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XDC 57-11-121

APEX-371

XDC 57-11-121

"MONTE CARLO RESEARCH SERIES: MONTE CARLO PROGRAM FOR A LINEAR REACTOR WITH VOID GAPS"

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November 13, 1957

GENERAL ELECTRIC-AIRCRAFT NUCLEAR PROPULSION DEPARTMENT-CINCINNATI 15, OHIO

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ABSTRACT OF REPORT NO. XDC 57-11-121

TITLE: Monte Carlo Research Series: Monte Carlo Program for a Linear Reactor with Void Gaps

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DATE: November 13, 1957

A Monte Carlo calculation for computing the diffusion coefficient and diffusion length in a linear system, with alternate solid and void segments, is described in this report. The program code is for the IBM 704.

MONTE CARLO PROGRAM FOR A LINEAR REACTOR WITH VOID GAPS

1.0 INTRODUCTION

In January, 1956, one of us was asked to investigate the effect of void regions on the behavior of a reactor. The first published work on this problem was done by D. J. Behrens in 1949.[1] Behrens' paper was concerned with an infinite system of homogeneous solid material, in which closed, void regions were interspersed. His calculations indicated that the effect of void regions on the migration length squared, M^2 , was two-fold:

1) An isotropic increase in M^2 proportional to the inverse square of the over all density of the reactor material (homogenized density)

2) A correction, in addition to the density effect, depending upon the ratio of the void volume to the product of the mean free path, (in the solid regions) and the surface of the void region

Behrens' work is not applicable to small reactors or (what amounts to the same thing) to reactors with large void regions. The "void" correction presently used in ANPD diffusion theory reactor programs is due to D. S. Selengut and R. M. Cohen, Reactor Analysis Unit. The Selengut-Cohen correction is, apparently, a successful recipe. It performs a Behrens' correction by modifying the product of the diffusion coefficient and the buckling with an energy dependent factor. Absorption effects are treated using a transmission factor for the neutron energy concerned.

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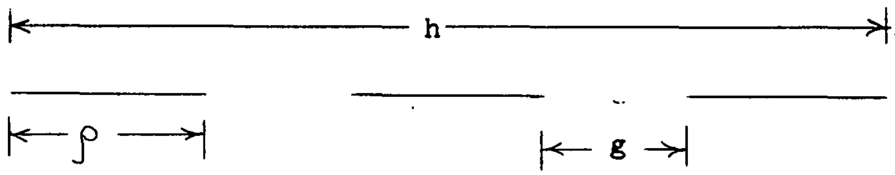
[1] D. J. Behrens, Proc. Phys. Soc. London A, 62 - pp. 607-16 (Oct. 1949)

2.0 BARE LINEAR REACTOR PROGRAM

2.1 Geometry

The subject of this report is a Monte Carlo computation for a bare linear reactor. In what follows, this program will be referred to as P(1-D) Bare.

The system concerned, is a finite sequence of void and solid material segments, so arranged that the terminal segments are solid material segments, and that void and solid segments alternate with one another. The void segments have a common length g, and the solid segments a common length ρ. One specifies such a system, in P(1-D) Bare, by assigning particular values to g, h, and n where g is the gap length, h is the length of the system, and n is the number of gaps.



2.2 Quantities Computed

P(1-D) Bare computes the diffusion length, diffusion coefficient and crow flight distance from emission to capture of monoenergetic particles in the linear system, defined in (2.1). The Green's Function for a given point source location is presented in histogram form.

2.3 Computation Method

A given number of particles are started from a specified emission point, and their scattering histories are developed. The direction of emission and scattering is assumed to be distributed uniformly over a space with two sample points; namely, positive and negative direction. The free path length between collisions is sampled from the exponential distribution. The individual jump lengths and their squares, and the emission point to capture point distance and its square, are tallied for diffusion length and diffusion coefficient computation. The capture point locations are counted in the appropriate histogram interval.

The details of particle tracing and counting operations are described in five flow charts. The general flow chart is Figure 1. Figures 2, 3, 4 and 5 present a refined description of the Direction, Jump Length, Capture-Scatter and Histogram blocks.

3.0 PURPOSE

This program was constructed for two reasons:

1) The Theoretical Physics Unit could educate itself in the use of the Monte Carlo method by writing P(1-D) Bare.
2) P(1-D) Bare was simple enough that its running time would be short. It would provide an inexpensive tool to block out areas for detailed study on Behrens' correction with more complex and expensive Monte Carlo codes.

4.0 OUTPUT

Output for the program consists of the following:

(1) Average jump length of each particle
(2) Average jump length squared of each particle
(3) Migration distance (labled W in program) for each particle
(4) Migration distance squared for each particle
(5) The segment and subsegment location of each particle
(6) Total number of escapes to the right
(7) Total number of escapes to the left

(8) Total average jump length

(9) Total average jump length squared

(10) Total average migration distance

(11) Total average migration distance squared

(12) Histogram - (giving the total number of particles in each subsegment of n number of fuel segments)

The program is set up in such a way as to enable the person running the program to skip over the items 1 through 5 that are concerned with the output of each individual particle. This is done by putting an unconditioned jump from location $04641_{(8)}$ to location $04675_{(8)}$ into the program by means of an octal correction card. The remaining output for the total number of particles will not be changed.

