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ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue
Argonne, Illinois 60439-4801

WORKSHOPS AND PROBLEMS FOR BENCHMARKING EDDY CURRENT CODES

by

L.R. Turner
Argonne National Laboratory

K. Davey
Georgia Institute of Technology

N. Ida
The University of Akron

D. Rodger
University of Bath

A. Kameari
Mitsubishi Atomic Power Industries, Inc.

A. Bossavit
Electricite de France

C.R.I. Emson
Rutherford Appleton Laboratory

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WORKSHOPS AND PROBLEMS FOR BENCHMARKING EDDY CURRENT CODES

by

L.R. Turner, K. Davey, N. Ida, D. Rodger, A. Kameari,
A. Bossavit, and C.R.I. Emson

ABSTRACT

A series of six workshops was held in 1986 and 1987 to compare eddy current codes, using six benchmark problems. The problems included transient and steady-state ac magnetic fields, close and far boundary conditions, magnetic and non-magnetic materials. All the problems were based either on experiments or on geometries that can be solved analytically. The workshops and solutions to the problems are described. Results show that many different methods and formulations give satisfactory solutions, and that in many cases reduced dimensionality or coarse discretization can give acceptable results while reducing the computer time required. A second two-year series of TEAM (Testing Electromagnetic Analysis Methods) workshops, using six more problems, is underway.

1. INTRODUCTION

The design of first wall, blanket, and shield (FWBS) systems for tokamak reactors under consideration now and in the future requires the computation of forces, voltages, and magnetic field distortions resulting from transient eddy currents induced by changing magnetic fields. The paths of these eddy currents are often three-dimensional (3-D) and quite complex. Existing computer codes for the solution of eddy current problems are inadequate for the needed computations. In early 1985 Sam Berk of the Office of Fusion Energy, U.S. Department of Energy, suggested that the development and validation of 3-D eddy current codes would benefit from certain benchmark problems that could be used to validate the codes. A series of workshops was proposed in which the solution of problems by different methods and codes could be compared. Community response to the idea was judged through two questionnaires and a general meeting of interested people held at Fort Collins, Colorado in June 1985. That response supported three features that were incorporated into the workshops:

(1) Several regional workshops followed by a single global workshop: All the regional workshops had far more regional participants than overseas participants, but there were enough who had attended earlier workshops to provide continuity. Solutions consequently improved from workshop to workshop.

(2) Inclusion of 2-D and 3-D, transient and steady state problems: This wider scope of the workshops led to wider recognition and participation in the workshops, and ultimately to more development and testing of transient codes than would have occurred had the workshops been limited to transient codes.

(3) Publication of the proceedings of each workshop: The proceedings of the regional workshops were published as informal reports of the host institutions. Their availability helped the progression in solutions from workshop to workshop. The proceedings of the Graz workshop were published as a special issue of the journal COMPEL[1-7], where they are accessible for future code developers.

At a three-day planning meeting held at Argonne National Laboratory (ANL), in November 1985 eleven participants from five countries defined the goals, format, schedule and problems for the workshops. The goals were stated as:

> The ultimate goal is to show the effectiveness of numerical techniques and associated computer codes in solving electromagnetic field problems, and to gain confidence in their predictions. The workshops should also provide cooperation between workers, leading to an interchange of ideas.

2. THE PROBLEMS

The problems were chosen to be applicable to electrical machine design, non-destructive testing, and other areas as well as fusion. They include 2-D and 3-D geometries, transient and steady-state ac magnetic fields, close and far boundary conditions, magnetic and non-magnetic materials.

Six problems were chosen; brief descriptions follow. All the problems are based either on experiments or on geometries that can be solved analytically. In each case, the field is to be found at specified points, and global quantities such as current, stored energy, force, and power dissipation are to be found as well. For transient problems, these are to be found at specified times; for steady-state problems, amplitudes and phases are to be found. To facilitate the comparison of solutions, uniform formats were specified for the presentation of results in tables and graphs.

2.1 The FELIX Cylinder Experiment

A hollow aluminum cylinder with axis perpendicular to uniform magnetic field. The field decays exponentially with time. Based on experiments[8,9]. Figure 1 shows the specified mesh.

2.2 Infinitely Long Cylinder in a Sinusoidal Field

An infinitely long hollow aluminum cylinder in a uniform magnetic field. The field varies sinusoidally with time. Figure 2 shows the specified mesh; some codes experienced difficulty in setting boundary conditions on a circular boundary.

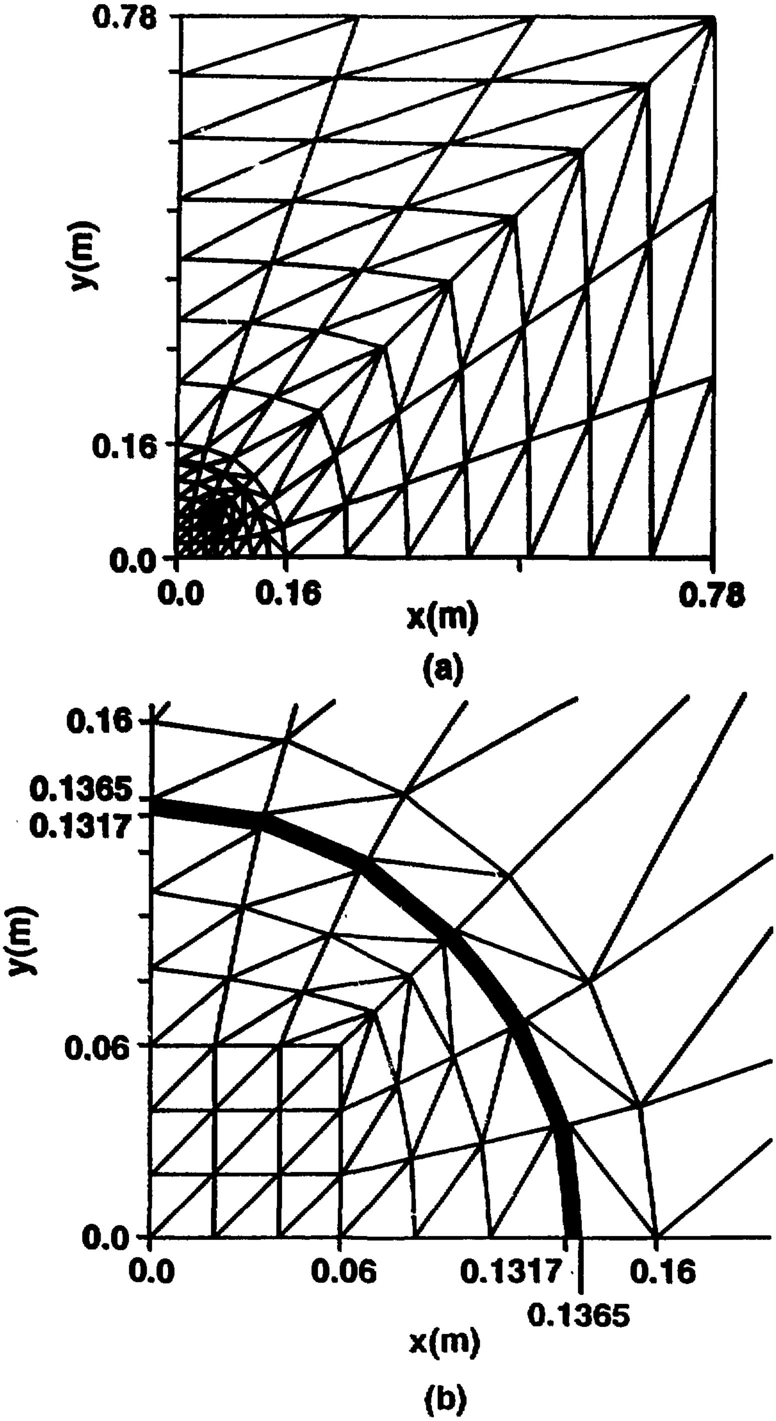

Figure 1. Mesh for Problem 1a, the FELIX cylinder.

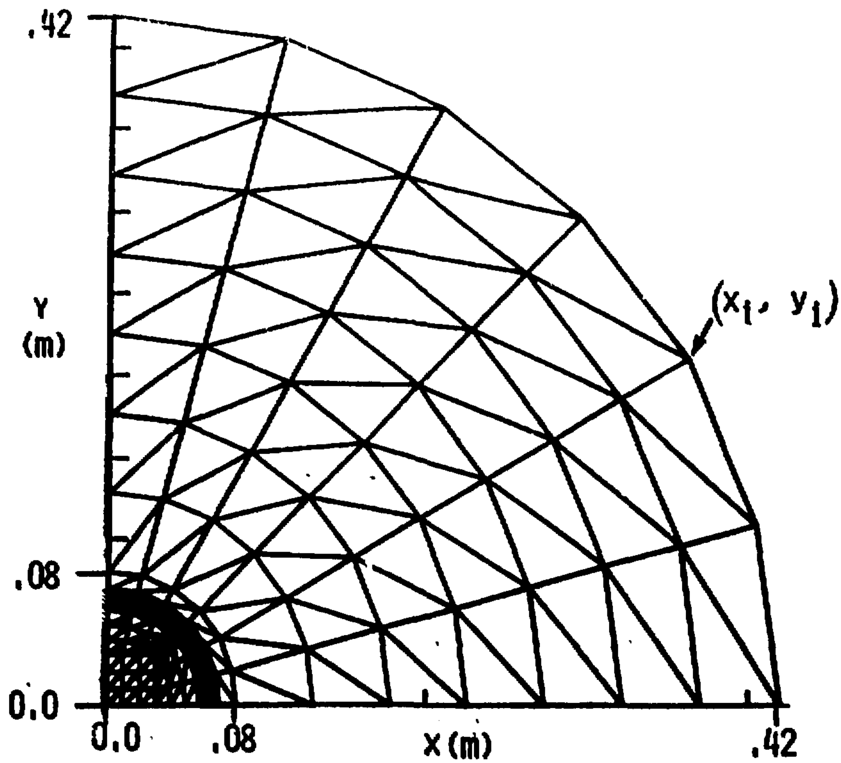

Figure 2. Specified mesh for Problem 2, the infinite cylinder.

2.3 The Bath Plate with Two Holes

A conducting ladder, having two holes, with a coil above carrying sinusoidal current. Figure 3 shows the plate and the two positions for the coil.

2.4 The FELIX Brick Experiment

A rectangular aluminum brick with a rectangular hole in a uniform magnetic field. The field decays exponentially with time. Figure 4 shows the geometry of the brick.

2.5 The Bath Cube

Four identical aluminum cubes enclosed within a laminated iron box under a laminated iron pole. A sinusoidal magnetomotive force (MMF) is applied between the pole and box. Figure 5 shows the cubes in position.

2.6 The Hollow Sphere

A hollow sphere in a uniform sinusoidally varying magnetic field. Figure 6 shows the intersection of the mesh with one of the coordinate planes.

3. THE WORKSHOPS 1986-1987

Five regional workshops were held between March 1986 and January 1987 in England, U.S., Japan, and France, as shown in Table 1. The proceedings of each regional workshop were published as a formal or informal laboratory report.

The culminating workshop was held at the Technical University of Graz, Austria, 20-21 August 1987. There were forty-four participants from eleven countries. The major focus of the workshop was the presentation of summaries of solutions to the six problems. Those summaries were the basis of the six papers published in the journal COMPEL[1-6] and of the brief description of results below. There were reports on the Tokyo, Lyon, and Atlanta workshops plus individual presentations on solution methods of the six problems and on many suggested problems for future workshops.

Following the workshop, a planning meeting was held at which six new problems were chosen and another round of regional workshops planned to be

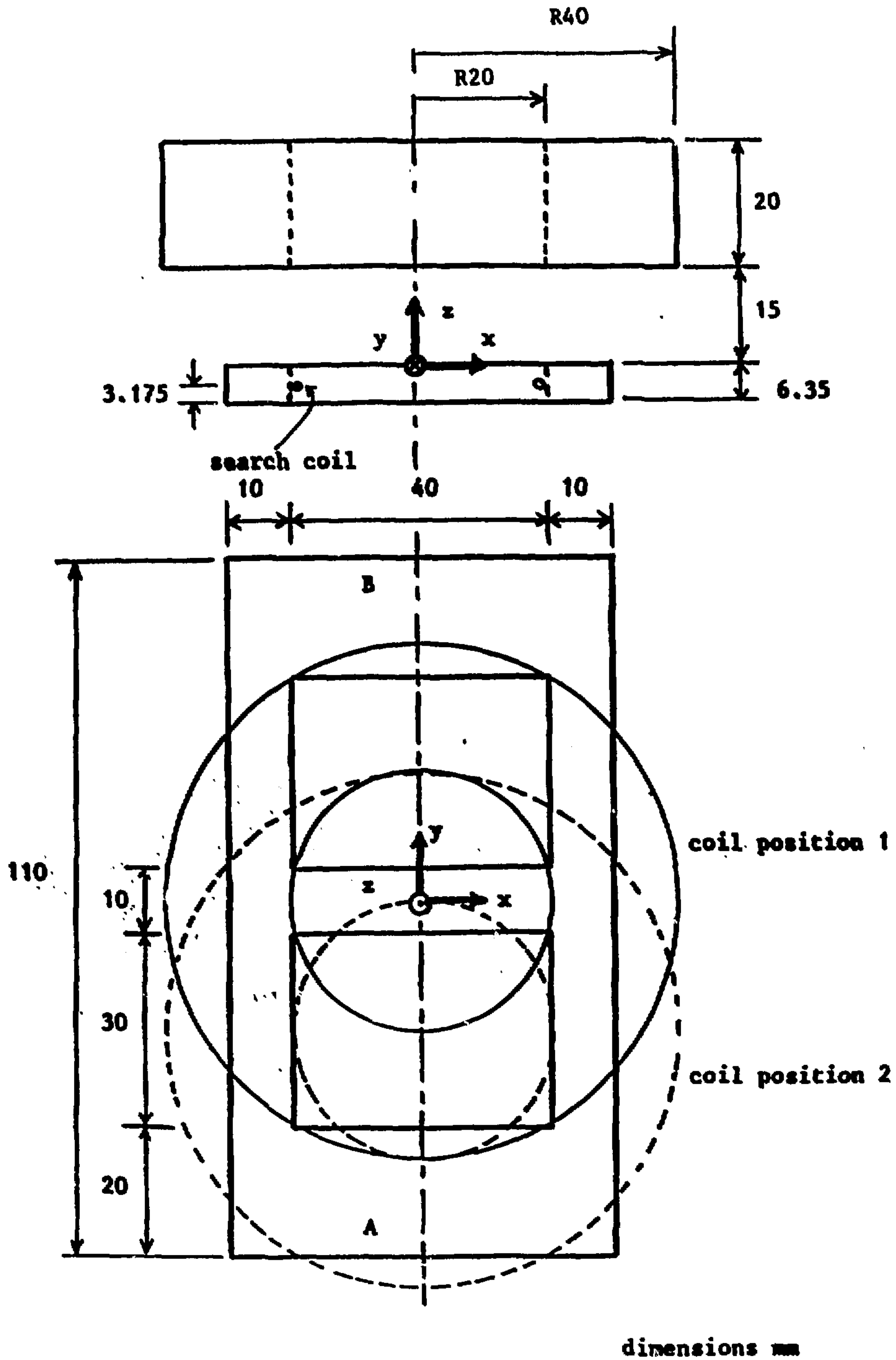

Figure 3. The conducting plate (Problem 3) and the two coil positions.

