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GFUN at SLAC:
A User's Guide to the Magnet Design Program GFUN

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I. Introduction

The GFUN programs[1] for designing magnets, which have been developed at the Rutherford Laboratory in England, are now operating at SLAC. Because GFUN uses the Unified Graphics routines[2], it can be used on either the GIF IDIIUM or IBM 2250 display stations with only small changes in the JCL cards.

The GFUN package consists of two programs: an on-line, interactive program and a batch program. The on-line program allows the user to draw iron and current regions; to erase or modify them; to write files on a disk so that the design can be saved for later use; to read, delete, and list the files. The on-line program can also calculate the field at a point, along a line, or over an area using the magnetization of the iron calculated by the batch program. The on-line program runs in the 150 kilobyte graphics partition on the IBM 360-91.

The batch program reads a file from the disk, calculates the magnetization of the iron, and writes a new file which includes the calculated magnetization. This program uses 300 kilobytes of space and permits the iron to be divided into as many as 84 elements.

The different options available at SLAC are described in this note. They are arranged in the order they might occur in typical use. To help find information on a particular option, an index is provided in Section IX.

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II. To Start from Scratch to Study a Magnet

1. Submit the scope job. When the job comes on-line, the seventeen option names will appear on the screen like this:

OPERATION: INDICATE WITH LIGHT-PEN

DRAW MODI REAS RECO WRIT READ FRAM PRIN BH HELP

GETB GETM NEW END DELE ROOM LIST

These seventeen names are light-pen detectable. To choose an option, activate its name with the light-pen.

2. The name REDO, which appears in the lower right-hand corner of the screen, is also light-pen detectable. To again be given the choice of options, activate REDO with the light-pen.

3. NEW. Option NEW initializes the parameters and presents the list of options for your next choice. NEW should be used as the first option in any session. LIST should be selected next.

4. FRAM. Option FRAM sets the scale and draws the coordinate axes. When you activate FRAM with the light-pen, the screen will show:

FRAM PARAMETERS

XMIN XMAX YMIN YMAX

with the default values of these boundaries below. If the values are satisfactory, activate the keyboard escape. Otherwise change them, then activate the keyboard escape.

5. BH. Option BH enables you to read in the points for a B-H curve. Use the keyboard to type in the values (B in Gauss, H in Oerstead); then press the keyboard escape. To change a value, activate the offending value with the light-pen, then correct and press the keyboard escape. To return to the option table, activate REDO with the

light-pen. Up to thirty B-H pairs are allowed in the B-H Table. Pairs must be stored in increasing order of H. The B=0, H=0 point need not be stored.

6. DRAW. Option DRAW creates an (iron or current) element or a group of elements, and draws them on the screen.

PARAMETERS FOR DRAW

MATE Material

MATE=0	Current carrying element. Current or current density must be specified.
MATE=3	Iron element, variable permeability.

SHAPE Shape of the element

SHAPE=0	Rectangle
SHAPE=1	Isosceles triangle.
SHAPE=2	Sector.
SHAPE=3	Quadrilateral.
SHAPE=4	Triangle.
SHAPE=5	Maps annular region with isosceles triangles.
SHAPE=6	Maps quadrilateral region with triangles, 2 per cell.
SHAPE=7	Maps quadrilateral region with triangles, 4 per cell.

SYMM Symmetry

SYMM=1	No symmetry assumed. All elements must be drawn.
SYMM=2	Symmetric dipole. Field in y direction. Iron geometry symmetric about x and y axes. Current symmetric about x; antisymmetric about y.
SYMM=-2	Asymmetric dipole. No symmetry about y axis.
SYMM=3	Axisymmetric about z(x). Field in z(x) direction.
SYMM=-3	Axisymmetric about z(x) axis. Symmetric under reflection through r(y) axis.

SYMM=4 — Quadrupole. Specify current for first octant. Specify iron for first quadrant.

NX or NR
NY or NPHI — See below under appropriate shapes.

J Current Density (Amp/cm^2) — One of these must be specified for current elements. If J=0 is read in, the program calculates J by dividing I by the area of the element.