5.0 INPUT

The program is read in from cards with the data cards behind the program deck. Sense switches 1 and 2 are down. Tapes 1 and 3 are used. Tape 1 is Gecop and the output is on Tape 3.

INPUT FORM:

<u>Card 1</u>

C2661, - LAMM,

(Card enters machine in floating point form) LAMM is the negative of the mean free path.

<u>Card 2</u>

C2669, H, G, N, P, XOFJ, SIGC, SIG, PART,

(Card enters the machine in floating point form)

H length of the reactor

G gap length

N number of gaps

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P solid segment length

XOFJ starting point of each particle

SIGC capture cross section

SIG total cross section

PART number of particles started

Card 3

D2678, 35, SEG, SSEG, IR2

(Card enters machine in fixed point form with scaling factor of 35 as the numbers are integers)

SEG number of fuels segments in histogram

SSEG number of subsegments contained in each fuel segment

IR2 number of particles started (same number as PART)

Card 4

12783, γ,

(This card enters the machine as a floating point, end of record card since it is the last card of the case)

γ is the reciprocal of the number of histogram subsegments per solid segment. An end of file card (8 punch in column one) should follow the last card of the final case.

DL9C DATA INPUT FORM

NAME__________ PHONE__________ CHARGE__________ DATE AND TIME RECEIVED BY KEYPUNCH__________

☐ Must be verified ☐ Verify if time allows

1																
C	2661	,	- LAMM	,		,		,		,		,		,		,
C	2669	,	H	,	G	,	N	,	P	,	XOFJ	,	SIGC	,	SIG	,
	PART	,		,		,		,		,		,		,		,
D	2678	,	35	,	SEG	,	SSEG	,	IR2	,		,		,		,
.	2783	,	γ	,		,		,		,		,		,		,
8																

