdxr, DELTA X, TCS, SCS

DEC tr, tdxr, DELTA X, TCS, SCS

Col

3

2867 DEC $\bar{S}_1, \bar{S}_2, \dots, \bar{S}_j$

DEC $\bar{S}_{j+1}, \dots, \bar{S}_{tdx + tr - 1}$

Col

3

6780 DEC $VFS_1, VFS_2, \dots, VFS_{ang/2}$

VFS - The incoming vector fluxes at the boundary. VFS_1 is the value for the largest μ and $VFS_{ang/2}$ the value for the smallest μ .
If $g = 1$, omit the above card.

TRA 1196

Output for HERD 2

HERD 2 has the same output as HERD 1 plus the following:

- 1) The specified incoming vector fluxes. (This is listed under point sources.)
- 2) The outgoing vector fluxes on the boundary.

3) $\int_1^0 \mu^x F d\mu$ at the boundary.

4) $\int_{-1}^0 |\mu|^x F d\mu$ at the boundary.

HERD 3 Input and Output

Title Card for HERD 3

The title card is the same as HERD 1 except columns 67-72 must contain HERD03 (HERD zero 3).

Data Cards and Transfer Card for HERD 3

The input format for HERD 3 is the same as HERD 2 except for columns 3-6.

Col

3

2670 DEC $\epsilon, \alpha, \gamma, \zeta, g, \text{OMEGA}$

Col

3

2676 DEC h, x, y

Col

3

2679 DEC $W_1, \dots, W_j$
DEC $W_{j+1}, \dots, W_{tr}$

Col

3

2699 DEC $S_1, \dots, S_j$
DEC $S_{j+1}, \dots, S_{tr}$

Col

3

2719 DEC tdx, tr, ang/2, problem number

Col

3

2723 DEC region number, tdxr, DELTA X, TCS, SCS
DEC tr, tdxr, DELTA X, TCS, SCS

Col

3

2922 DEC $\bar{S}_1, \dots, \bar{S}_j$
DEC $\bar{S}_{j+1}, \dots, \bar{S}_{tdx + tr - 1}$

Col

3

6835 DEC VFS₁, VFS_{ang/2}

TRA 1196

Output for HERD 3

The output for HERD 3 has the following additions:

- 1) The outgoing vector fluxes on the right boundary, A.
- 2) $\int_1^0 \mu^x F d\mu$ evaluated at the boundary, A.

APPENDIX II:

OPERATING INSTRUCTIONS FOR HERD 1, 2, AND 3

Tapes

Blank No. 2 for off-line output. No tapes are needed if all of the output is on-line.

Printer

SHARE Printer Board No. 2 must be used for on-line output.

Sense Switches

- 1 - down
- 2 - up
- 3 - down - on-line output
up - on-line output
- 4 - down - double spacing on the on-line printer
up - single spacing on the on-line printer
- 5 - down - no off-line output
up - off-line output (Tape 2)
- 6 - down

Starting

Ready the appropriate HERD program deck which can be followed by any number of problem decks (there must be no blank cards) in the Card Reader, set the necessary Sense Switches, ready the proper output unit, clear, and load cards. When the computer stops with a Select on the Card Reader for the last problem, press the Start Key on the Card Reader to read in the remaining cards.

Requestor Error

If a problem will not run because of a requestor error, feed the cards for that problem out of the hopper (the last card for any one problem is "TRA 1196") and start the next problem by entering the instruction (0 02000 0 02251)₈ on the panel input switches and pressing the Enter Instruction Key (computer must be on manual to do this).

Printing of Output Tape

Print under "Single Space." After each problem there is an end of file. Restore printer before printing the next problem.

Running Time

Most problems should take between 0.5-5 minutes.

Program Stops for HERD 1

- 1275 Illegal pseudo-operation or a blank card in input cards.
- 1613 Out of range decimal data.
- 2074 Illegal punch in an input card.
- 2250 Card reader end of file. Press start to write "END OF OUTPUT ON THIS TAPE" and rewind tape.
- 2253 Columns 67-72 of the title card do not contain HERD01.
- 3621 Epsilon ≥ 9 ; input error.
- 4173 Problem not converged after 150 iterations. Press START to get a forced edit.
[Problem may be continued by manually transferring to location (3664)₈.]
- 5040 Normal stop after writing "END OF OUTPUT ON THIS TAPE" and rewinding tape.