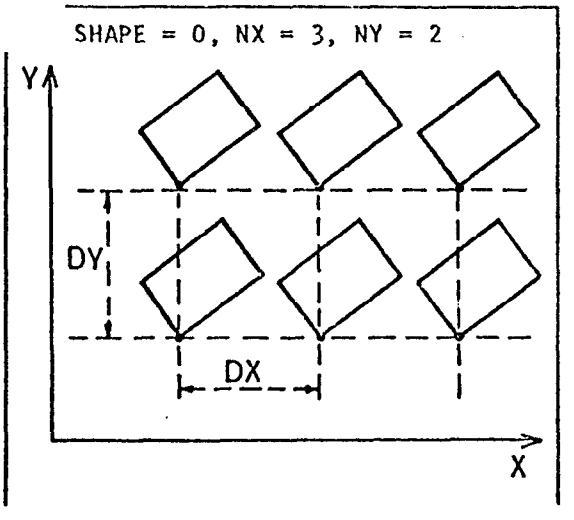
I Current (Amp)

PARAMETERS FOR SHAPE=0, RECTANGLE

X1,Y1 — Coordinates of lower left-hand corner (cm).

A — Base (cm).

B — Height (cm).



ANG — Angle between base and x-axis (degree).

Y3,X4,Y4 — Not used.

NX,NY — Number of repetitions of element desired in x and y directions.

DX,DY — Spacing between repetitions of elements (cm).

PARAMETERS FOR SHAPE=1, ISOSCELES TRIANGLE

A — Base.

B — Height

Others — Same as SHAPE=0.

PARAMETERS FOR SHAPE=2, SECTOR

R1	Inner radius.
PHI1	Angle of lower edge (degree).
T	Radial thickness.
ALPHA	Angular length (degree).
NR,NPHI	Number of repetitions of element desired in r and phi directions.
DR,DPHI	Radial and angular spacing between repetitions.

PARAMETERS FOR SHAPE=3, QUADRILATERAL

X1,Y1,X2,Y2, X3,Y3,X4,Y4	Coordinates of vertices, labeled in clockwise order.
NX,NY,DX,DY	Same as SHAPE=0.

PARAMETERS FOR SHAPE=4, TRIANGLE

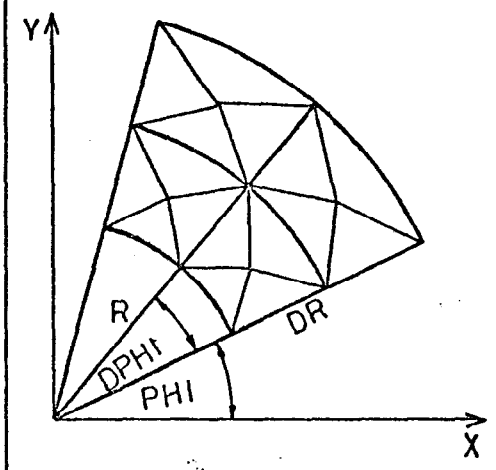
X1,Y1,X2, Y2,X3,Y3	Coordinates of vertices, labeled in clockwise order.
NX,NY,DX,DY	Same as SHAPE=0.

PARAMETERS FOR SHAPE=5, MAPPING SECTOR OR ANNULAR REGION WITH WITH ISOSCELES TRIANGLES. Creates 4*NR*NPHI elements.

R1	Inner radius
PHI1	Angle of lower edge (degree).
DR	Radial increment.

SHAPE = 5 Mapping

Sector/Annular region with isoceles triangles.

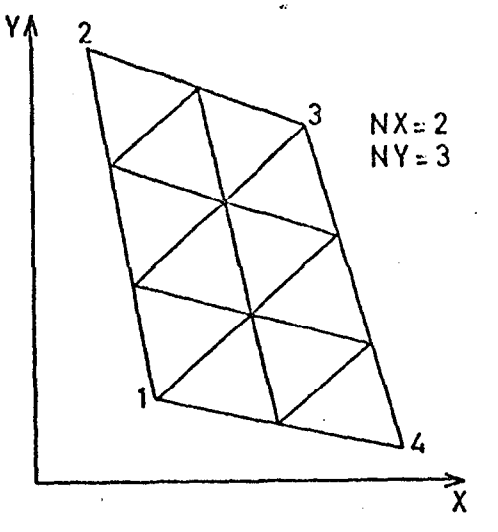


DPHI	Angular increment (degree)
NR	Number in radial direction.
NPHI	Number in phi direction
T,ALPHA	Not used.

PARAMETERS FOR SHAPE=6 or SHAPE=7, MAPPING QUADRILATERAL REGION WITH TRIANGLES.