1-D MONTE CARLO PROGRAM FOR A BARE LINEAR REACTOR

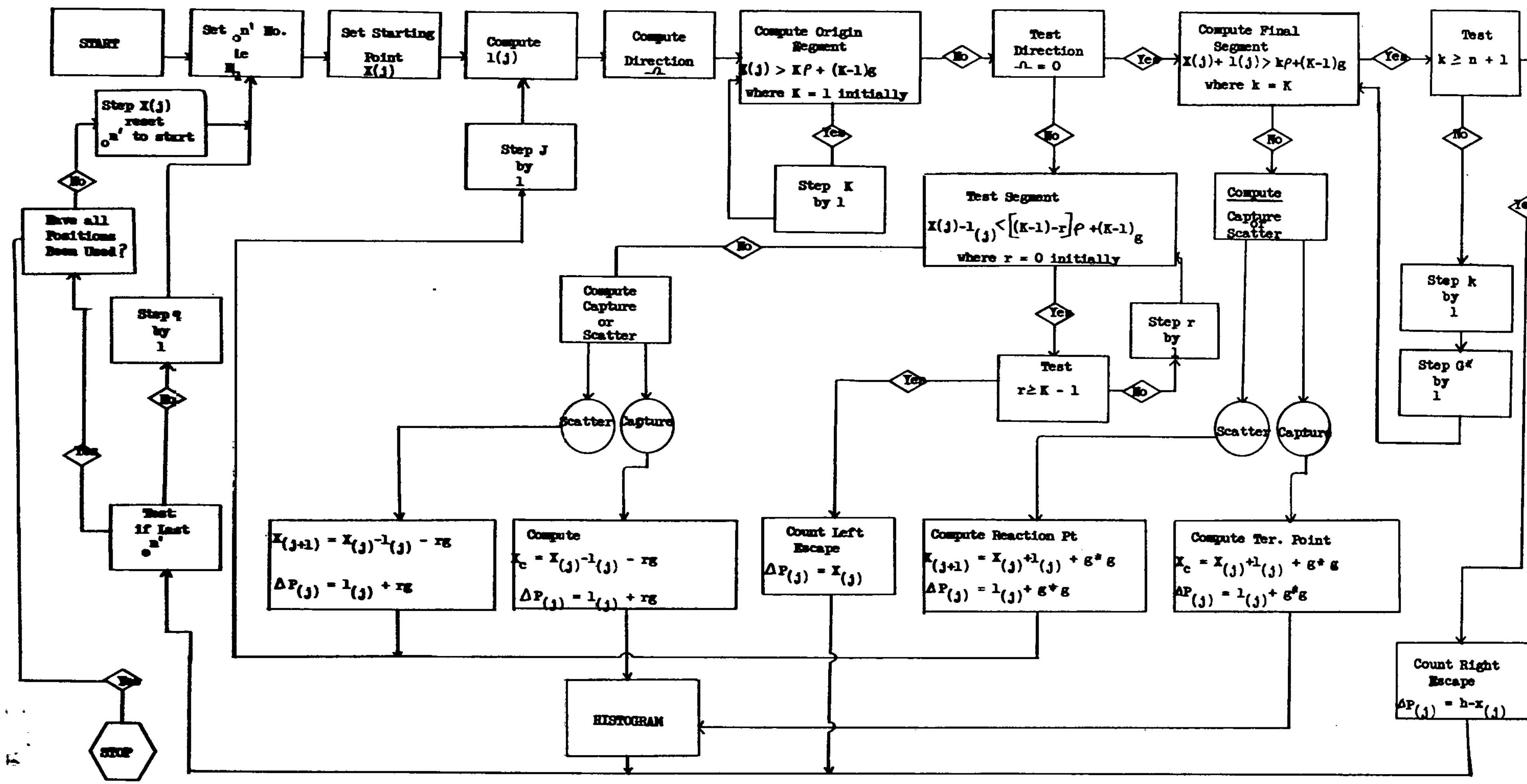

Figure 1

COMPUTE DIRECTION

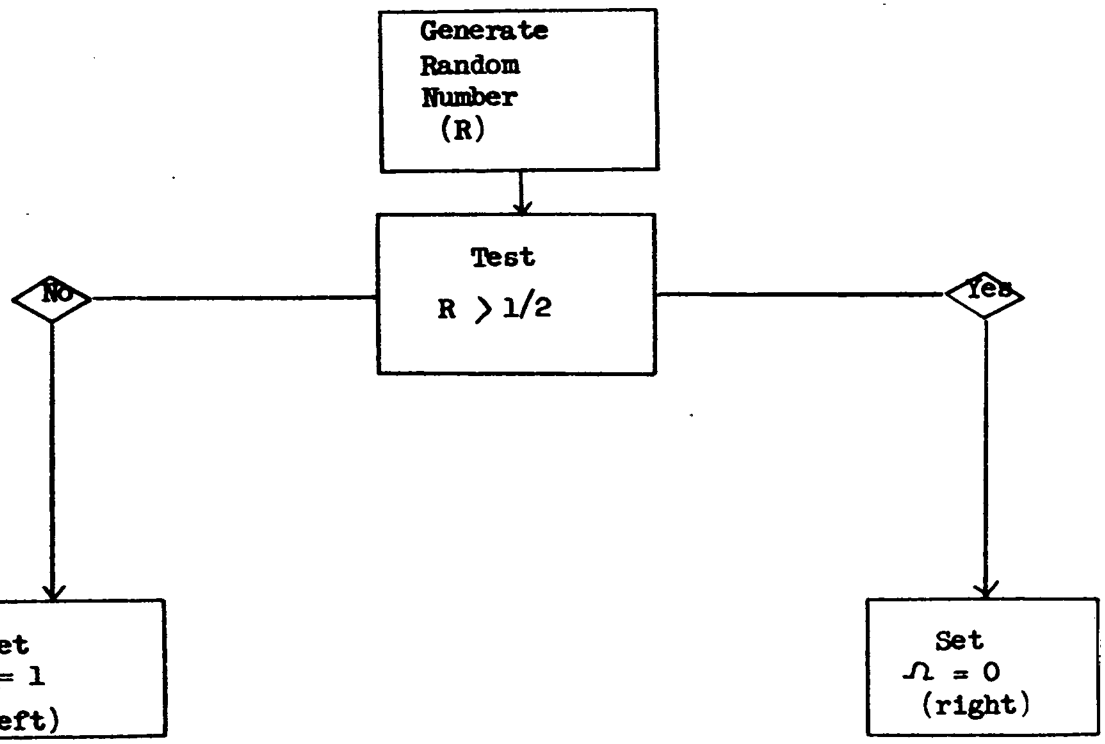

Figure 2

COMPUTING JUMP LENGTH

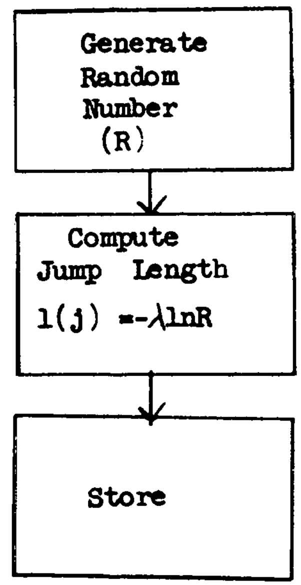

Figure 3

COMPUTE CAPTURE OR SCATTER

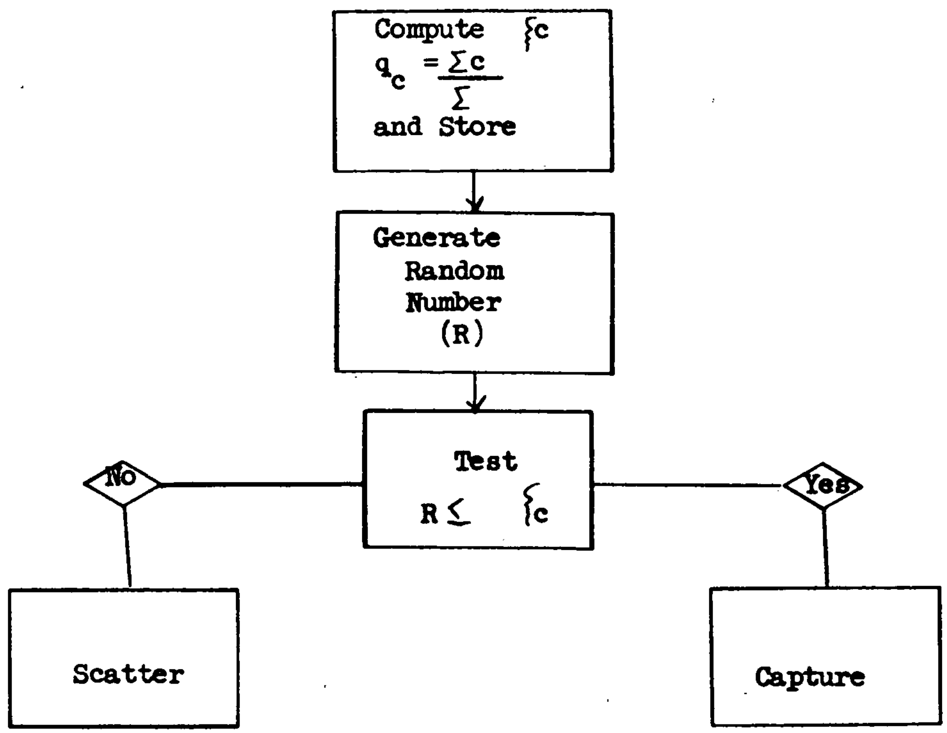

Figure 4

HISTORGRAM

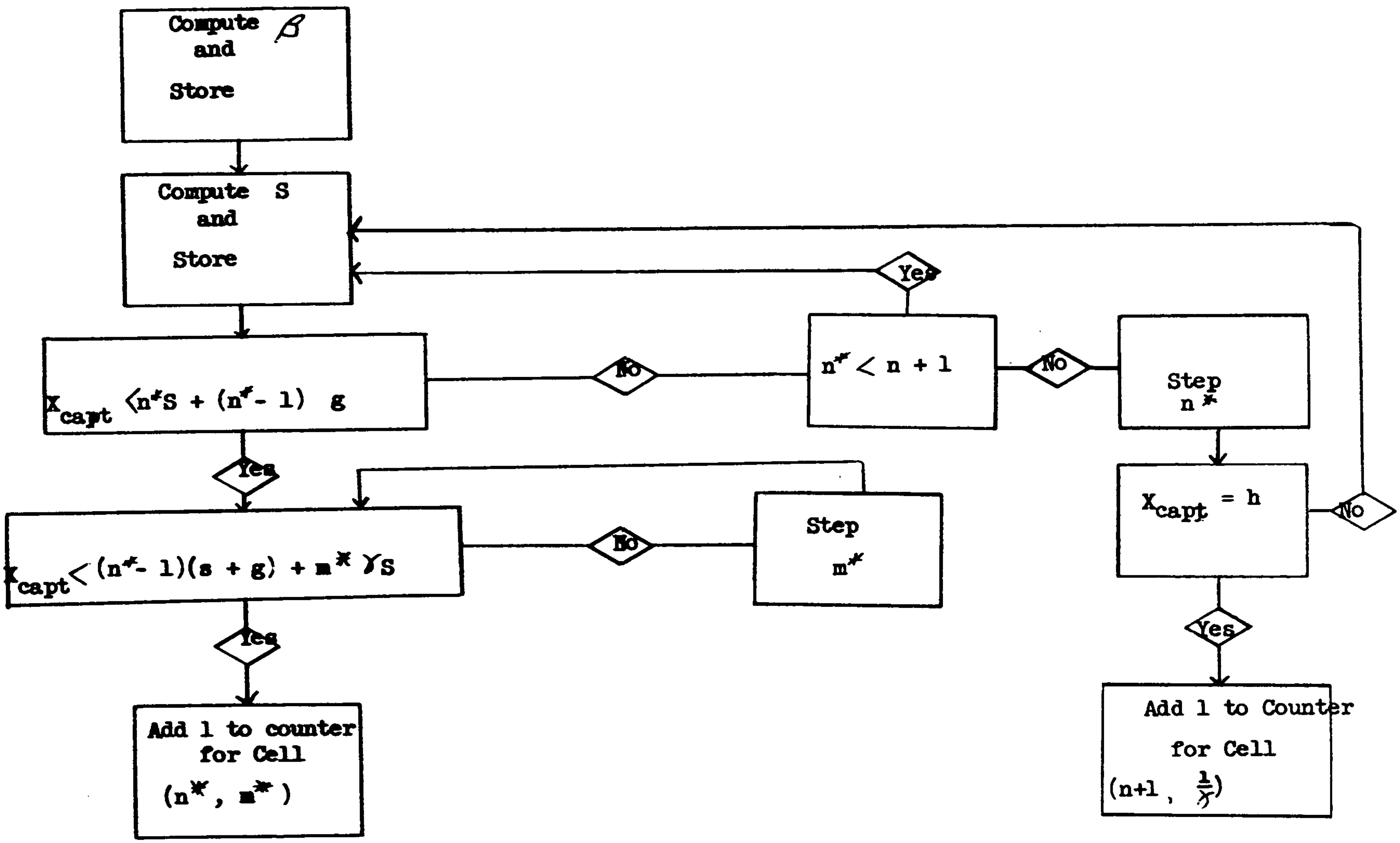

Figure 5

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```
 * 1-D MONTE CARLO PROGRAM
* TASK NUMBER 7276
* START PROGRAM
START SXJ DL9C,4
      ZER
      ZER
      HTJ
      CLA FL1
      STR NSQ
      STR J
      CLA XOFJ
      STR XOFJ2
      LDQ SEG
      MPY SSEG
      STQ IR4
      LXA IR2,2
      LXA IR1,1
      LXA IR4,4
      SXD SAVE,4
      SXD SAVE2,1
      SXD SAV3,1
      SXD SAVE6,1
* COMPUTE L LOG METHOD
      CLA TABLE
      SXJ RANO+1,4
      ZER 33
COMLJ SXJ RANO,4
      STR RAN
      SXJ LN,4
      HTJ
      STR TEMP
      LDQ LAMM
      FNM TEMP
      NOP
      STR LJ
* COMPUTE DIRECTION OMEGA
      SXJ RANO,4
      STR RAN+1
      SGA HALF
      UNJ PD1
      UNJ PD2
PD2   CLA FX1
PD3   STR OMEGA
      UNJ PD4
PD1   PXD 0,0
      UNJ PD3
*COMPUTE ORIGIN AND TEST SEGMENT
PD4   CLA XOFJ
      STR XJ1
* TEST SEGMENT
PD6   LDQ K
      FNM P
      STR TEMP
      CLA K
      FNS FL1
      STR NORE
```