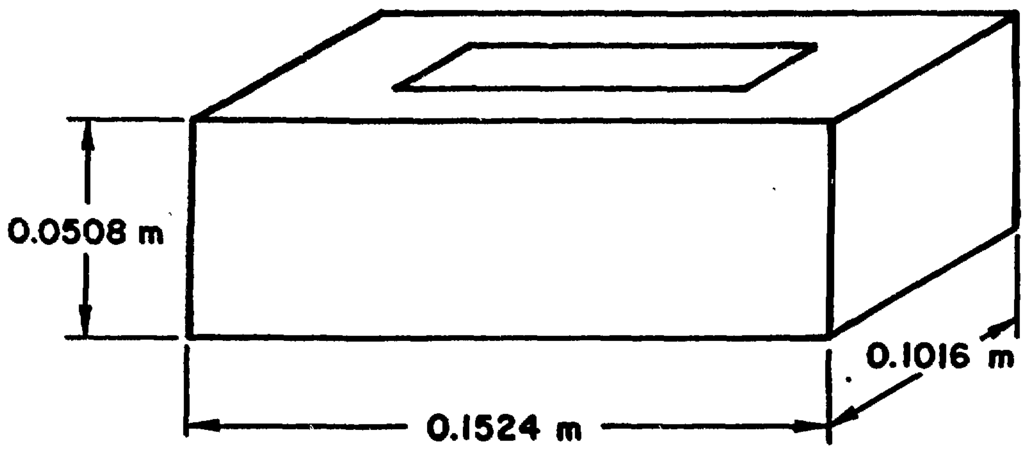

Figure 4. The FELIX brick test piece (Problem 4).

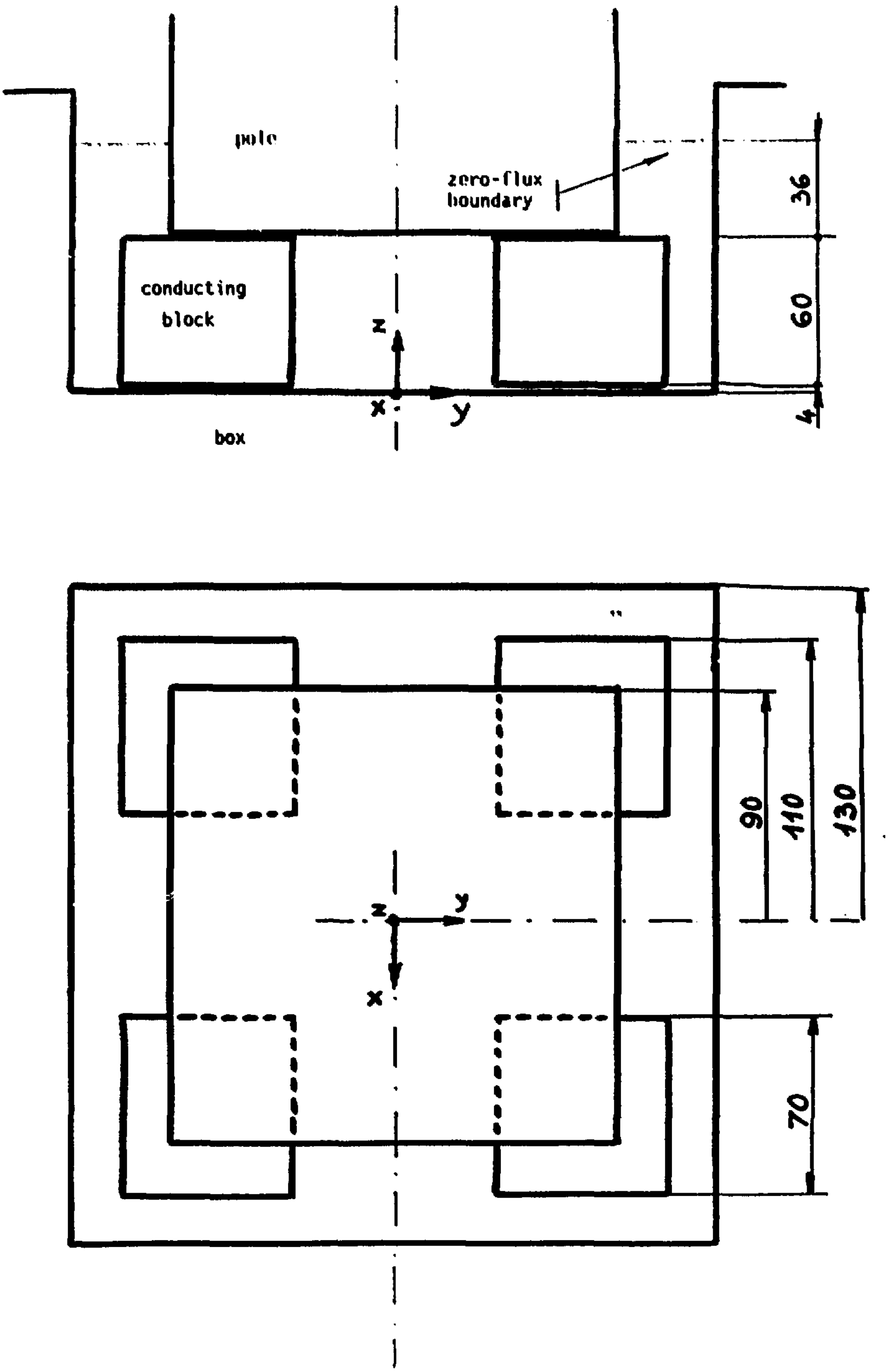

Figure 5. Plan and elevation views of Problem 5, the Bath cube.

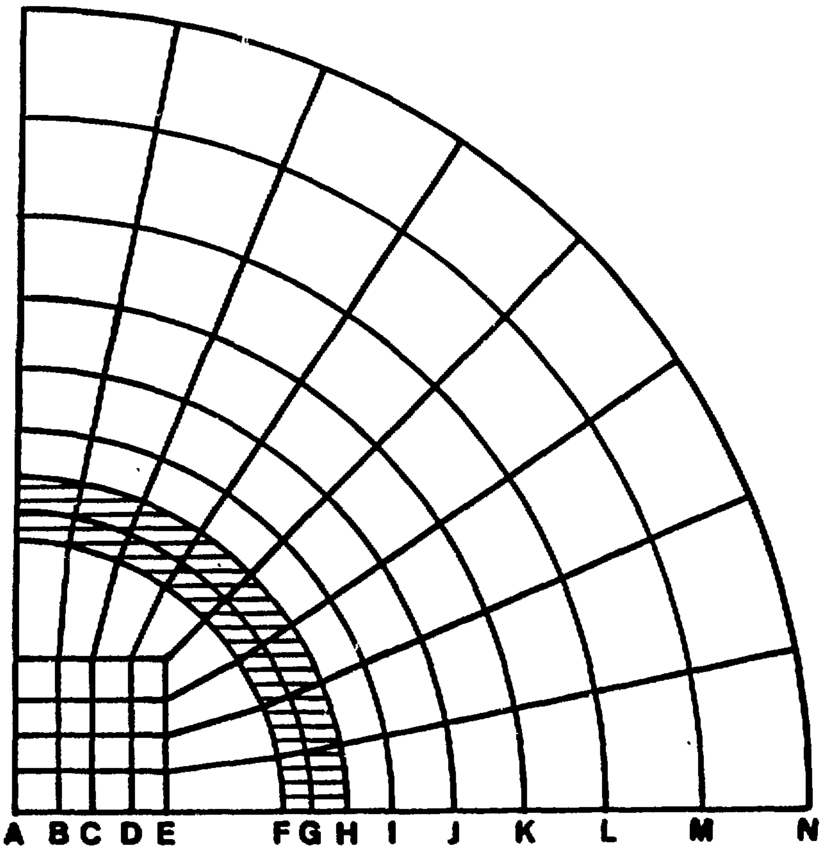

Figure 6. Problem 6, the hollow sphere, the specified mesh on each coordinate plane.

Table 1. Electromagnetic Workshops, 1986-1987

Date	Site	Chairman	Problems	Participants	Countries
27 March 1986	Rutherford Appleton Laboratory UK	Chris Emson	1,2,5,6	32	7
23-24 June 1986	Argonne National Laboratory USA	Larry Turner	1,2,6	15	4
20-21 Oct. 1986	Tokyo, Japan	Kenzo Miya & Takayoshi Nakata	1-6	62	7
18-19 Nov. 1986	Ecole Centrale Lyon, France	Alain Nicolas	1,2,5,6	36	7
12-13 Jan. 1987	Georgia Inst. of Technology Atlanta, USA	Kent Davey	2,5,6	10	4
20-21 Aug. 1987	Technical University of Graz Graz, Austria	Larry Turner	1-6	44	11

followed by an international workshop held in conjunction with COMPUMAG-Tokyo in 1989.

The new problems and workshops are described in Section 5.

4. RESULTS

One of the most interesting observations is the wide variety of methods and formulations that give good results[1,4,6]. Another important observation is that approximate methods frequently give good results with greatly reduced complexity and computation time[1-3].

4.1 Finite Hollow Cylinder, Exponential Field Decay[1]

Seventeen solutions were compared; thirteen used 3-D or shell codes; the other four used 2-D (infinite length) approximations. Two geometries were studied with length, outside diameter, and thickness respectively (1a) 1.2 m, 0.273 m, 0.0048 m and (1b) 0.2 m, 0.1397 m, 0.0127 m. In Problem 1b the ratio of length to diameter for the cylinder is only 1.43; and yet 2-D codes, effectively treating the ratio as infinite, gave surprisingly good results for the induced fields. For those 2-D solutions, the predicted currents were too large, and power loss too small, as would be expected when end effects are ignored. Davey[1] concluded that of the many techniques employed, none stood out as notably more or less accurate than the others. The number of unknowns ranged from thirty to more than four-thousand. Techniques that incorporated some knowledge of the spatial variation of the field benefited from the great reductions in the number of unknowns, but of course, suffer from loss of generality. Eigenvalue-based techniques, in particular, perform better with fewer unknowns because of the elimination of spurious eigenvalues.

Figure 7 shows the total current at two locations in the long cylinder as a function of time.

4.2 Infinite Hollow Cylinder in Sinusoidal Field[2]

Ten solutions, using nine different codes, were compared with analytical results. (Others were presented at the regional workshops.) Most were 2-D finite element codes and were found to give good results, as shown in Fig. 8. Space did not permit including all the results in (2). A more complete set of results appears as an appendix to this memo.

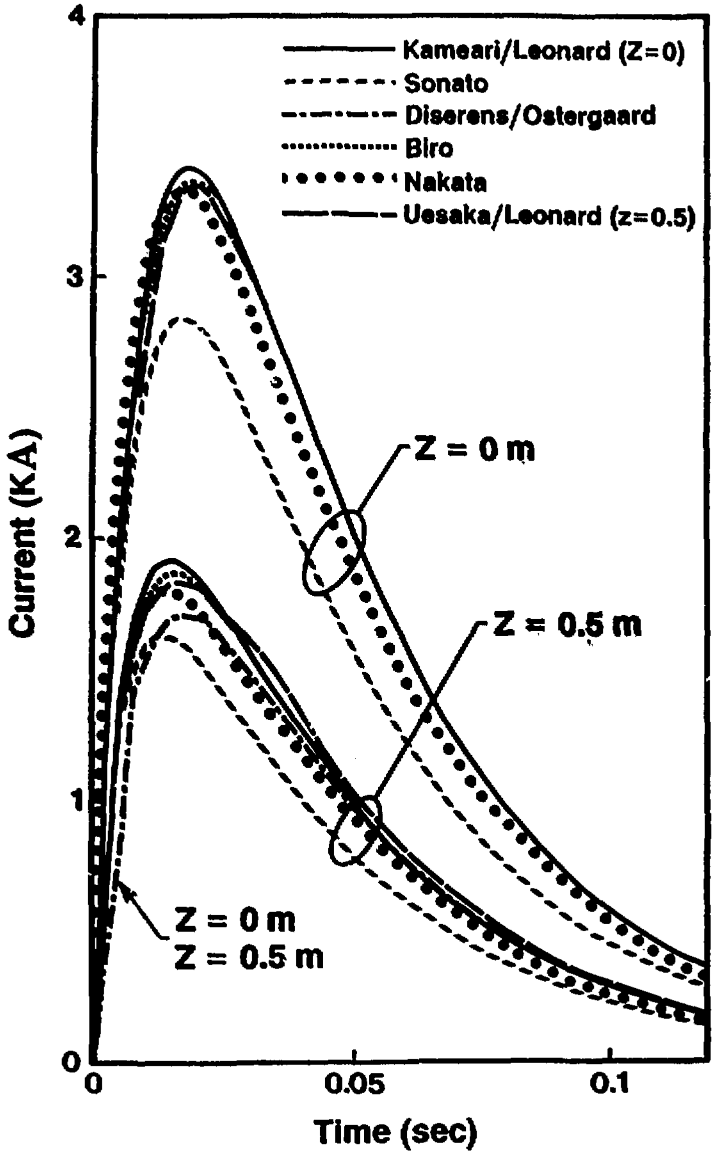

Figure 7. Time variation of circulating current in the FELIX cylinder (Problem 1a).