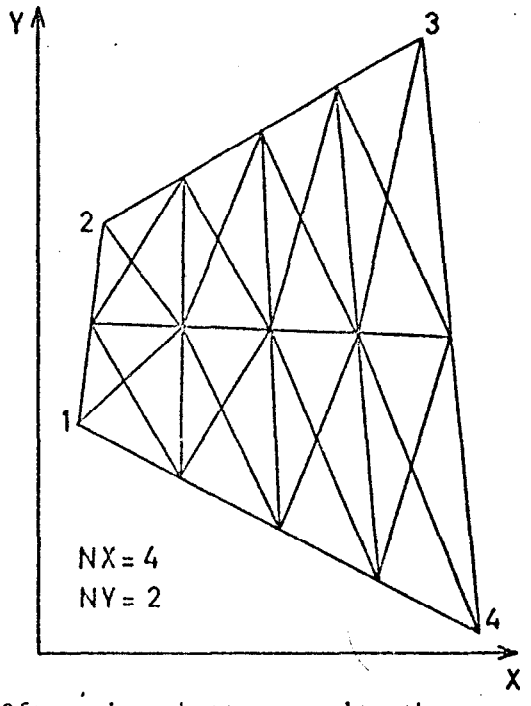
SHAPE=6 creates 2*NX*NY elements.

SHAPE = 6 Mapping quadrilateral region with triangles 2 per cell



Diagonals can be given other sense by starting corner numbering one place round

SHAPE = 7 Mapping quadrilateral region 4 per cell



(Often gives better results than SHAPE = 6)

SHAPE=7 creates 4*NX*NY elements.

X1,Y1,X2,Y2, X3,Y3,X4,Y4 Coordinates of vertices, labeled in clockwise order.

NX,NY Number of intervals in X and Y.

DX,DY Not used.

7. ERAS. Option ERAS erases the specified elements and renumbers the others sequentially.

PARAMETERS FOR ERAS

MATE Material. (Same as for DRAW)

E1 First element to be ased.

E2 Last element to be erased. If E2 is left = 0, it will be set = E1

8. MODI. Option MODI allows some parameters of the specified element or elements to be modified. Parameters same as ERAS plus DRAW. (Operating hint: MODI changes the default values for the DRAW parameters. Thus, to make changes to a set of elements, it is often convenient to execute MODI for the first element, select REDO rather than escape, select ERAS for the set, then select DRAW and put in the corrections.)

9. RECO. Option RECO reconstructs the picture of the elements on the screen. Parameters are the same as FRAM and permit changing the scale.

10. PRIN. Option PRIN prints on the screen information about the magnet being studied to enable the user to check the parameters. The same information appears on the output from the line printer.

11. GETM. Option GETM (calculating the magnetization on-line) is not implemented at SLAC. To calculate the magnetization, use option WRIT and run the batch-mode program GETM described below.

12. WRIT. Option WRIT writes the magnet currently being studied onto a file or disk, from which it can be brought back by the READ option and/or read by the batch program GETM. Specify the file name of up to eight characters. The generation number, NGEN, will automatically be set one higher than the highest generation number of any existing file with the same name. Caution: always use the LIST option before using the WRIT option. Failure to do so could mean that your file cannot be read back -- or that no other file can be read back.

Use WRIT to safeguard information you are afraid of losing through error, to save information you want for a later session, or to serve as input to the off-line GETM program.

13. END. Option END ends the on-line job.

III. To Start from an Existing File to Study a Magnet

If the problem requires any information, even if it is only the B-H curve, contained on another file, it is easier to start with that file than to start from scratch.

1. NEW. Option NEW initializes the parameters.

2. LIST. Option LIST lists the names and generation numbers of all files currently filed. It also sets some checks for file reading and writing; thus the caution under WRIT, above.

3. READ. Option READ reads a file into active memory, and prints the information it contains on the screen and on the paper output. Specify the file name and generation number.

4. Now ERAS, DRAW, MODI, RECO, PRIN, etc., as described in Section II.

5. ROOM. Option ROOM tells how many file blocks remain. A 20-track allocation permits 30 file blocks. Most problems use two blocks.

6. DELE. Option DELE deletes a file. Specify file name and generation number.

7. HELP. Option HELP is not fully implemented. It is supposed to print

operating instructions on the screen, but only gives the remaining CPU time.