```
        LDQ G
        FNM NORE
        FNA TEMP
        SGA XJ1
        UNJ PD5
        UNJ PD5
        CLA K
        FNA FL1
        STR K
        UNJ PD6
* TEST DIRECTION
PD5     CLA OMEGA
        ZEJ PD7
PD17    CLA XJ1
        FNS LJ
        STR DEAR
        CLA NORE
        FNS R
        STR TEMP
        LDQ P
        FNM TEMP
        STR TEMP
        LDQ G
        FNM NORE
        FNA TEMP
        SGA DEAR
        UNJ PD8
        UNJ PD9
* COMPUTE CAPTURE OR SCATTER
PD9     CLA SIGC
        FDH SIG
        STQ SSIG
        SXJ RANO,4
        STR RAN+2
        SGA SSIG
        UNJ PD10              SCATTER
        UNJ PD11              CAPTURE
PD11    CLA CAPT              CAPTURE
        FNA FL1
        STR CAPT
        LDQ R
        FNM G
        STR TEMP
        CLA XJ1
        FNS LJ
        FNS TEMP
        STR XCT
        CLA LJ
        FNA TEMP
        STR DPJC1
        CLA DELP
        FNA DPJC1
        STR DELP
        LDQ DPJC1
        FNM DPJC1
        STR NPER
```