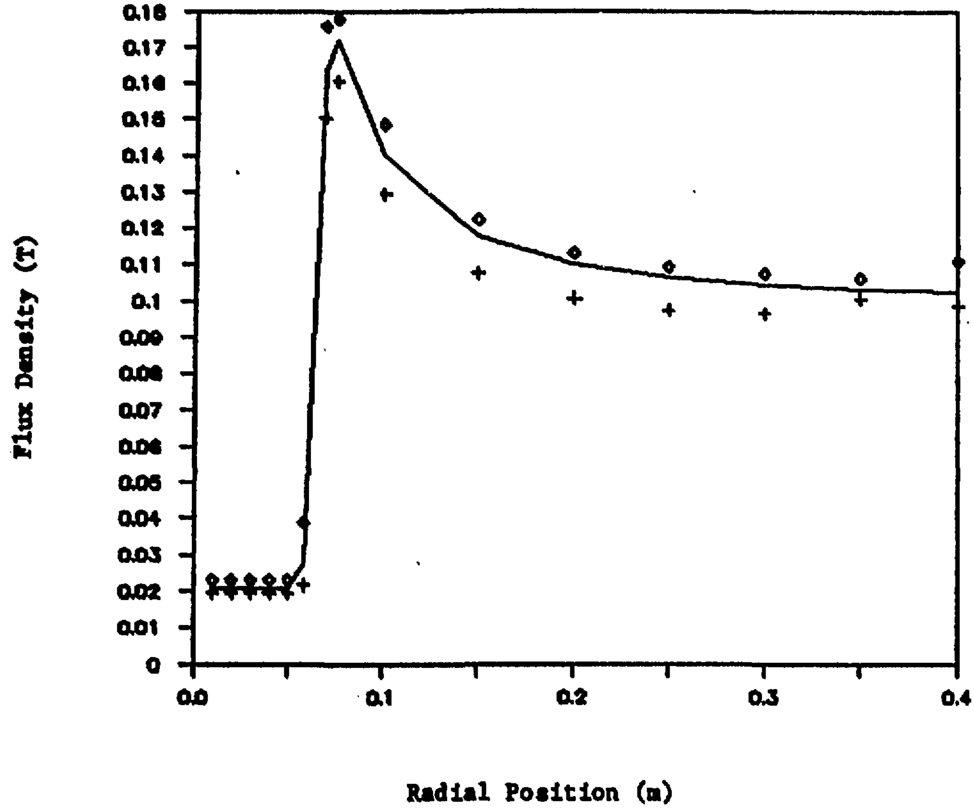

Figure 8. Variation of flux density in the direction perpendicular to the applied field for Problem 2, the infinite cylinder.

4.3 The Bath Plate[3]

Seven solutions using seven different codes were compared with experiment[10] as shown in Fig. 9. Coil positions between the two square holes (position 1) and directly above one of the holes (position 2) were computed at frequencies of 50 Hz and 200 Hz. Rodger[3] found "Most programs show greatest error for the 200 Hz coil position 2 case. This is not surprising, the recommended mesh is becoming rather coarse at this frequency." Different methods treated the holes in very different ways, but all produced generally acceptable results. The good results of the two methods that treated the conductor as a thin sheet suggest that the problem is basically two-dimensional.

4.4 The FELIX Brick[4]

In problem 4, a rectangular aluminum brick with a rectangular hole through it, a 3-D solution is required. Thirteen solutions with eleven different codes were compared. Results were generally found to be in good agreement, as illustrated in Fig. 10, which shows the total circulating current as a function of time.

4.5 The Bath Cube[5]

Five solutions employing five computer codes were compared with experiment[11] for this problem, which consists of four aluminum blocks symmetrically located in an alternating magnetic field. Results for the variation of the amplitude and phase of the magnetic field in the gap between an aluminum block and the lower pole diverged from the experimental results and from one another, as shown in Fig. 11. This, the most three-dimensional of the six problems, requires further computation and comparison.

4.6 The Hollow Sphere[6]

The problem consists of a hollow conducting shell in a uniform sinusoidal field; analytical solutions are available for comparison. It can be computed as either an axisymmetric problem or a true 3-D problem. Of the 21 solutions with 17 codes, seven were with axisymmetric codes, seven with 3-D codes, and the others by the surface impedance method, boundary integral method, and one-

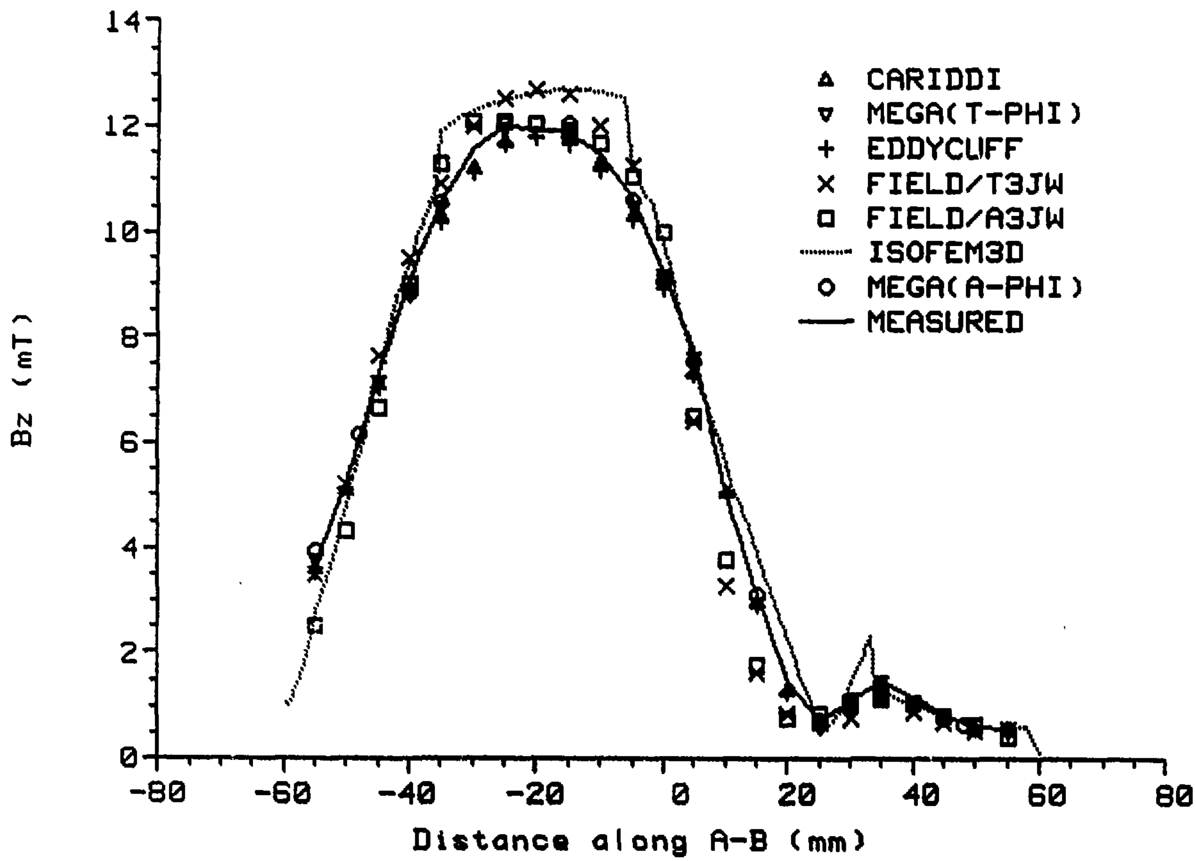

Figure 9. Problem 3, the Bath plate. Field variation along lines A-B of Fig. 3 for coil position 2 and 50 Hz.

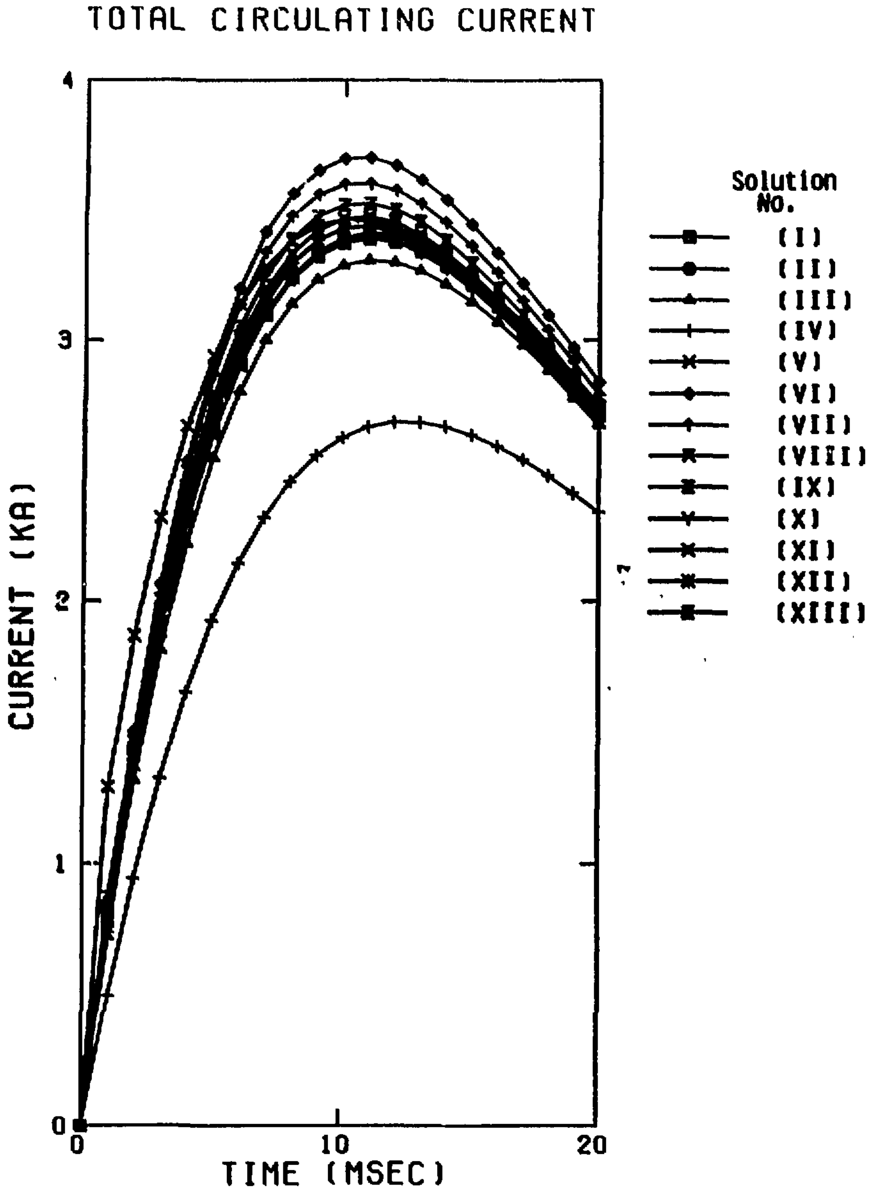

Figure 10. Time variation of the total circulating current in the FELIX brick, Problem 4.