Program Stops for HERD 2

- 1275 Illegal pseudo-operation or a blank card in the input cards.
- 1613 Out of range decimal data.
- 2074 Illegal punch in an input card.
- 2250 Card reader end of file. Press start to write "END OF OUTPUT ON THIS TAPE" and rewind tape.
- 2253 Columns 67-72 of the title card do not contain HERD02.
- 3746 Epsilon ≥ 9 ; input error.
- 4320 Problem not converged after 150 iterations. Press START to get a forced edit.
[Problem may be continued by manually transferring to location (4011)₈.]
- 5311 Normal stop after writing "END OF OUTPUT ON THIS TAPE" and rewinding tape.

Program Stops for HERD 3

- 1275 Illegal pseudo-operation or a blank card in input cards.
- 1613 Out of range decimal data.
- 2074 Illegal punch in an input card.
- 2250 Card reader end of file. Press Start to write "END OF OUTPUT ON THIS TAPE" and rewind tape.
- 2253 Columns 67-72 of the title card do not contain HERD03.
- 3755 Epsilon ≥ 9 ; input error.
- 4327 Problem not converged after 150 iterations. Press START to get a forced edit.
[Problem may be continued by manually transferring to location (4020)₈.]
- 5377 Normal stop after writing "END OF OUTPUT ON THIS TAPE" and rewinding tape.

INPUT FOR HERD 1

	BCD	57H	SAMPLE PROBLEM	HERD01
2451	DEC	5,1,1,1.03		
2455	DEC	1.0,1.0		
2475	DEC	0,1.		
2495	DEC	31,2,4,1		
2499	DEC	1,11,.016510,1.0,.230769		
	DEC	2,21,.079756,1.0,.99363		
	TRA	1196		

Running Time - 58 sec

SAMPLE PROBLEM HERD01

ANGLES/2= 4
 PROBLEM 1
 REGION TDXR DX TCS SCS
 1 11 0.016510 1.0000 0.2308
 2 21 0.079756 1.0000 0.9936

W= 0.103000E 01 DIFF= 0 I= 36

REGION-WISE SOURCES
 0. 0.1000000E 01

SCALAR FLUXES

0.1086248E 02	0.1087245E 02	0.1090298E 02	0.1095487E 02	0.1102966E 02	0.1112966E 02	0.1125803E 02
0.1141895E 02	0.1161787E 02	0.1186179E 02	0.1215964E 02	0.1336823E 02	0.1407118E 02	0.1458486E 02
0.1501154E 02	0.1538599E 02	0.1572135E 02	0.1602361E 02	0.1629618E 02	0.1654141E 02	0.1676106E 02
0.1695654E 02	0.1712899E 02	0.1727934E 02	0.1740833E 02	0.1751657E 02	0.1760453E 02	0.1767259E 02
0.1772100E 02	0.1774997E 02	0.1775961E 02				