```
      CLA DELP2
      FNA NPER
      STR DELP2
      CLA XCT
      FNS XOFJ2
      STR W
      LDQ W
      FNM W
      STR WSQ
      CLA AVGW
      FNA W
      STR AVGW
      CLA AVGW2
      FNA WSQ
      STR AVGW2
* DETERMINE SEGMENT AND SUB-SEGMENT
PD20  LDQ G
      FNM N
      FDH H
      STQ BETA
      CLA N
      FNA FL1
      STR TEMPS
      CLA FL1
      FNS BETA
      STR TEMP
      LDQ TEMP
      FNM H
      FDH TEMPS
      STQ S
      CLA SSEG
      SUB FX1
      STR SSGM1
PD14  LDQ N*
      FNM S
      STR TEMP
      CLA N*
      FNS FL1
      STR TEMPS
      LDQ G
      FNM TEMPS
      FNA TEMP
      SGA XCT
      UNJ PD12
      UNJ PD13
PD13  CLA N
      FNA FL1
      SGA N*
      UNJ STEPN
      UNJ TXC
TXC   CLA XCT
      SGA H
      UNJ PD14
      UNJ TE
      UNJ PD14
STEPN CLA N*
```

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```
        FNA  FL1
        STR  N*
        CLA  N*D
        ADD  FX1
        STR  N*D
        UNJ  PD14
TE      LDQ  SEG
        MPY  SSEG
        STR  HERE
        CLA  AAA
        ADD  HERE
        SUB  FX1
        STA  FIX
        STA  FIX2
        UNJ  FIX
PD12    CLA  N*
        FNS  FL1
        STR  TEMP
        CLA  S
        FNA  G
        STR  TEMPS
        LDQ  TEMP
        FNM  TEMPS
        STR  TEMP
        LDQ  M*
        FNM  GAMA
        STR  TEMPS
        LDQ  S
        FNM  TEMPS
        FNA  TEMP
        SGA  XCT
        UNJ  PD15
        UNJ  PD16
PD16    CLA  M*
        FNA  FL1
        STR  M*
        CLA  M*D
        ADD  FX1
        STR  M*D
        UNJ  PD12
PD15    LDQ  N*D
        MPY  SSEG
        STQ  TEM
        CLA  TEM
        SUB  SSGM1
        ADD  M*D
        SUB  FX1
        STR  STAY
        CLA  AAA
        ADD  STAY
        SUB  FX1
        STA  FIX
        STA  FIX2
FIX     CLA  --
        FNA  FL1
FIX2    STR  --
```

```
        UNJ PD24
PD10    CLA SCAT
        FNA FL1
        STR SCAT
        LDQ G
        FNM R
        STR TEMP
        CLA XJ1
        FNS LJ
        FNS TEMP
        STR XJP1
        STR XOFJ
        CLA LJ
        FNA TEMP
        STR DPJS1
        CLA DELP
        FNA DPJS1
        STR DELP
        LDQ DPJS1
        FNM DPJS1
        STR NPER
        CLA DELP2
        FNA NPER
        STR DELP2
        UNJ PD23
PD8     CLA K
        FNS FL1
        SGA R
        UNJ STRO
        UNJ *+1
        UNJ ESCL
STRO    CLA R
        FNA FL1
        STR R
        UNJ PD17
ESCL    CLA LESC
        FNA FL1
        STR LESC
        CLA XJ1
        STR DPJLE
        CLA DELP
        FNA DPJLE
        STR DELP
        LDQ DPJLE
        FNM DPJLE
        STR NPER
        CLA DELP2
        FNA NPER
        STR DELP2
        UNJ PD24
* COMPUTE YES DIRECTION
PD7     CLA XJ1
        FNA LJ
        STR TEST
        CLA K
        STR WEEK
```

```
PD28   LDQ P
       FNM WEEK
       STR TEMP
       CLA K
       FNS FL1
       STR NORE
       LDQ NORE
       FNM G
       FNA TEMP
       SGA TEST
       UNJ PD18
       UNJ PD18
       CLA N
       FNA FL1
       SGA WEEK
       UNJ STKO
       UNJ PD19
       UNJ PD19
STKO   CLA WEEK
       FNA FL1
       STR WEEK
      oCLA G*
       FNA FL1
       STR G*
       UNJ PD28
PD19   CLA RESC
       FNA FL1
       STR RESC
       CLA H
       FNS XJ1
       STR DPJRE
       CLA DELP
       FNA DPJRE
       STR DELP
       LDQ DPJRE
       FNM DPJRE
       STR NPER
       CLA DELP2
       FNA NPER
       STR DELP2
       UNJ PD24
PD18   CLA SIGC
       FDH SIG
       STQ SSIG
       SXJ RANO,4
       STR RAN+3
       SGA SSIG
       UNJ PD21                SCATTER
       UNJ PD22                CAPTURE
PD22   CLA CAPT                CAPTURE
       FNA FL1
       STR CAPT
       LDQ G*
       FNM G
       FNA LJ
       FNA XJ1
```

```
        STR  XCT
        LDQ  G*
        FNM  G
        FNA  LJ
        STR  DPJCO
        CLA  DELP
        FNA  DPJCO
        STR  DELP
        LDQ  DPJCO
        FNM  DPJCO
        STR  NPER
        CLA  DELP2
        FNA  NPER
        STR  DELP2
        CLA  XCT
        FNS  XOFJ2
        STR  W
        LDQ  W
        FNM  W
        STR  WSQ
        CLA  AVGW
        FNA  W
        STR  AVGW
        CLA  AVGW2
        FNA  WSQ
        STR  AVGW2
        UNJ  PD20
PD21    CLA  SCAT
        FNA  FL1
        STR  SCAT
        LDQ  G*
        FNM  G
        FNA  LJ
        FNA  XJ1
        STR  XJP1
        STR  XOFJ
        LDQ  G*
        FNM  G