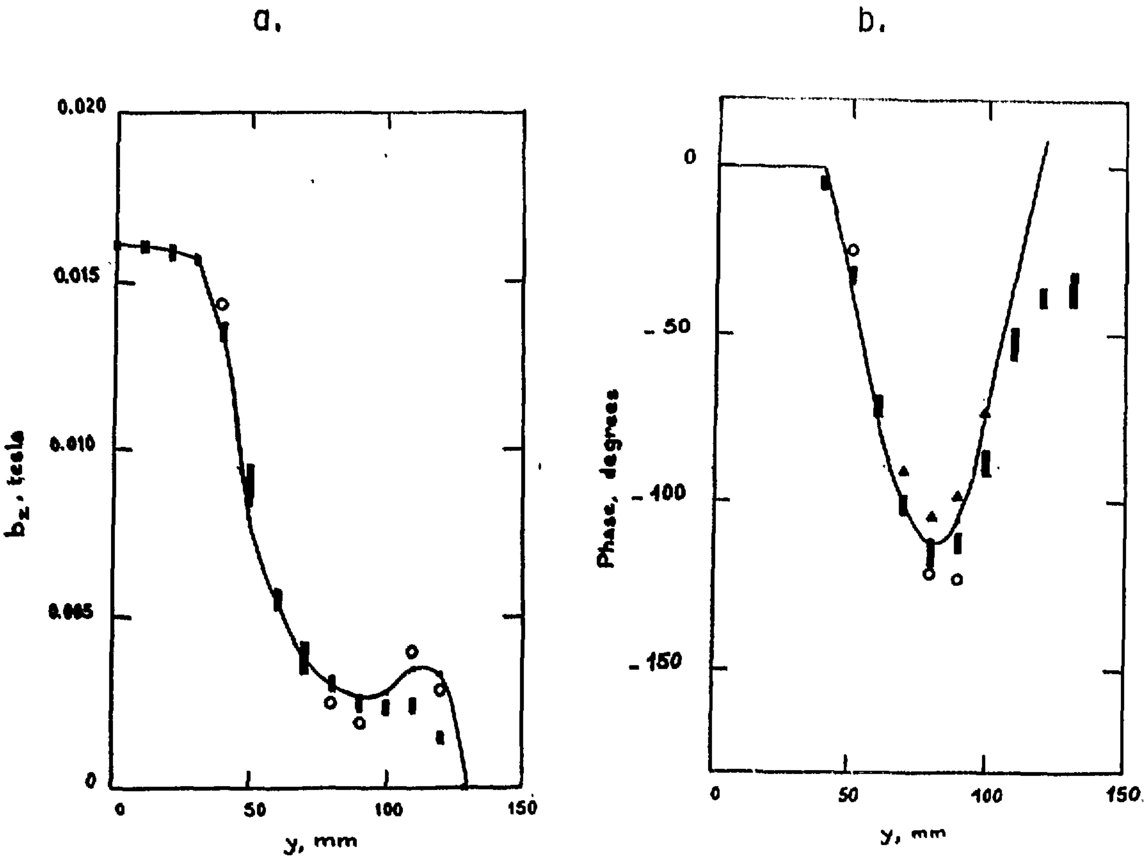

Figure 11.Variation of flux density under the Bath cube (Problem 5).
a. magnitude, b. phase.

shell and multiple-shell models. Each gave good results within its region of applicability, as shown in Fig. 12.

4.7 General Results

One goal of the workshops, to "provide cooperation between workers, leading to an interchange of ideas", was certainly achieved. The workshops identified key codes and code-developers in Japan, Europe, and America.

The workshop problems appeared to be useful to 3-D code developers. At COMPUMAG-Graz, about twenty papers used the workshop problems to demonstrate the use of the methods of the papers. The same was observed in at least three earlier meetings: Symposium on Field Calculations in Electrical Engineering (Graz, September 1986), IUTAM Symposium on Coupled Problems (Tokyo, October 1986), and IEEE Workshop on Electromagnetic Field Computation (Schenectady, October 1986) and at the International Symposium for Fusion Nuclear Technology (Tokyo, April 1988).

Comparison of workshop solutions also uncovered errors in the post-processors of some widely-used eddy current codes.

5. TEAM WORKSHOPS 1988-1989

Another series of TEAM (Testing Electromagnetic Analysis Methods) Workshops is underway. The schedule for the workshops is shown in Table 2.

Participants will compare their computed results for one or more of the problems. The problems include transient and steady-state ac magnetic fields, close and far boundary conditions, magnetic and non-magnetic materials. All the problems are based either on experiments or on geometries that can be solved analytically. The problems are described here, and in more detail in Ref. (12).

(5) Bath cube. Four identifical aluminum cubes enclosed within a laminated iron box under a laminated iron pole. A sinusoidal magnetomotive force (MMF) is applied between the pole and box. This was the only problem of the original six that was not adequately solved. See Ref. (5). The problem has been expanded as well.

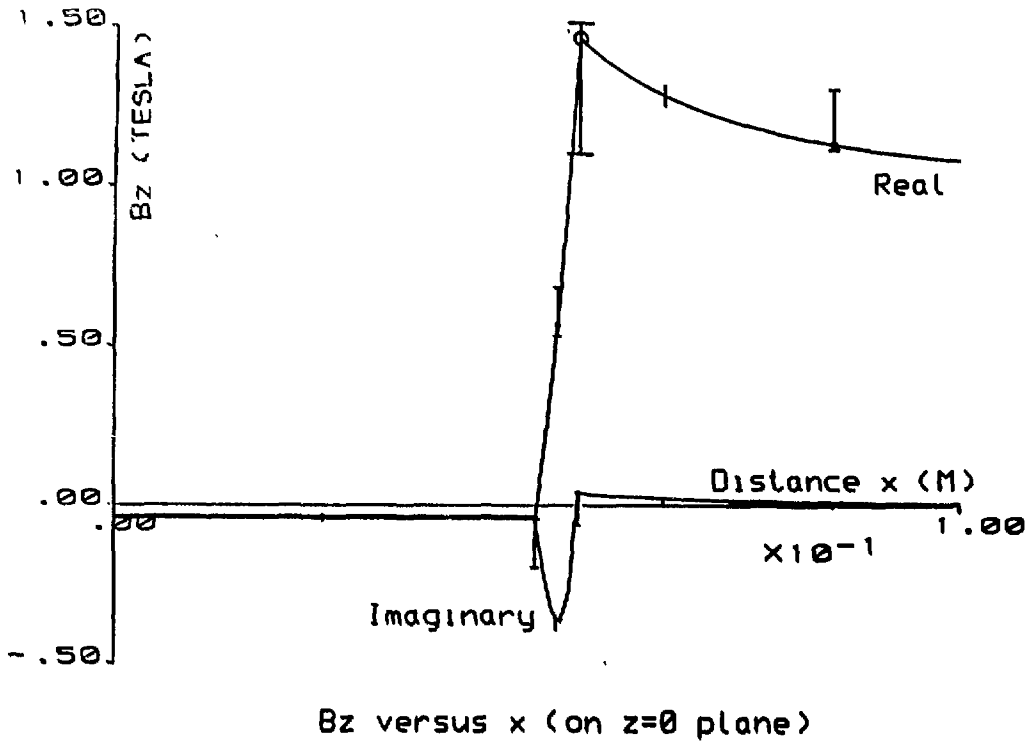

Figure 12. Problem 6, the hollow sphere variation of flux density in the x direction.

Table 2. TEAM Workshop Schedule, 1988-1989

Dates	Location	For More Information, Contact
18-19 July 1988 (after INTERMAG/MMM)	University of British Columbia, Vancouver, BC, Canada	Dr. Larry Turner Argonne National Laboratory Building 205 9700 South Cass Avenue Argonne, IL 60439 USA
5-6 October 1988	Capri, Italy	DELTACONGRESSI Via Posillipo 80123 Naples, Italy
20-21 March 1989	Paris, France	Dr. J.-C. Verite Electricite de France Direction des Etudes et Recherches 1 Av. du General de Gaulle F-92141 Clamart FRANCE
10-11 April 1989	Akron, Ohio, USA	Prof. Nathan Ida Electrical Engineering Department The University of Akron Akron, OH 44325 USA
11-12 September 1989 (after COMPUMAG-Tokyo)	Okayama, Japan	Prof. Takayoshi Nakata Electrical Engineering Department Okayama University Tsushima, Okayama 700 JAPAN

(7) Plate and hole. This is effectively a new version of the Bath plate, but with a much thicker conductor. A 3-D multiply-connected geometry. See Fig. 13.

(8) Coil above crack. A crack of defined dimensions in metal conductor. A probe consists of one inducing solenoid and two receptive solenoids. The differential impedance of the receptive solenoids is to be found as a function of position. A problem in non-destructive testing (NDT). The geometry is shown in Fig. 14.

(9) Coil moving in a cylinder. A coil with ac excitation moves in a metal tube. The eddy currents in the tube and the impedance of the coil are to be found. Different velocities for the coil present different degrees of difficulty for the problem.

(10) Plate over a coil. A steel plate (nonlinear permeability) located above a coil. A nonlinear problem. Preliminary computations showed that this problem requires substantial computer time; it is being revised.

(11) Sphere in a step field. A hollow, conducting sphere in a spatially uniform step field. The field, current, and power are to be found as functions of time. A transient problem. The sphere geometry is identical to that of Problem 6, as shown in Fig. 6.

(12) Cantilevered beam in crossed field. A coupled problem with moving conductor. The motion of the beam causes the current and deflection to be very different from what they would be if coupling were not present. Based on a FELIX experiment. See Fig. 15.

The problems have been prepared by:

David Rodger, Bath University, UK (Problem 5)
Alain Bossavit, Electricite de France, France (Problem 5)
Takayoshi Nakata, Okayama University, Japan (Problems 7, 10)
Jean-Claude Verite, Electricite de France, France (Problem 8)
Nathan Ida, University of Akron, USA (Problem 9)

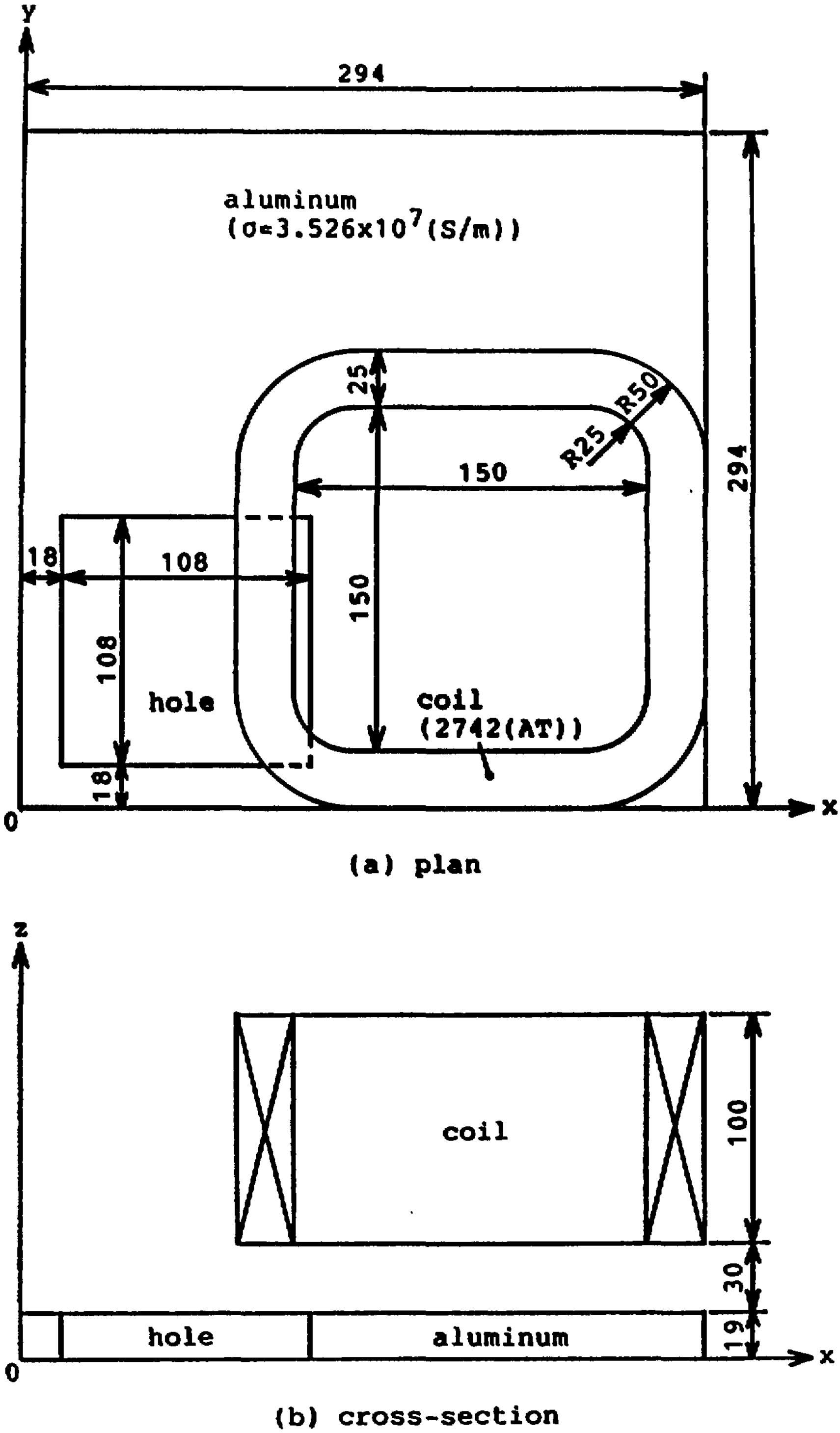

Figure 13. Problem 7. Asymmetrical conductor with a hole.