VECTOR FLUXES

0.7039833E 01	0.6539700E 01	0.5020879E 01	0.1684008E 01	0.6938128E 01	0.6411094E 01	0.4837139E 01
0.1593104E 01	0.6838296E 01	0.6285733E 01	0.4662599E 01	0.1522529E 01	0.6740348E 01	0.6163602E 01
0.4496934E 01	0.1468307E 01	0.6644299E 01	0.6044690E 01	0.4339847E 01	0.1428107E 01	0.6550171E 01
0.5928992E 01	0.4191070E 01	0.1399094E 01	0.6457992E 01	0.5816517E 01	0.4050369E 01	0.1379793E 01
0.6367799E 01	0.5707285E 01	0.3917548E 01	0.1369005E 01	0.6279641E 01	0.5601334E 01	0.3792457E 01
0.1365940E 01	0.6193583E 01	0.5498722E 01	0.3674997E 01	0.1370168E 01	0.6246811E 01	0.5649559E 01
0.4357709E 01	0.5362036E 01	0.6334690E 01	0.5836798E 01	0.4995599E 01	0.6787765E 01	0.6440183E 01
0.6036956E 01	0.5561110E 01	0.7393743E 01	0.6556204E 01	0.6240869E 01	0.6055052E 01	0.7728016E 01
0.6679046E 01	0.6444231E 01	0.6485399E 01	0.7963594E 01	0.6806282E 01	0.6644555E 01	0.6860973E 01
0.8155935E 01	0.6936078E 01	0.6840168E 01	0.7189717E 01	0.8323503E 01	0.7066942E 01	0.7029846E 01
0.7478365E 01	0.3472993E 01	0.7197623E 01	0.7212664E 01	0.7732509E 01	0.8607258E 01	0.7327053E 01
0.7387916E 01	0.7956753E 01	0.8727814E 01	0.7454322E 01	0.7555064E 01	0.8154880E 01	0.8835648E 01
0.7578642E 01	0.7713701E 01	0.8329993E 01	0.8931489E 01	0.7699335E 01	0.7863524E 01	0.8484638E 01
0.9015906E 01	0.7815812E 01	0.8004309E 01	0.8620899E 01	0.9089359E 01	0.7927559E 01	0.8135899E 01
0.8740487E 01	0.9152216E 01	0.8034128E 01	0.8258179E 01	0.8844797E 01	0.9204770E 01	0.8135123E 01
0.8371075E 01	0.8934973E 01	0.9247256E 01	0.8230196E 01	0.8474537E 01	0.9011942E 01	0.9279851E 01
0.8319035E 01	0.8568535E 01	0.9076460E 01	0.9302639E 01	0.8401362E 01	0.8653052E 01	0.9129145E 01
0.9315902E 01	0.8476931E 01	0.8728083E 01	0.9170484E 01	0.9319516E 01	0.8545501E 01	0.8793607E 01
0.9200842E 01	0.9313496E 01	0.8606857E 01	0.8849610E 01	0.9220509E 01	0.9297842E 01	0.8660792E 01
0.8896069E 01	0.9229697E 01	0.9272500E 01	0.8707109E 01	0.8932955E 01	0.9228547E 01	0.9237371E 01
0.8745514E 01	0.8960220E 01	0.9217136E 01	0.9192312E 01	0.8776112E 01	0.8977801E 01	0.9195478E 01
0.9137132E 01	0.8798400E 01	0.8985610E 01	0.9163528E 01	0.9071583E 01	0.8812266E 01	0.8983533E 01
0.9121177E 01	0.8995355E 01	0.8817481E 01	0.8971421E 01	0.9068251E 01	0.8908058E 01	0.8813793E 01
0.8949083E 01	0.9004501E 01	0.8809216E 01	0.8800917E 01	0.8916281E 01	0.8929598E 01	0.8698235E 01
0.8778528E 01	0.8872713E 01	0.8843112E 01	0.8574381E 01	0.8746244E 01	0.8817996E 01	0.8744484E 01
0.8436709E 01	0.8703596E 01	0.8751632E 01	0.8632970E 01	0.8283920E 01	0.8649962E 01	0.8672913E 01
0.8507482E 01	0.8113960E 01	0.8584381E 01	0.8580680E 01	0.8366141E 01	0.7922806E 01	0.8504991E 01
0.8472564E 01	0.8204909E 01	0.7700687E 01	0.8407288E 01	0.8342640E 01	0.8013277E 01	0.7420124E 01
0.8278591E 01	0.8173964E 01	0.7760579E 01	0.6997810E 01	0.8157380E 01	0.8008730E 01	0.7449445E 01
0.5805160E 01	0.8037752E 01	0.7846758E 01	0.7151972E 01	0.4859329E 01	0.7919778E 01	0.7688107E 01
0.6867771E 01	0.4109076E 01	0.7803513E 01	0.7532812E 01	0.6596427E 01	0.3513854E 01	0.7689000E 01
0.7380890E 01	0.6337512E 01	0.3041582E 01	0.7576268E 01	0.7232347E 01	0.6090591E 01	0.2666876E 01
0.7465342E 01	0.7087173E 01	0.5855230E 01	0.2359660E 01	0.7356238E 01	0.6945355E 01	0.5630999E 01
0.2134055E 01	0.7248968E 01	0.6806874E 01	0.5417481E 01	0.1947510E 01	0.7143544E 01	0.6671707E 01
0.5214269E 01	0.1800113E 01					

REGION INTEGRALS
 SOURCE SIGMA A X FLUX UFDU FROM -1 TO 1
 0. 0.1429132E 01 -0.1429507E 01
 0.1595120E 01 0.1655694E-00

INPUT FOR HERD 2

	BCD	57H	SAMPLE PROBLEM	HERD02
2615	DEC	6,1,0,1,1,1.008		
2621	DEC	1,5,1		
2624	DEC	1.0		
2644	DEC	0		
2664	DEC	41,1,4,2		
2668	DEC	1,41,.003175,.4,.3		
	TRA	1196		

Running Time - 24 sec

ANGLES/2= 4 SAMPLE PROBLEM HERD02

EM 2
REGION TDXR DX TCS SCS
1 41 0.003175 0.4000 0.3000

W= 0.100800E 01 DIFF= 0 I= 10

REGION-WISE SOURCES
0.