IV. To Find the Field of a Magnet after the Magnetization Is Found by the Batch Program

1. NEW, FRAM, LIST as described in Sections II and III.

2. READ the file created by the off-line GETM program described below.

3. GETB. Option GETB calculates the magnetic field at a given point anywhere in air, anywhere in a current element or at the center of an iron element. If there are no iron elements, GETB can be used at any time to find the field from the current elements. If there are iron elements, the magnetization must be calculated off-line before GETB is used.

   A. Field at a point.

      Specify the x and y coordinates and press the keyboard escape. Values of the field components at that point will appear on the screen and on the line printer output. Activate REDO when finished.

   B. Field along a line.

      Specify the initial x and y coordinates and the number of points desired (NX if along a line parallel to the x axis; NY for a line parallel to the y axis). To plot a graph of the field, either NX or NY must = 1. Then specify the following parameters.

GRAF — The quantity to be graphed.

GRAF=0 Homogeneity, percent difference from the central field.

GRAF=1 B_y.

GRAF=2 B_x.

GRAF=3 $B = (B_x + B_y)^{\frac{1}{2}}$

PRIN — Switch on printing and plotting field

PRIN	Printing on Screen	Printing on Line Printer	Graph on Screen
2	yes	yes	yes
1	no	yes	yes
0	no	no	yes
-1	no	yes	no
-2	yes	yes	no

DX or DY — Increment in X or Y

HMIN & HMAX — Limits on graph. If HMIN=HMAX=0, the limits will be set by the program.

C. Field along a circle.

Specify the X and Y coordinates of the circle center, the radius, the angular separation in degrees, and the number of points desired.

Set GRAF=6.

D. Field over a rectangular area.

Only the parameters X, Y, NX, NY, DX, DY, and PRIN (PRIN=-2 or -1) are used.

V. To Find the Magnetization with the Batch Job Program GETM

1. GETM reads the magnet data from a disk file, solves for the field in the iron elements, iterates the specified number of times, and writes the magnet data, including the magnetization, on another disk file.

2. Data cards.

Card 1 — NGEN, NAME: Format I3, 1X, 2A4

- NGEN — The generation number of the file containing the input data.
- NAME — The name of the file containing the input data, up to eight characters.

Card 2 — NIT, NITD, NRECAL, NPRINT: Format 4I5

- NIT — Total number of iterations to be done.
- NITD — Number of iterations done so far. Set NITD=0 the first time. If inspection of the output shows that the calculation has not converged, set NITD to the previous value of NIT, set NGEN to the generation number of the output file, set NIT higher, and repeat.
- NRECAL — Matrix calculation flag.
  - NRECAL=0 Store the coefficient matrix on disk and read it back each time.
  - NRECAL=1 Recalculate the coefficient matrix each time. Storing on disk always takes less CPU time.
- NPRINT — Line printer output switch.
  - NPRINT=0 Print only the largest change in H each step and the final magnetization.
  - NPRINT=1 Same as 0 plus values of each H at the center of each element for the first three and last three interations.
  - NPRINT=2 Same as 0 plus the matrix of coefficients between iron elements.

NPRINT=3 Same as 1 plus the matrix of coefficients.

Card 3 CHICN, HEXT, CHIFAC: Format 3F10.3

CHICN Initial value of susceptibility to use if NITD=0. Values of 20. and 1000. have worked well.

HEXT External field. Some simple tests of GFUN require a uniform field applied in the y direction. Otherwise, set this to 0.

CHIFAC Overcorrection factor to speed convergence. Set it to 1 for no overcorrection.

3. DELETE option.

Data sets on the disk file may be deleted by inserting the following two cards.

Card 1 DELETE: Format 4X, A6

Card 2 NGEN, NAME: Format I3, 1X, 2A4

VI. Conclusions

These notes should help the user of GFUN as it is now available at SLAC. However, some GFUN features are not yet available at SLAC. These include (1) provision for automatic optimization of field uniformity; (2) contours of equal field intensity; (3) three-dimensional geometries.

VII. Acknowledgements

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VIII. References

[1] M. J. Newman, C. W. Trowbridge, and L. R. Turner, Proc. 4th Int. Conf. on Magnet Technology, Brookhaven (1972).

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[2] R. C. Beach, The SLAC Unified Graphics System, Fortran Version, CGTM No. 143 (1972).

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