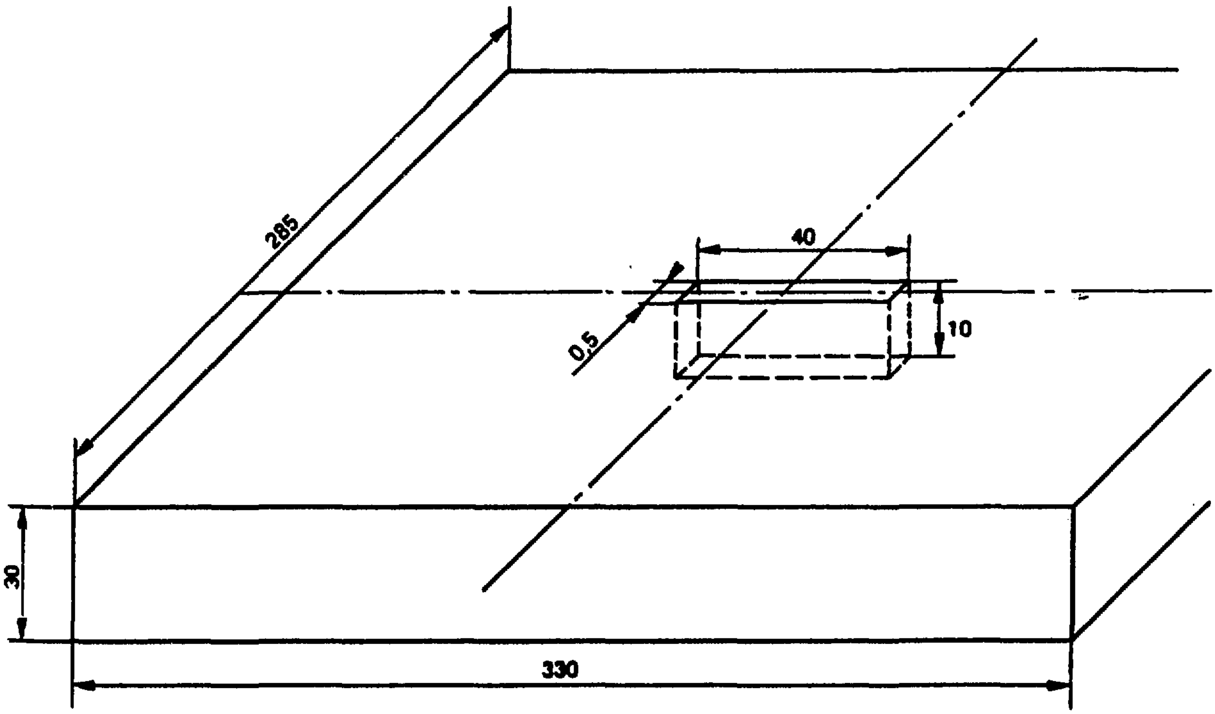

Figure 14. Problem 8. The block with simulated crack.

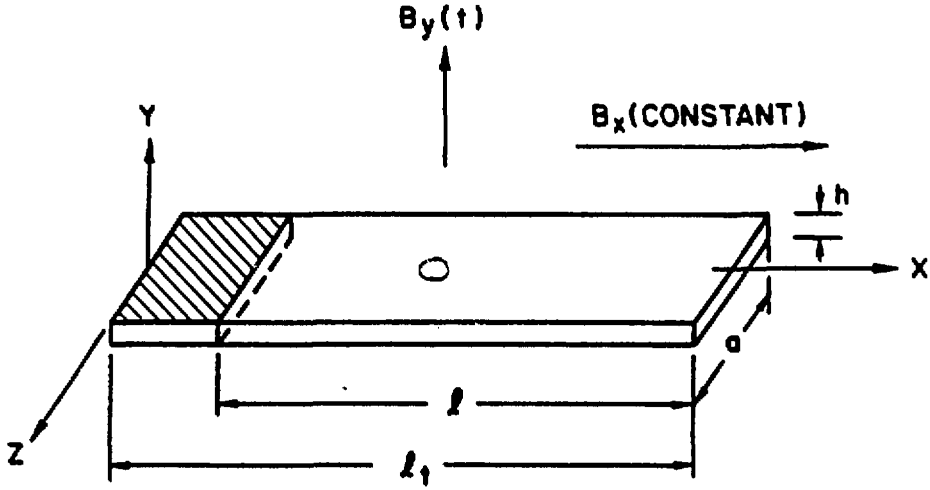

Figure 15. Schematic diagram for the cantilever beam (Problem 12).

Chris Emson, Rutherford Appleton Laboratory, UK (Problem 11)
Thanh Hua, Argonne National Laboratory, USA (Problem 12)

6. IN CONCLUSION

These workshops and benchmark problems were of use to the developers and users of eddy current codes. With the publications of the problems and solutions(1-7), it is hoped that they will be useful to even more code developers and users.

7. ACKNOWLEDGEMENTS

Many persons deserve credit for the planning and realization of the workshops and problems. The eleven participants in the planning meeting at Argonne National Laboratory, in November 1985, defined the goals, format, schedule and problems. The chairmen of the regional workshops shown in Table 1 planned the workshops and published proceedings. Finally, the members of the electromagnetics community enthusiastically supported the workshops, and the participants patiently endured the disorganization of the early workshops and the ambiguities of the original statements of the problems.

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APPENDIX A

INFINITE CYLINDER IN A UNIFORM SINUSOIDAL FIELD
(Comparison of Results, Problem 2)

Nathan Ida

Electrical Engineering Department
University of Akron

INFINITE CYLINDER IN A UNIFORM SINUSOIDAL FIELD
(Comparison of Results, Problem 2)

Nathan Ida
Electrical Engineering Department
The University of Akron
Akron, Ohio 44325

INTRODUCTION

The results reported here are a compilation of data presented at the Electromagnetic Workshop at Rutherford Appleton Laboratory in March 1986, at the Workshop at Argonne National Laboratory in June 1986 and at the International Workshop at Graz, Austria in August 1987. A total of ten solutions to problem No. 2 are presented and compared directly in tables. In some cases, variations on the specified problem were also available. These are marked in the tables and the conditions under which the calculations were performed are explained.

Some of the results presented were not available in a form which allowed direct comparison. For example, the field values from PROFI were presented as r and rather than x and y components. These results were included but any comparison should be made in the right context. In addition, not all field and phase angle data were available at all required points.

In some cases, results for the problem were reported for more than one type of element, for different number of elements or for different boundaries. These are also marked in the tables.

PROBLEM DESCRIPTION

The problem solved here consists of an infinitely long cylinder with inner radius of 0.05715m and outer radius of 0.06985m. The cylinder is made of aluminum alloy 6061 with resistivity $=3.94\times10^{-08}$. The cylinder and its dimensions are shown in Fig. 1. A uniform field of 0.1 Tesla at 60 Hz is applied perpendicular to the cylinder axis. In order to facilitate comparison, a mesh was recommended as shown in Fig. 2. The mesh has nodes at 0.01 m spacing in the region $0 \le x \le 0.03$, $0 \le y \le 0.03$ m. In the regions surrounding this square, the nodes on the inner radius of 0.05715 m are separated 15 degrees apart. The nodes on the other three boundaries are spaced equidistant apart. Straight lines are drawn connecting the nodes on $y=0.03$ (or $x=0.03$) to the nodes on $r=0.05715$. These lines have nodes equidistantly spaced. In the cylindrical region, nodes are placed at $r=$ 0.05715, 0.05969, 0.06223, 0.06447, 0.06731, 0.06985 and 0.080 m at $=0$, 15, 30, 45, 60, 75 and 90 degrees. The total number of nodes is 128 and the number of (quadrilateral) elements is 105. The user was free to use other meshes in addition to this recommended mesh. A complete description of the problem can be found elsewhere [1,2]. Other general information relevant to this work can be found in [3,4]

BOUNDARY CONDITIONS

Boundary conditions were specified to create a Y-directed field of 0.1T. The actual method of specification of boundary conditions was left open because different codes handle boundary conditions differently.

METHODS AND FORMULATIONS

Contributions to this summary were produced by 10 authors or groups of authors using 9 computer codes. Because these solutions are axisymmetric solutions, the formulations and codes are quite similar. A short description of each follows. The letter in front of each name or code is later used for identification of results. When possible references are also given.

A) 'PE2D' C. R. I. Emson, Rutherford Appleton Laboratory. A finite element formulation of the time harmonic Poisson's equation in cylindrical coordinates (Axisymmetric/2-D) is used for the solution.

$$\nabla\cdot(\nu\nabla A) = -j\omega\sigma A \qquad (1)$$

Quadratic triangular elements and an ICCG algorithm were used for the results presented [5].

B) 'PE2D' R. J. Lari and L. Turner Argonne National Laboratory. Program PE2D was used with either linear or quadratic triangular elements [6,7] solving Eq. (1).

C) 'PROFI' U. Hamm, Technische Hochschule, Darmstadt. Eq. (1) is solved in cylindrical coordinates using a finite difference formulation [8].

D) 'No Name' T Morisue, University of Tokushima. A finite element formulation of Eq. (1) with triangular (linear) elements is used [9].

E) 'EDDYNDT' N. Ida, The University of Akron. Eq. (1) is solved using linear quadrilateral elements and an ICCG solution algorithm [10].

F) 'Analytic' A. Ivanyi, I Bardi and O. Biro, Technical University of Budapest. The solution to the problem is found by solving the z-directed magnetic vector potential. This satisfies Laplace's equation in the air regions and Helmholtz' equation in the conductor. In cylindrical coordinates the solutions can be written by separation of variables. The azymuthal variation is harmonic and the radial is described in terms of power functions for Laplace's equation and of Bessel functions of the first kind for Helmholtz' equation. This solution was used for comparison of the various solutions [11].

G) 'ANSYS' D. F. Ostergaard, Swanson Analysis Systems, Inc. ANSYS uses a finite element formulation of Eq. (1) in cylindrical coordinates [12,13], with four node isoparametric elements and a frontal solver.

H) 'No Name' E. M. Deeley, King's College. A surface impedance formulation with the magnetic scalar potential as the variable is used, with linear triangular elements and an ICCG solver [14,15].

I) 'FIELD/A2JW' T. Nakata, N. Takahashi, K. Fujiwara and K. Okazaki, Okayama University. Eq. (1) is solved with first order triangular elements and a

Gauss Elimination algorithm [16].

J) 'WEMAP' V. K. Garg and M. Ashkin and D. Simmen, Westinghouse Electric Corporation. An axisymmetric formulation of Eq. (1) with linear triangular elements is used [17].

RESULTS AND DISCUSSION

The results are summarized in five tables:

Table 2.1.1 summarizes the field amplitudes and phase angles on four selected mesh points along a radius at 0.0 Degrees.

Table 2.1.2 presents the field amplitudes and phase angles along two mesh lines - along a radius at 0.0 Degrees and at 45 Degrees.

Table 2.2 summarizes the field amplitudes and phase angles inside elements, along a radius at various angles (7.5, 14.0, 20.0 Deg.). All of these points are inside the outer radius of the cylinder (R<0.07m)

Table 2.3 summarizes the field amplitudes and phase angles at the same angles as in Table 2.2 but for points external to the cylinder (R>0.07m)

Table 2.4 summarizes global quantities.

The results presented in tables are also summarized in Figures 3 through 7. In all cases, the lowest and highest result reported are presented together with the analytical solution for the X and Y components of the flux density. In most cases, the results are quite similar but, at times, the variations are relatively large, especially within and close to the cylinder. At these points the variations can be upward of 30% while inside and outside the cylinder they are normally below 10%.

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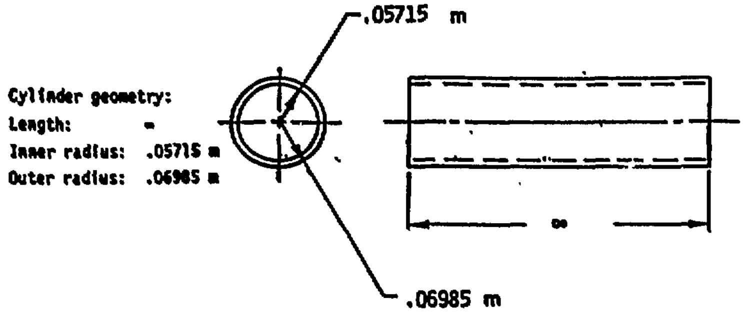

Figure 1. Cylinder geometry and dimensions

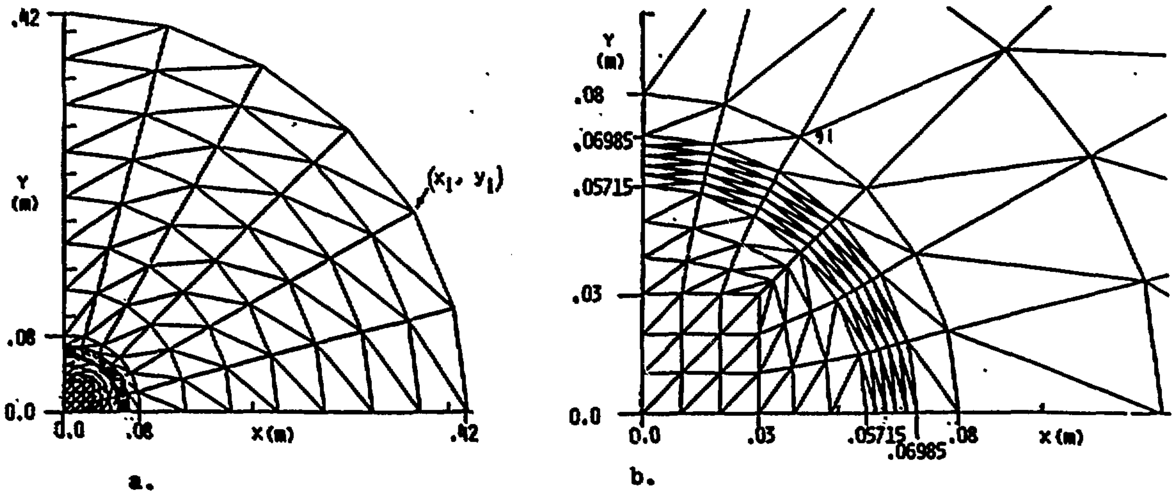

Figure 2. Specified Mesh.
a. Whole mesh
b. Detail at center of mesh

Table 2.1.1 Field Points at Mesh Points

R [m]	Φ [Deg]	B_x [T]	θ_x [Deg]	B_y [T]	θ_y [Deg]	PROG.
0.0	0.0	.0	-155.5	.0220	-85.5	B2
		.0	180.0	.0206	-85.4	B3
		----	------	-----	-----	C
		0.0	0.0	.0212	-95.0	D
		----	------	-----	-----	E
		0.0	0.0	.0211	-95.0	F
		.0	.0	.0223	-94.4	G
		.0	.0	.0218	-94.6	G1
		.0	.0	.0214	-94.9	G2
		.0000	------	.0200	-82.8	H
		0.0	-178.3	.0230	86.3	I
		0.0	179.6	.0221	85.7	I1
		0.0	0.0	.0218	85.6	J
.01	0.0	0.0	-30.7	.0233	-86.4	A
		0.00	-169.8	.0229	-86.3	B
		.0	93.8	.0197	-85.6	B1
		.0	-169.5	.0220	-85.6	B2
		.0	88.1	.0206	-85.4	B3
		.0001	-95.0	.0220	-94.9	C
		0.0	------	.0212	-95.0	D
		.0	------	.0275	-91.0	E
		.0	0.0	.0211	-95.0	F
		.0	------	.0199	-82.8	H
		0.0	-178.4	.0230	86.4	I
		0.0	179.3	.0221	85.7	I1
		0.0	36.8	.0218	85.6	J
.02	0.0	0.0	-11.9	.0233	-86.3	A
		0.0001	-175.5	.0229	-86.4	B
		.0	-41.5	.0197	-85.6	B1
		.0	-172.6	.0220	-85.6	B2
		.0	91.4	.0206	-85.4	B3
		.0002	-94.0	.0220	-94.8	C
		0.0	------	.0212	-95.0	D
		.0008	------	.0276	-91.0	E
		.0	0.0	.0211	-95.0	F
		.0	------	.0198	-82.7	H
		.0001	-178.2	.0230	86.6	I
		.0	179.0	.0221	85.7	I1
		0.0	22.4	.0218	85.6	J
.03	0.0	.0002	-4.7	.0233	-86.0	A
		.0002	-179.4	.0230	-86.8	B
		.0	174.0	.0197	-85.6	B1
		.0	-175.6	.0220	-85.7	B2
		.0	81.6	.0206	-85.4	B3
		.0002	-93.9	.0220	-94.8	C
		0.0	------	.0212	-95.0	D
		.0008	------	.0276	-91.0	E
		.0	0.0	.0211	-95.0	F