        FNA  LJ
        STR  DPJSO
        CLA  DELP
        FNA  DPJSO
        STR  DELP
        LDQ  DPJSO
        FNM  DPJSO
        STR  NPER
        CLA  DELP2
        FNA  NPER
        STR  DELP2
        UNJ  PD23
PD23    CLA  J
        FNA  FL1
        STR  J
        CLA  FL1
        STR  K
        STR  M*
```

```
      STR N*
      CLA RO
      STR R
      STR G*
      UNJ COMLJ
PD24  CLA DELP
      FDH J
      STQ DAVG
      CLA DELP2
      FDH J
      STQ DAVG2
      CLA DVGT
      FNA DAVG
      STR DVGT
      CLA DVGT2
      FNA DAVG2
      STR DVGT2
      LXD SAVE6,1
      IXJ PRINT,1,1
      SXD SAVE6,1
      UNJ JUMP
PRINT SXJ RESTO,4
      SXJ PRSET,4
      ZER HEAD,3,18           INPUT DATA
      SXJ WRITE,4
      SXJ WRITE,4
      SXJ PRSET,4
      ZER HEAD1,1,6
      CLA H
      SXJ ENFLO,4
      ZER 12,2                (H)
      SXJ WRITE,4
      SXJ PRSET,4
      ZER HEAD2,1,6
      CLA G
      SXJ ENFLO,4
      ZER 12,2
      SXJ WRITE,4
      SXJ PRSET,4
      ZER HEAD3,1,6
      CLA N
      SXJ ENFLO,4
      ZER 12,0
      SXJ WRITE,4
      SXJ PRSET,4
      ZER HEAD4,1,6
      CLA P
      SXJ ENFLO,4
      ZER 12,2
      SXJ WRITE,4
      SXJ PRSET,4
      ZER HEAD5,3,18
      CLA XOFJ2
      SXJ ENFLO,4
      ZER 24,2
      SXJ WRITE,4
```

```
        SXJ PRSET,4
        ZER HEAD6,2,12
        CLA SIGC
        SXJ ENFLO,4
        ZER 18,3
        SXJ WRITE,4
        SXJ PRSET,4
        ZER HEAD7,2,12
        CLA SIG
        SXJ ENFLO,4
        ZER 18,3
        SXJ WRITE,4
        SXJ PRSET,4
        ZER HEAD8,3,18
        CLA PART                     NO OF PARTICLES
        SXJ ENFLO,4
        ZER 24,0
        SXJ WRITE,4
        SXJ PRSET,4
        ZER HEAD9,3,18
        CLA TABLE
        SXJ ENSCN,4
        ZER 30,7,27
        SXJ WRITE,4
        SXJ WRITE,4
        SXJ WRITE,4
        SXJ WRITE,4
        SXD SAVE6,1
JUMP    NOP
        LXD SAV3,1
        IXJ PR,1,1
        UNJ STAR
PR      SXJ PRSET,4
        ZER HED20
        SXJ WRITE,4
        SXJ WRITE,4
STAR    CLA N*
        SXJ ENFLO,4
        ZER 6,0
        CLA M*
        SXJ ENFLO,4
        ZER 12,0
        CLA DAVG
        SXJ ENFLN,4
        ZER 30,6
        CLA DAVG2
        SXJ ENFLN,4
        ZER 48,6
        CLA W
        SXJ ENFLN,4
        ZER 60,5
        CLA WSQ
        SXJ ENFLN,4
        ZER 72,5
        SXJ WRITE,4
        SXD SAV3,1
```

```
IXJ TESTN,2,1
CLA DVGT
FDH PART
STQ AJUM
CLA DVGT2
FDH PART
STQ AJUM2
CLA AVGW
FDH CAPT
STQ TAW
CLA AVGW2
FDH CAPT                    -CLEAR AFTER EACH SET
STQ TAWSQ                   -CLEAR AFTER EACH SET
SXJ RESTO,4
SXJ PRSET,4
ZER HED21
SXJ WRITE,4
SXJ WRITE,4
SXJ WRITE,4
CLA RESC
SXJ ENFLO,4
ZER 12,0
CLA LESC
SXJ ENFLO,4
ZER 42,0
SXJ WRITE,4
SXJ WRITE,4
SXJ WRITE,4
SXJ PRSET,4
ZER HED22
SXJ WRITE,4
SXJ WRITE,4
CLA AJUM                    A JUM
SXJ ENFLN,4
ZER 18,6
CLA AJUM2
SXJ ENFLN,4
ZER 48,6
SXJ WRITE,4                 A JUM 2
SXJ WRITE,4
SXJ WRITE,4
SXJ PRSET,4
ZER HED23,7,42
SXJ WRITE,4
CLA TAW
SXJ ENFLN,4
ZER 18,6
CLA TAWSQ
SXJ ENFLN,4
ZER 36,6
SXJ WRITE,4
SXJ RESTO,4
SXJ PRSET,4
ZER HED24,6,36
SXJ WRITE,4
SXJ WRITE,4
```

```
        SXJ WRITE,4
        SXJ PRSET,4
        ZER HED25
        SXJ WRITE,4
        SXJ WRITE,4
        SXD PUT,2
        SXD PUTT,1
        CLA SEG
        ADD FX1
        STR SEG1
        CLA SSEG
        ADD FX1
        STR SSEG1
        LXA SEG1,2
        LXA SSEG1,1
DEF     CLA FX11
        IXJ DEF1,2,1
        LXD PUT,2
        LXD PUTT,1
        UNJ TESD
DEF1    CLA FX12
        IXJ PRIN,1,1
        UNJ OVER
PRIN    CLA FX11
        SXJ ENINT,4
        ZER 12
PRIN1   CLA FX12
        SXJ ENINT,4
        ZER 24
PRIN2   CLA HIS
        SXJ ENFLO,4
        ZER 36,0
        SXJ WRITE,4
        CLA PRIN2
        ADD FX1
        STR PRIN2
        CLA FX12
        ADD FX1
        STR FX12
        UNJ DEF1
OVER    LXA SSEG1,1
        CLA FX1
        STR FX12
        CLA FX11
        ADD FX1
        STR FX11
        SXJ WRITE,4
        UNJ DEF
TESD    CLA FL1
        STR NSQ
        CLA FX1
        STR FX11
        STR FX12
        LXA IR1,1
        LXA IR4,4
        SXD SAVE,4
```

```
        SXD SAV3,1
        CLA XOFJ2
        STR XOFJ
        UNJ TESDD
PD25    CLA FL1
        STR J
        STR K
        STR M*
        STR N*
        CLA FX1
        STR M*D
        STR N*D
        CLA R0
        STR R
        STR G*
        STR DELP
        STR DELP2