SCALAR FLUXES

0.1024880E 01	0.1025629E 01	0.1025356E 01	0.1027062E 01	0.1027747E 01	0.1028411E 01	0.1029054E 01
0.1029676E 01	0.1030278E 01	0.1030859E 01	0.1031420E 01	0.1031962E 01	0.1032483E 01	0.1032985E 01
0.1033467E 01	0.1033930E 01	0.1034374E 01	0.1034738E 01	0.1035204E 01	0.1035591E 01	0.1035959E 01
0.1036308E 01	0.1036639E 01	0.1036951E 01	0.1037245E 01	0.1037521E 01	0.1037779E 01	0.1038019E 01
0.1038240E 01	0.1038444E 01	0.1038629E 01	0.1038797E 01	0.1038947E 01	0.1039079E 01	0.1039194E 01
0.1039291E 01	0.1039370E 01	0.1039432E 01	0.1039476E 01	0.1039502E 01	0.1039511E 01	

POINT SOURCES

0.9305682E 00	0.6699905E 00	0.3300095E-00	0.6943184E-01
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VECTOR FLUXES ON THE BOUNDARY

0.8744461E 00	0.6303104E 00	0.3453771E-00	0.3141803E-00
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INTEGRAL OF UEXPX F DU FROM -1 TO 0

0.5248796E 00
0.3201904E-00
0.2364902E-00
0.1884372E-00
0.1568002E-00
0.1343186E-00

INTEGRAL OF UEXPX F DU FROM 1 TO 0

0.5000000E-00
0.3333333E-00
0.2500000E-00
0.2000000E-00
0.1666666E-00
0.1428571E-00

REGION INTEGRALS

SOURCE	SIGMA A X FLUX	UFDU FROM -1 TO 1
0.	0.1214081E-01	

INPUT FOR HERD 3

	BCD	57H	SAMPLE PROBLEM	HERD03
2670	DEC	6,1,0,0,1,1.0		
2676	DEC	1,5,0		
2679	DEC	1.0		
2699	DEC	0		
2719	DEC	41,1,4,3		
2723	DEC	1,41,.005,.75,.5		
	TRA	1196		

Running Time - 13 sec

SAMPLE PROBLEM HERD03
 ANGLES/2= 4
 PROBLEM 3
 REGION TDXR DX TCS SCS
 1 41 0.005000 0.7500 0.5000

 W= 0.100000E 01 DIFF= 0 I= 5

 REGION-WISE SOURCES
 C.

 POINT SOURCES
 C.1000000E 01 0.1000000E 01 0.1000000E 01 0.1000000E 01

 VECTOR FLUXES ON THE BOUNDARY
 C.4573526E-01 0.6175165E-01 0.1132927E-00 0.2885858E-00

 VECTOR FLUXES ON THE RIGHT BOUNDARY
 C.8963775E 00 0.8502509E 00 0.7446925E 00 0.3678880E-00

 INTEGRAL OF UEXPX F DU FROM -1 TO 0
 0.1152248E-00
 0.3656901E-01
 0.2019208E-01
 0.1381033E-01
 0.1046164E-01
 0.8413886E-02

 INTEGRAL OF UEXPX F DU FROM 1 TO 0
 1.0000000E 00
 0.5000000E-00
 0.3333333E-00
 0.2500000E-00
 0.2000000E-00
 0.1666666E-00

 INTEGRAL OF UEXPXFDU FROM 1 TO 0 ON RIGHT BOUNDARY
 0.7432185E 00
 0.4175919E-00
 0.2876750E-00
 0.2187432E-00
 0.1763131E-00
 0.1476122E-00

 REGION INTEGRALS
 SOURCE SIGMA A X FLUX UFDU FROM -1 TO 1
 0. 0.4583741E-01 0.4175919E-00