Table 2.1.1 Field Points at Mesh Points (Continued)

R [m]	ϕ [Deg]	B_x [T]	θ_x [Deg]	B_y [T]	θ_y [Deg]	PROG.
		.0	------	.0196	-82.6	H
		.0002	-177.6	.0230	86.9	I
		0.0	179.4	.0220	85.8	I1
		0.0	61.9	.0218	85.6	J

A - PE2D, Chris Emson, Rutherford Laboratory.
B - PE2D, Robert Lari, Argonne National Laboratory.
B1 - PE2D, Robert Lari, Same as B but with Quadratic Triangular Elements
B2 - PE2D, Robert Lari, 4 times the number of elements in B.
B3 - PE2D, Robert Lari, 4 times the number of elements in B1.
C - PROFI, Technische Hochschule, Darmstadt.
D - No Name, Toshiya Morisue, Tokushima University.
E - EDDYNDT, Nathan Ida, The University of Akron.
F - Analytical Solution, Oskar Biro, Technical University, Budapest.
G - ANSYS, Dale Ostergaard, Swanson Analysis Systems, Inc.
G1 - ANSYS, Dale Ostergaard, 4 times the number of elements in G
G2 - ANSYS, Dale Ostergaard, 4 times the number of elements in G with modified boundary (outer boundary at 0.84m).
H - No name, E. M. Deeley, King's College, London
I - FIELD/A2JW, T. Nakata, Okayama University
I1 - Same as I but with four times the number of elements
J - WEMAP, V. K. Garg, Westinghouse Electric Corporation

Table 2.1.2 Field Points on Mesh Lines

R [m]	ϕ [Deg]	B_x [T]	θ_x [Deg]	B_y [T]	θ_y [Deg]	PROG.
.04	0.0	.0006	-3.4	.0234	-85.0	A
		0.0006	178.1	.0229	-87.7	B
		.0	-178.9	.0197	-85.6	B1
		.0001	179.5	.0220	-85.9	B2
		.0	-109.7	.0206	-85.4	B3
		.0002	-93.8	.0220	-94.8	C
		0.0	------	.0212	-95.0	D
		.0008	-46.4	.0276	-91.0	E
		.0	0.0	.0211	-95.0	F
		.0	------	.0196	-82.5	H
		0.0005	-176.6	.0229	87.7	I
		0.0001	-179.3	.0220	86.0	I1
		0.0	15.0	.0218	85.6	J
.05	0.0	.0017	-1.1	.0235	-89.9	A
		0.0010	175.6	.0230	-93.5	B
		.0	-178.6	.0197	-86.8	B1
		.0004	178.4	.0219	-86.8	B2
		.0	-176.7	.0206	-85.3	B3
		.0002	-93.9	.0220	-94.8	C
		0.0	------	.0210	-95.0	D
		.0008	-46.6	.0275	-90.8	E
		.0	0.0	.0211	-95.0	F
		.0	------	.0197	-82.4	H
		.0010	-174.8	.0212	93.7	I
		.0004	-178.1	.0219	86.8	I1
		0.0	-0.1	.0218	85.9	J
.05842	0.0	.0052	-0.1	.0363	-136.9	A
		.0013	3.0	.0293	-123.9	B
		.0013	167.3	.0287	-129.6	B1
		.0003	28.8	.0282	-125.7	B2
		.0001	170.0	.0278	-127.8	B3
		.0002	-92.9	.0290	-56.6	C
		.0	.0	.0222	-35.8	D
		.0009	-22.8	.0295	-33.8	E
		.0	.0	.0280	-53.8	F
		.0030	177.2	.0320	-46.9	G
		.0012	175.9	.0288	-53.4	G1
		.0012	175.6	.0282	-53.6	G2
		.0001	------	.0260	-125.1	H
		.0009	-13.4	.0232	148.9	I
		0.0002	-38.5	.0192	141.9	I1
		.0023	2.7	.0309	-48.4	J
0.06858	0.0	.0205	-11.4	.1736	176.4	A
		.0211	-10.2	.1648	177.8	B
		.0037	-22.7	.1549	176.9	B1
		.0110	-9.6	.1710	177.6	B2
		.0007	-23.6	.1630	177.5	B3

Table 2.1.2 Field Points on Mesh Lines (Continued)

R [m]	ϕ [Deg]	B_x [T]	θ_x [Deg]	B_y [T]	θ_y [Deg]	PROG.
		.0002	-57.8	.1710	2.3	C
		.0	.0	.1630	-4.0	D
		.0010	-10.4	.1740	-3.3	E
		.0	.0	.1667	2.1	F
		.0196	-169.7	.1619	2.1	G
		.0106	-169.6	.1711	2.7	G1
		.0104	-169.9	.1679	2.4	G2
		.0	------	.1568	178.8	H
		.0205	9.7	.1536	-173.2	I
		.0109	9.4	.1603	-171.4	I1
		.0038	20.2	.1728	3.1	J
0.075	0.0	.0184	-13.6	.1708	174.5	A
		0.0205	-13.4	.1690	174.9	B
		.0028	-27.3	.1600	174.1	B1
		.0110	-14.0	.1801	173.8	B2
		.0001	-167.7	.1697	174.0	B3
		.0003	-31.9	.1780	5.9	C
		.0	------	.1737	6.4	D
		.0038	13.7	.1795	2.8	E
		.0	0.0	.1745	5.7	F
		.0	------	.1682	175.0	H
		.0213	13.2	.1706	-175.5	I
		.0108	14.0	.1804	-173.9	I1
		.0028	27.3	.1772	6.0	J
0.10	0.0	.0119	-14.4	.1464	175.4	A
		0.0139	-14.4	.1478	175.3	B
		.0001	-107.8	.1344	179.9	B1
		.0062	-13.7	.1464	175.6	B2
		.0003	166.6	.1384	175.7	B3
		.0006	-9.3	.1390	4.3	C
		0.0	.0	.1418	3.9	D
		0.0043	13.7	.1440	2.1	E
		0.0	.0	.1418	3.9	F
		.0	------	.1462	176.1	H
		.0154	14.4	.1587	179.2	I
		.0056	13.8	.1536	176.6	I1
		.0003	29.5	.1496	4.6	J
0.15	0.0	.0052	-14.5	.1232	177.2	a
		.0062	-14.3	.1238	177.2	B
		.0009	166.4	.1095	177.6	B1
		.0027	-13.7	.1218	177.5	B2
		.0002	166.9	.1153	177.6	B3
		.0008	-2.5	.1210	2.4	C
		0.0	------	.1185	2.0	D
		.0024	13.6	.1231	2.3	E
		.0	0.0	.1185	2.1	F
		.0	------	.1189	178.0	H
		.0068	14.3	.1268	180.0	I

Table 2.1.2 Field Points on Mesh Lines (Continued)

R [m]	ϕ[Deg]	B_x [T]	θ_x [Deg]	B_y [T]	θ_y [Deg]	PROG.
		.0024	13.8	.1239	179.0	I1
		.0004	13.5	.1218	2.5	J
0.20	0.0	.0028	-14.5	.1136	178.2	A
		.0033	-14.3	.1138	178.2	B
		.0003	166.4	.1017	178.4	B1
		.0015	-13.7	.1132	178.4	B2
		.0001	167.1	.1074	178.4	B3
		.0009	-1.2	.1120	1.5	C
		.0	.0	.1104	1.3	D
		.0013	13.7	.1131	1.8	E
		.0	.0	.1104	1.3	F
		.0	------	.1049	179.4	H
		.0035	14.3	.1150	-179.5	I
		.0013	13.8	.1140	-180.0	I1
		.0	13.0	.1129	1.6	J
.25	0.0	.0017	-14.5	.1096	178.7	A
		.0021	-14.3	.1096	178.7	B
		.0002	168.6	.0982	178.9	B1
		.0009	-13.7	.1093	178.8	B2
		.0	167.4	.1038	178.9	B3
		.0	------	.1066	.8	D
		.0009	13.6	.1094	1.4	E
		.0	0.0	.1066	0.8	F
		.0	------	.1049	179.4	H
		.0021	14.3	.1102	-179.5	I
		.0009	13.8	.1096	-179.5	I1
		0.0	12.1	.1092	1.2	J
.30	0.0	.0010	-14.5	.1076	178.9	A
		.0014	-14.3	.1073	179.0	B
		.0008	178.0	.0971	179.1	B1
		.0007	-13.7	.1072	179.1	B2
		.0	168.6	.1018	179.1	B3
		.0009	-0.4	.1060	0.8	C
		.0	------	.1046	.6	D
		.0008	13.6	.1048	1.1	E
		.0	0.0	.1046	0.6	F
		.0	------	.1027	179.7	H
		.0014	14.3	.1077	-179.5	I
		.0006	13.8	.1072	-179.1	I1
		0.0	-1.0	.1072	0.9	J
.35	0.0	.0005	-14.5	.1066	179.1	A
		.0010	-14.3	.1060	179.2	B
		.0010	179.4	.1073	179.3	B1
		.0005	-13.7	.1059	179.2	B2
		.0004	178.8	.1010	179.3	B3
		.0009	-0.2	.1050	0.7	C
		.0	------	.1034	.4	D

Table 2.1.2 Field Points on Mesh Lines (Continued)

R [m]	ϕ [Deg]	B_x [T]	θ_x [Deg]	B_y [T]	θ_y [Deg]	PROG.
		.0009	13.6	.1028	0.9	E
		.0	0.0	.1034	0.4	F
		.0	------	.1013	179.8	H
		.0010	14.3	.1063	-179.5	I
		.0005	13.8	.1060	-179.2	I1
		0.0	8.5	.1063	0.8	J
.40	0.0	.0001	-14.5	.1062	179.1	A
		-----	-14.3	-----	179.3	B
		-----	179.4	-----	179.4	B1
		.0003	-13.7	.0957	179.3	B2
		-----	179.4	.1108	179.4	B3
		.0009	-0.1	.1030	0.6	C
		.0	------	.1026	.3	D
		.0007	13.6	.1007	0.2	E
		.0	------	.1006	179.9	H
		.0	0.0	.1026	0.3	F
		.0008	14.2	.1054	-179.4	I
		.0003	14.0	.1052	-179.3	I1
		0.0	13.3	.1060	0.8	J
.05	45.0	.0006	-20.7	.0233	-89.1	A
		.0007	-174.1	.0231	84.1	B
		.0002	-0.7	.0197	-85.9	B1
		.0002	-174.3	.0220	-84.8	B2
		.0	45.4	.0206	-85.4	B3
		.0152	-94.8	.0155	-94.8	C
		.0001	-95.0	.0212	-95.0	D
		.0088	-95.1	.0218	-95.1	E
		.0	0.0	.0211	-95.0	F
		.0004	63.9	.0203	-82.9	H
		.0003	178.1	.0230	86.1	I
		.0001	177.4	.0220	85.6	I1
		.0001	2.1	.0218	85.8	J
.05842	45.0	.0111	-0.3	.0261	-115.3	A
		.0134	2.7	.0270	-118.4	B
		.0098	3.4	.0217	-111.4	B1
		.0102	4.5	.0245	-111.2	B2
		.0094	4.5	.0226	-109.9	B3
		.0150	-94.2	.0210	-56.6	C
		.0106	-158.6	.0187	-64.2	D
		.0101	-11.5	.0195	-64.2	E
		.0091	175.2	.0230	-71.2	F
		.0113	177.2	.0252	-65.0	G
		.0094	175.8	.0238	-70.8	G1
		.0092	175.6	.0233	-71.0	G2

Table 2.1.2 Field Points on Mesh Lines (Continued)