        STR DAVG
        STR DAVG2
        STR W
        STR WSQ
        UNJ COMLJ
TESTN   CLA NSQ
        FNA FL1
        STR NSQ
        CLA XOFJ2
        STR XOFJ
        UNJ PD25
TESDD   CLA FL1
        STR J
        STR K
        STR M*
        STR N*
        CLA FX1
        STR M*D
        STR N*D
        CLA R0
        STR R
        STR G*
        STR W
        STR WSQ
        STR AVGW
        STR AVGW2
        STR DELP
        STR DELP2
        STR DAVG
        STR DAVG2
        STR DVGT
        STR DVGT2
        CLA AAA
        ADD D299
        STA TT
        LXA D299,1
TT      STZ --,1
        IXJ TT,1,1
        UNJ START
```

```
LAMM  FLO -1
HALF  FLO .5
K     FLO 1
FL1   FLO 1
N*    FLO 1
M*    FLO 1
FIVE  FLO 5
LAMDA ZER
H     ZER
G     ZER
N     ZER
P     ZER
XOFJ  ZER
SIGC  ZER
SIG   ZER
PART  ZER
TABLE DEC 3.1415927
SEG   ZER
SSEG  ZER
IR2   ZER
IR4   ZER
FX1   DEC 1
FX2   DEC 2
L3    DEC 3
D199  DEC 199
D299  DEC 299
IR1   DEC 2
M*D   DEC 1
N*D   DEC 1
FX11  DEC 1
FX12  DEC 1
PUT   ZER
PUTT  ZER
BETA  ZER
STAY  ZER
SAVE  ZER
SAVE1 ZER
SAVE2 ZER
SAV3  ZER
RAN   ZER
      LOC L+10
LN    SRT
TEMP  ZER
OMEGA ZER
XJ1   ZER
NORE  ZER
DEAR  ZER
SSIG  ZER
CAPT  ZER
XC1   ZER
DPJC1 ZER
TEMPS ZER
G*    ZER
S     ZER
SCAT  ZER
DPJS1 ZER
```

```
LESC   ZER
DPJLE  ZER
TEST   ZER
WEEK   ZER
RESC   ZER
DPJRE  ZER
TEM    ZER
XCO    ZER
GAMA   ZER
SAVE6  ZER
DPJCO  ZER
XJP1   ZER
DPJSO  ZER
RO     ZER
DELP   ZER
DELP2  ZER
DAVG   ZER
DAVG2  ZER
NPER   ZER
XCT    ZER
DVGT   ZER
DVGT2  ZER
J      ZER
R      ZER
NSQ    ZER
XOFJ2  ZER
LJ     ZER
W      ZER
WSQ    ZER
AVGW   ZER
AVGW2  ZER
SSGM1  ZER
HERE   ZER
AJUM   ZER
AJUM2  ZER
TAW    ZER
TAWSQ  ZER
SSEG1  ZER
SEG1   ZER
AAA    ZER HIS
HIS    ZER
       LOC L+299
HEAD   BCI 3,       INPUT  DATA
HEAD1  BCI 1,    H=
HEAD2  BCI 1,    G=
HEAD3  BCI 1,    N=
HEAD4  BCI 1,    P=
HEAD5  BCI 3,  STARTING POINT=
HEAD6  BCI 2,  SIGMA C =
HEAD7  BCI 2,  SIGMA =
HEAD8  BCI 3, NO. OF PARTICLES=
HEAD9  BCI 3,  RANDOM NO. GEN.=
HED20  BCI 9,   SEG.  SUB-SEG.  JUMP LENGTH   JUMP LENGTH SQ.
       BCI 3, W         W SQ.
HED21  BCI 9,  NO. OF RIGHT ESCAPES          NO. OF LEFT ESCAPES
       BCI 3,
```

```
HED22 BCI 9,      TOTAL AVG. JUMP LENGTH     TOTAL AVG. JUMP LENGTH
      BCI 3, SQ.
HED23 BCI 7,      TOTAL AVG. W       TOTAL AVG. W SQ.
HED24 BCI 6,                            HISTOGRAM
HED25 BCI 9,         SEG.     SUB-SEG.     NO OF PARTICLES
      BCI 3,
DL9C  EQU 33
PRSET EQU 34
ENFLO EQU 35
WRITE EQU 39
RESTO EQU 40
ENFLN EQU 43
ENINT EQU 36
ENSCN EQU 37
* RANDOM NUMBER GENERATOR
* CALLING SEQUENCE TO SET UP
*      SXJ RANO+1,4
* ZERN (N IS NUMBER OF BITS IN RNUM.)
* INITIAL RNUM IS IN AC
* CALLING SEQUENCE TO USE
*      SXJ RANO,4
* RESULTING RNUM IS IN FIRST N BITS OF AC
* THIS PROGRAM HAS 60 INSTRUCTIONS AND USES ONE FREE STORAGE LOCATION
RANO  UNJ RN2
      STR 1R                    STORES INITIAL RNUM
      CLA 1,4                   PUTS N IN AC
      SGA L33                   NUMBER 33 IS COMPARED TO N
      CLA L33
      NOP
      SUB L33                   FORMS N-33
      STA RN4
      STA RN1
      STA RN5
* SET MASK
      LDQ ONES                  PUTS ONE IN ALL BITS OF Q-REG
RN1   LLS -
      STQ MASK
      CLA MASK                  FILLS FIRST N BITS AC WITH ONES
      ANS 1R                    FORMS N BIT RNUM
      CLA L2
RN4   ALS -
      ORS 1R
* SET UP MPY
      CLA 1MPY                  PUTS K IN AC
RN5   ARS -
      ALS 3                     FORMS 8K
      ADD L5                    FORMS(8K+5)
      STR MPY
      UNJ 2,4
L5    DEC 5
ONES  OCT 377777777774
L33   DEC 33
MASK  ZER
L2    DEC 2
1R    ZER
MPY   ZER
```

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```
1MPY   OCT 24420404020
* COMPUTE RNUM
RN2    LDQ 1R
       MPY MPY                   FORMS RN-1R
       STQ 1R
       SXD ERAS8,1
       CLA 1R
       ANA MASK
       STR FREE
       OVJ RN6
RN6    LXA RN9,1                 PUTS A ONE IN INDEX 1
RN7    CLA FREE
       ALS 1
       OVJ RN8
       STR FREE
       RXJ RN7,1,1               ADD A ONE TO INDEX 1
RN8    LRS 36                    PUTS FRATIONAL PART IN Q-REGISTER
       PXD 0,1
       ALS 9
       SUB RN10
       SSP
       STR FREE                  STORES EXPONENT
       LLS 27
       ADD FREE                  COMPLETES FLOATING OPERATION
       LXD ERAS8,1
       UNJ 1,4
RN9    ZER 1
RN10   OCT 201000000000
ERAS8  ZER
*
```