R [m]	ϕ [Deg]	B_x [T]	θ_x [Deg]	B_y [T]	θ_y [Deg]	PROG.
		.0089	6.5	.0217	-106.6	H
		.0119	-2.4	.0196	127.5	I
		.0009	-4.0	.0241	110.0	I1
		.0109	-3.6	.0243	-67.4	J
.06858	45.0	.0782	-11.0	.0905	-175.1	A
		.0772	-11.4	.0953	-176.4	B
		.0736	-10.7	.0830	-176.3	B1
		.0814	-11.0	.0943	-176.7	B2
		.0769	-10.2	.0874	-175.8	B3
		.0170	-59.3	.1230	2.3	C
		.0752	-175.7	.0890	9.4	D
		.0740	-10.4	.0920	-15.4	E
		.0783	-170.2	.0896	-4.6	F
		.0733	-169.7	.0899	-4.5	G
		.0805	-169.6	.0920	-4.1	G1
		.0790	-169.9	.0902	-4.3	G2
		.0736	-8.9	.0832	-174.5	H
		.0776	10.9	.0868	180.0	I
		.0807	10.6	.0926	176.1	I1
		.0822	10.6	.0922	-3.7	J
.075	45.0	.0732	-13.7	.0969	-178.9	A
		.0684	-13.6	.1026	-179.9	B
		.0696	-13.6	.0918	179.7	B1
		.0757	-13.7	.1046	179.4	B2
		.0737	-13.5	.0972	179.7	B3
		.0230	-33.0	.1280	5.9	C
		.0755	-166.3	.1004	.4	D
		.0741	13.7	.1014	4.6	E
		.0757	-166.8	.1000	0.0	F
		.0673	-12.4	.0971	-179.7	H
		.0748	13.4	.0970	179.6	I
		.0780	13.8	.1023	-179.7	I1
		.0768	13.6	.1020	0.3	J
.10	45.0	.0517	-14.6	.0969	-179.4	A
		.0444	-14.3	.1035	179.5	B
		.0438	-13.6	.0913	179.8	B1
		.0432	-13.7	.1039	179.5	B2
		.0422	-13.5	.0970	179.8	B3
		.0425	-166.8	.0999	0.0	D
		.0440	13.7	.1000	1.8	E
		.0426	-166.8	.1000	0.0	F
		.0415	-12.4	.0992	-179.9	H
		.0519	14.3	.0996	-179.6	I
		.0458	13.8	.1015	-179.2	I1
		.0486	13.6	.1011	0.1	J

Table 2.1.2 Field Points on Mesh Lines (Continued)

R [m]	ϕ [Deg]	B_x [T]	θ_x [Deg]	B_y [T]	θ_y [Deg]	PROG.
.15	45.0	.0236	-14.5	.0993	-179.9	A
		.0202	-14.3	.1043	179.4	B
		.0181	-13.6	.0915	179.8	B1
		.0190	-13.7	.1032	179.6	B2
		.0185	-13.5	.0972	179.7	B3
		.0580	-2.8	.0870	2.4	C
		.0189	-166.8	.0999	0.0	D
		.0186	13.7	.0999	0.4	E
		.0189	-166.8	.1000	0.0	F
		.0192	-12.5	.0969	-179.6	H
		.0258	14.3	.0958	179.4	I
		.0199	13.8	.1022	-179.8	I1
		.0201	13.6	.1013	0.2	J
.20	45.0	.0141	-14.5	.1000	-180.0	A
		.0109	-14.3	.1032	179.5	B
		.0101	-13.6	.0918	179.8	B1
		.0106	-13.7	.1028	179.6	B2
		.0104	-13.5	.0973	179.7	B3
		.0643	-1.3	.0800	1.5	C
		.0106	-166.8	.1000	0.0	D
		.0096	13.7	.1000	1.8	E
		.0106	-166.8	.1000	0.0	F
		.0103	-12.5	.0975	-179.7	H
		.0121	14.3	.1020	-179.6	I
		.0111	13.8	.1023	-179.7	I1
		.0111	13.6	.1020	0.3	J
.25	45.0	.0082	-14.5	.1005	179.9	A
		.0069	-14.3	.1029	179.6	B
		.0064	-13.6	.0918	179.8	B1
		.0068	-13.7	.1026	179.6	B2
		.0066	-13.5	.0973	179.7	B3
		.0669	-0.7	.0780	1.1	C
		.0068	-166.8	.1000	0.0	D
		.0066	13.7	.1000	0.2	E
		.0068	-166.8	.1000	0.0	F
		.0064	-12.5	.0977	-179.7	H
		.0090	14.3	.1007	-179.9	I
		.0088	13.8	.1014	-179.8	I1
		.0069	13.6	.1018	0.3	J
.30	45.0	.0052	-14.5	.1008	179.9	A
		.0048	-14.3	.1027	179.6	B
		.0046	-13.0	.0917	179.7	B1
		.0047	-13.7	.1025	179.6	B2
		.0046	-13.5	.0973	179.7	B3
		.0684	-0.4	.0763	0.8	C
		.0047	-166.8	.1000	0.0	D
		.0041	13.7	.1000	0.2	E
		.0047	-166.8	.1000	0.0	F

Table 2.1.2 Field Points on Mesh Lines (Continued)

R [m]	ϕ [Deg]	B_x [T]	θ_x [Deg]	B_y [T]	θ_y [Deg]	PROG.
		.0044	-12.4	.0977	-179.7	H
		.0051	14.3	.1023	-179.7	I
		.0049	13.7	.1024	-179.7	I1
		.0046	13.6	.1018	0.3	J
.35	45.0	.0036	-14.5	.1011	179.8	A
		.0035	-14.3	.1026	179.6	B
		.0070	-6.5	.0918	179.7	B1
		.0035	-13.7	.1025	179.7	B2
		.0034	-13.2	.0973	179.7	B3
		.0693	-0.2	.0754	0.7	C
		.0035	-166.8	.1000	0.0	D
		.0030	13.7	.1000	0.2	E
		.0035	-166.8	.1000	0.0	F
		.0032	-12.3	.0978	-179.7	H
		.0045	14.3	.1017	-179.8	I
		.0037	13.7	.1024	-179.7	I1
		.0032	13.6	.1016	0.2	J
.40	45.0	.0024	-14.5	.1012	179.8	A
		-----	------	-----	178.0	B
		-----	-180.0	-----	180.0	B1
		----	-13.7	-----	180.0	B2
		-----	------	-----	180.0	B3
		.0699	-0.1	.0750	0.6	C
		.0026	-166.8	.1000	0.0	D
		.0025	13.7	.1000	0.2	E
		.0027	-166.8	.1000	0.0	F
		.0027	-12.1	.0977	-179.7	H
		.0027	14.2	.1023	-179.7	I
		.0028	13.6	.1024	-179.7	I1
		.0022	13.7	.1014	0.2	J

A - PE2D, Chris Emson, Rutherford Laboratory.
B - PE2D, Robert Lari, Argonne National Laboratory.
B1 - PE2D, Robert Lari, Same as B but with Quadratic Triangular Elements
B2 - PE2D, Robert Lari, 4 times the number of elements in B.
B3 - PE2D, Robert Lari, 4 times the number of elements in B1.
C - PROFI, Technische Hochschule, Darmstadt.
D - No Name, Toshiya Morisue, Tokushima University.
E - EDDYNDT, Nathan Ida, The University of Akron.
F - Analytical Solution, Oskar Biro, Technical University, Budapest.
G - ANSYS, Dale Ostergaard, Swanson Analysis Systems, Inc.
G1 - ANSYS, Dale Ostergaard, 4 times the number of elements in G
G2 - ANSYS, Dale Ostergaard, 4 times the number of elements in G with modified boundary (outer boundary at 0.84m).
H - No name, E. M. Deeley, King's College, London
I - FIELD/A2JW, T. Nakata, Okayama University
I1 - Same as I but with four times the number of elements
J - WEMAP, V. K. Garg, Westinghouse Electric Corporation

Table 2.2 Field Points Inside of Elements, R<0.07m.

R [m]	ϕ [Deg]	B_x [T]	θ_x [Deg]	B_y [T]	θ_y [Deg]	PROG.
.01	7.5	.0	-35.4	.0233	-86.4	A
		.0001	-168.7	.0229	-86.3	B
		.000	61.5	.0197	-85.6	B1
		.0	-167.8	.0220	-85.6	B2
		.0	82.0	.0206	-85.4	B3
		.0030	-94.6	.0220	-94.9	C
		0.0	------	.0212	-95.0	D
		.0	0.0	.0211	-95.0	F
		.0	87.1	.0199	-82.8	H
		.0	-178.3	.0230	86.4	I
		.0	179.3	.0221	85.7	I1
.02	7.5	.0	-15.0	.0233	-86.4	A
		.0001	-173.9	.0229	-86.4	B
		.0000	-36.4	.0197	-85.6	B1
		.0	-171.5	.0220	-85.6	B2
		.0	146.0	.0206	-85.4	B3
		.0030	-94.7	.0200	-94.8	C
		.0	------	.0212	-95.0	D
		.0	0.0	.0211	-95.0	F
		.0	88.6	.0199	-82.7	H
		.0001	-178.5	.0230	86.5	I
		.0	179.1	.0221	85.7	I1
.03	7.5	.0002	-6.2	.0233	-86.1	A
		.0002	-177.6	.0230	-86.7	B
		.0000	-105.0	.0197	-85.6	B1
		.0	-174.9	.0220	-85.7	B2
		.0	-101.0	.0206	-85.4	B3
		.0030	-94.7	.0210	-94.8	C
		.0	------	.0212	-95.0	D
		.0	0.0	.0211	-95.0	F
		.0001	84.7	.0197	-82.7	H
		.0001	-177.9	.0230	86.8	I
		.0	179.2	.0220	85.8	I1
.04	7.5	.0005	-2.7	.0234	-85.6	A
		.0005	-179.8	.0230	-87.2	B
		.0000	-175.7	.0197	-85.6	B1
		.0001	-177.9	.0220	-85.8	B2
		.0	-35.1	.0206	-85.4	B3
		.0030	-94.7	.0210	-94.8	C
		.0	------	.0212	-95.0	D
		.0	0.0	.0211	-95.0	F
		.0	12.8	.0196	-82.5	H
		.0003	-177.1	.0230	86.8	I
		.0	-179.7	.0220	85.9	I1

Table 2.2 Field Points Inside of Elements, R<0.07m (Continued)

R [m]	ϕ [Deg]	B_x [T]	θ_x [Deg]	B_y [T]	θ_y [Deg]	PROG.
.05	7.5	.0018	0.0	.0234	-90.8	A
		.0004	168.1	.0231	-93.4	B
		.0000	-177.9	.0197	-86.7	B1
		.0002	179.9	.0220	-86.0	B2
		.0	-168.6	.0206	-85.4	B3
		.0030	-94.7	.0210	-94.8	C
		.0001	-95.4	.0212	-95.0	D
		.0	0.0	.0211	-95.0	F
		.0001	-81.1	.0196	-82.4	H
		.0008	-176.2	.0231	86.4	I
		.0002	-178.5	.0220	86.0	I1
.05842	7.5	.0080	.8	.0390	-140.9	A
		.0004	4.0	.0364	-139.4	B
		.0021	5.8	.0322	-138.9	B1
		.0019	6.7	.0289	-126.5	B2
		.0026	4.3	.0276	-127.2	B3
		.0030	-94.2	.0290	-56.5	C
		.0027	-158.6	.0220	-36.6	D
		.0024	175.2	.0280	-54.3	F
		.0022	4.4	.0254	-124.0	H
		.0010	-21.1	.0296	125.9	I
		.0050	-4.1	.0350	137.2	I1
.06858	7.5	.0305	-12.5	.1721	175.9	A
		.0313	-11.5	.1672	176.5	B
		.0208	-12.7	.1578	175.5	B1
		.0214	-10.6	.1691	177.3	B2
		.0200	-10.4	.1604	177.6	B3
		.0030	-59.2	.1760	2.3	C
		.0195	-175.7	.1606	-3.2	D
		.0203	-170.2	.1640	2.0	F
		.0185	-8.9	.1505	179.1	H
		.0216	11.5	.1693	-177.0	I
		.0328	12.4	.1760	-175.6	I1
.01	14.0	.0	-40.4	.0233	-86.4	A
		.0	-167.8	.0229	-86.3	B
		.0000	28.3	.0197	-85.6	B1
		.0	-166.7	.0220	-85.6	B2
		.0	-86.6	.0206	-85.4	B3
		.0050	-94.7	.0210	-94.9	C
		.0	------	.0212	-95.0	D
		.0	0.0	.0211	-95.0	F
		.0	87.1	.0199	-82.8	H
		.0	-178.3	.0230	86.4	I
		.0	179.3	.0221	85.7	I1

Table 2.2 Field Points Inside of Elements, R<0.07m (Continued)

R [m]	ϕ [Deg]	B_x [T]	θ_x [Deg]	B_y [T]	θ_y [Deg]	PROG.
.02	14.0	.0	-17.8	.0233	-86.4	A
		.0001	-172.6	.0229	-86.4	B
		.0	-35.4	.0197	-85.6	B1
		.0	-170.9	.0220	-85.6	B2
		.0	-128.6	.0206	-85.4	B3
		.0050	-94.7	.0210	-94.8	C
		.0	------	.0212	-95.0	D
		.0	0.0	.0211	-95.0	F
		.0001	88.6	.0198	-82.8	H
		.0001	-178.5	.0230	86.5	I
		.0	179.2	.0221	85.7	I1
.03	14.0	.0002	-7.7	.0233	-86.3	A
		.0002	-176.0	.0230	-86.6	B
		.0	-90.7	.0197	-85.6	B1
		.0	-174.0	.0220	-85.6	B2
		.0	-107.6	.0206	-85.4	B3
		.0050	-94.7	.0210	-94.8	C
		.0	------	.0212	-95.0	D
		.0	0.0	.0211	-95.0	F
		.0001	84.7	.0197	-82.7	H
		.0001	-177.9	.0230	86.8	I
		.0	178.9	.0220	85.8	I1
.04	14.0	.0005	-3.6	.0234	-86.0	A
		.0004	-177.9	.0230	-86.9	B
		.0	-169.2	.0197	-85.6	B1
		.0001	-176.2	.0220	-85.6	B2
		.0	-52.0	.0206	-85.4	B3
		.0050	-94.8	.0210	-94.8	C
		.0	------	.0212	-95.0	D
		.0	0.0	.0211	-95.0	F
		.0001	40.9	.0196	-82.6	H
		.0003	-177.1	.0230	86.8	I
		.0001	179.3	.0221	85.8	I1
.05	14.0	.0014	0.2	.0234	-90.4	A
		.0003	174.5	.0231	-91.6	B
		.0	-165.7	.0197	-86.6	B1
		.0002	-177.6	.0220	-85.7	B2
		.0	-168.6	.0206	-85.4	B3
		.0050	-94.8	.0210	-94.8	C
		.0	-95.0	.0215	-95.0	D
		.0	0.0	.0211	-95.0	F
		.0001	-64.6	.0196	-82.4	H
		.0008	-176.2	.0231	86.4	I
		.0002	180.0	.0221	85.7	I1

Table 2.2 Field Points Inside of Elements, R<0.07m (Continued)

R [m]	ϕ [Deg]	B_x [T]	θ_x [Deg]	B_y [T]	θ_y [Deg]	PROG.
.05842	14.0	.0075	1.2	.0344	-135.3	A
		.0053	3.2	.0336	-134.8	B
		.0050	3.2	.0277	-131.3	B1
		.0043	4.2	.0290	-126.8	B2
		.0047	4.3	.0276	-127.2	B3
		.0050	-94.2	.0290	-56.6	C
		.0050	-158.6	.0216	-38.4	D
		.0043	175.2	.0270	-55.5	F
		.0041	4.4	.0251	-123.3	H
		.0010	-21.1	.0296	125.9	I
		.0050	-4.1	.0350	137.2	I1
.06858	14.0	.0382	-11.5	.1628	177.1	A
		.0388	-11.2	.1594	177.4	B
		.0349	-11.3	.1478	176.9	B1
		.0381	-10.7	.1631	177.4	B2
		.0362	-10.4	.1548	177.7	B3
		.0060	-59.2	.1661	2.3	C
		.0356	-175.7	.1550	-3.5	D
		.0368	-170.2	.1575	1.7	F
		.0344	-8.9	.1463	179.2	H
		.0216	11.5	.1693	-177.0	I
		.0328	12.0	.1760	-175.6	I1
.01	20.0	.0	-44.9	.0233	-84.4	A
		.0	-167.0	.0229	-86.2	B
		.0	7.1	.0197	-85.6	B1
		.0	-165.7	.0220	-85.6	B2
		.0	-88.2	.0206	-85.4	B3
		.0075	-94.7	.0210	-94.9	C
		.0	------	.0212	-95.0	D
		.0010	------	.0212	-95.1	E
		.0	0.0	.0211	-95.0	F
		.0	87.1	.0199	-82.8	H
		.0001	-178.3	.0230	86.4	I
		.0	179.0	.0221	85.7	I1
.02	20.0	.0001	-20.7	.0233	-86.4	A
		.0001	-171.5	.0229	-86.3	B
		.0	-34.7	.0197	-85.6	B1
		.0	-169.7	.0220	-85.6	B2
		.0	-114.5	.0206	-85.4	B3
		.0075	-94.7	.0210	-94.8	C
		.0	------	.0212	-95.0	D
		.0009	------	.0212	-95.1	E
		.0	0.0	.0211	-95.0	F
		.0001	88.6	.0199	-82.8	H
		.0001	-178.5	.0230	86.5	I
		.0	179.0	.0221	85.7	I1

Table 2.2 Field Points Inside of Elements, R<0.07m (Continued)

R [m]	ϕ [Deg]	B_x [T]	θ_x [Deg]	B_y [T]	θ_y [Deg]	PROG.
.03	20.0	.0002	-9.7	.0233	-86.5	A
		.0002	-174.7	.0230	-86.4	B
		.0	-88.7	.0197	-85.6	B1
		.0	-173.1	.0220	-85.6	B2
		.0	-114.4	.0206	-85.4	B3
		.0075	-94.7	.0210	-94.8	C
		.0	------	.0212	-95.0	D
		.0010	------	.0212	-95.1	E
		.0	0.0	.0211	-95.0	F
		.0002	85.2	.0197	-82.7	H
		.0002	179.9	.0230	86.6	I
		.0001	178.4	.0221	85.7	I1
.04	20.0	.0004	-6.1	.0234	-86.3	A
		.0004	-176.2	.0230	-86.6	B
		.0	-165.5	.0197	-85.6	B1
		.0001	-174.9	.0220	-85.7	B2
		.0	-81.4	.0206	-85.4	B3
		.0075	-94.7	.0210	-94.8	C
		.0	------	.0212	-95.0	D
		.0016	------	.0212	-95.1	E
		.0	0.0	.0211	-95.0	F
		.0001	56.6	.0197	-82.6	H
		.0003	179.3	.0230	86.8	I
		.0001	178.1	.0221	85.8	I1
.05	20.0	.0016	-0.2	.0234	-89.9	A
		.0002	4.5	.0231	-90.6	B
		.0001	-0.1	.0197	-86.4	B1
		.0002	-175.2	.0220	-85.6	B2
		.0	-162.7	.0206	-85.4	B3
		.0075	-94.8	.0210	-94.8	C
		.0001	-95.0	.0209	-95.0	D
		.0022	-95.1	.0210	-95.1	E
		.0	0.0	.0211	-95.0	F
		.0001	-50.6	.0197	-82.5	H
		.0005	177.8	.0230	86.1	I
		.0001	177.5	.0221	85.7	I1
.05842	20.0	.0039	1.2	.0245	-104.3	A
		.0076	2.6	.0359	-138.1	B
		.0071	3.1	.0305	-136.2	B1
		.0064	3.9	.0288	-126.3	B2
		.0065	4.3	.0273	-126.5	B3
		.0075	-94.2	.0278	-56.6	C
		.0068	-158.6	.0210	-41.5	D
		.0026	-15.0	.0220	-36.6	E
		.0059	175.2	.0270	-57.3	F
		.0054	4.3	.0244	-120.9	H
		.0060	-2.8	.0281	121.7	I

Table 2.2 Field Points Inside of Elements, R<0.07m (Continued)

R [m]	ϕ [Deg]	B_x [T]	θ_x [Deg]	B_y [T]	θ_y [Deg]	PROG.
		.0087	-3.8	.0341	135.8	I1
		.0032	-5.4	.0247	-66.0	J
.06858	20.0	.0047	1.1	.0249	-106.9	A
		.0501	-11.4	.1531	177.1	B
		.0468	-11.5	.1433	176.2	B1
		.0520	-10.8	.1541	177.8	B2
		.0496	-10.5	.1464	178.0	B3
		.0085	-59.2	.1610	2.3	C
		.0485	-175.7	.1457	-4.0	D
		.0198	-11.5	.1606	-3.3	E
		.0504	-170.2	.1485	1.2	F
		.0451	-8.9	.1360	179.9	H
		.0543	11.2	.1448	-178.4	I
		.0536	12.1	.1675	-176.0	I1
		.0049	9.4	.1450	0.3	J
.01	45.0	.0	66.2	.0233	-86.4	A
		.0	-163.4	.0229	-86.2	B
		.0	-22.7	.0197	-85.6	B1
		.0	-162.6	.0220	-85.5	B2
		.0	-108.0	.0206	-85.4	B3
		.0152	-94.9	.0156	-94.7	C
		.0	------	.0212	-95.0	D
		.0018	------	.0223	-95.1	E
		.0	0.0	.0211	-95.0	F
		.0001	87.1	.0200	-82.8	H
		.0	-178.5	.0230	86.4	I
		.0	179.6	.0221	85.7	I1
		.0	21.6	.0218	85.6	J
.02	45.0	.0	-66.4	.0233	-86.6	A
		.0001	-163.9	.0229	-86.1	B
		.0	-34.7	.0197	-85.6	B1
		.0	-162.7	.0220	-85.5	B2
		.0	-125.1	.0206	-85.4	B3
		.0152	-94.8	.0155	-94.8	C
		.0	------	.0212	-95.0	D
		.0022	------	.0233	-95.1	E
		.0	0.0	.0211	-95.0	F
		.0002	87.1	.0200	-82.9	H
		.0001	-179.0	.0230	86.3	I
		.0	179.8	.0221	85.6	I1
		.0	53.2	.0218	85.6	J

Table 2.2 Field Points Inside of Elements, R<0.07m (Continued)

R [m]	ϕ [Deg]	B_x [T]	θ_x [Deg]	B_y [T]	θ_y [Deg]	PROG.
.03	45.0	.0001	-52.1	.0233	-87.0	A
		.0002	-166.5	.0231	-85.8	B
		.0	-18.5	.0197	-85.6	B1
		.0	-163.0	.0220	-85.5	B2
		.0	-144.3	.0206	-85.4	B3
		.0152	-94.8	.0152	-94.8	C
		.0	------	.0212	-95.0	D
		.0041	------	.0224	-95.1	E
		.0	0.0	.0211	-95.0	F
		.0003	85.5	.0200	-82.9	H
		.0003	179.3	.0230	86.3	I
		.0	179.1	.0220	85.6	I1
		.0	-70.1	.0218	85.6	J
.04	45.0	.0003	-26.7	.0232	-87.6	A
		.0004	-171.8	.0230	85.3	B
		.0	-7.0	.0197	-85.6	B1
		.0001	-168.4	.0220	-85.3	B2
		.0	-152.7	.0206	-85.4	B3
		.0152	-94.8	.0155	-94.8	C
		.0	------	.0212	-95.0	D
		.0062	------	.0224	-95.1	E
		.0	0.0	.0211	-95.0	F
		.0004	78.8	.0201	-82.8	H
		.0002	179.6	.0230	86.2	I
		.0001	178.0	.0221	85.6	I1
		.0003	83.6	.0218	85.6	J
.05	45.0	.0006	-20.7	.0233	-89.1	A
		.0007	-174.1	.0231	84.1	B
		.0002	-0.7	.0197	-85.9	B1
		.0002	-174.3	.0220	-84.8	B2
		.0	45.4	.0206	-85.4	B3
		.0152	-94.8	.0155	-94.8	C
		.0001	-95.0	.0212	-95.0	D
		.0088	-95.1	.0218	-95.1	E
		.0	0.0	.0211	-95.0	F
		.0004	63.9	.0203	-82.9	H
		.0003	-178.1	.0230	86.1	I
		.0001	177.4	.0220	85.6	I1
		.0001	2.1	.0218	85.8	J
.05842	45.0	.0111	-0.3	.0261	-115.3	A
		.0134	2.7	.0270	-118.4	B
		.0098	3.4	.0217	-111.4	B1
		.0102	4.5	.0245	-111.2	B2
		.0094	4.5	.0226	-109.9	B3
		.0150	-94.2	.0210	-56.6	C
		.0106	-158.6	.0187	-64.2	D
		.0101	-11.5	.0195	-64.2	E
		.0091	175.2	.0230	-71.2	F

Table 2.2 Field Points Inside of Elements, R<0.07m (Continued)

R [m]	ϕ [Deg]	B_x [T]	θ_x [Deg]	B_y [T]	θ_y [Deg]	PROG.
		.0113	177.2	.0252	-65.0	G
		.0094	175.8	.0238	-70.8	G1
		.0092	175.6	.0233	-71.0	G2
		.0089	6.5	.0217	-106.6	H
		.0119	-2.4	.0196	127.5	I
		.0095	-4.0	.0241	110.0	I1
		.0109	-3.6	.0243	-67.4	J
.06858	45.0	.0783	-11.0	.0905	-175.1	A
		.0772	-11.4	.0953	-176.4	B
		.0736	-10.7	.0830	-176.3	B1
		.0814	-11.0	.0943	-176.7	B2
		.0769	-10.2	.0874	-175.8	B3
		.0170	-59.3	.1230	2.3	C
		.0752	-175.7	.0890	9.4	D
		.0740	-10.4	.0920	-15.4	E
		.0783	-170.2	.0896	-4.6	F
		.0733	-169.7	.0899	-4.5	G
		.0805	-169.6	.0920	-4.1	G1
		.0790	-169.9	.0902	-4.3	G2
		.0736	-8.9	.0832	-174.5	H
		.0776	10.9	.0868	180.0	I
		.0807	10.6	.0926	176.1	I1
		.0822	10.6	.0922	-3.7	J

A - PE2D, Chris Emson, Rutherford Laboratory.
B - PE2D, Robert Lari, Argonne National Laboratory.
B1 - PE2D, Robert Lari, Same as B but with Quadratic Triangular Elements
B2 - PE2D, Robert Lari, 4 times the number of elements in B.
B3 - PE2D, Robert Lari, 4 times the number of elements in B1.
C - PROFI, Technische Hochschule, Darmstadt.
D - No Name, Toshiya Morisue, Tokushima University.
E - EDDYNDT, Nathan Ida, The University of Akron.
F - Analytical Solution, Oskar Biro, Technical University, Budapest.
G - ANSYS, Dale Ostergaard, Swanson Analysis Systems, Inc.
G1 - ANSYS, Dale Ostergaard, 4 times the number of elements in G.
G2 - ANSYS, Dale Ostergaard, 4 times the number of elements in G with modified boundary (outer boundary at 0.84m).
H - No name, E. M. Deeley, King's College, London.
I - FIELD/A2JW, T. Nakata, Okayama University.
I1 - Same as I but with four times the number of elements.
J - WEMAP, V. K. Garg, Westinghouse Electric Corporation.

Table 2.3 Field Points Inside of Elements, R>0.07m.

R [m]	ϕ [Deg]	B_x [T]	θ_x [Deg]	B_y [T]	θ_y [Deg]	PROG.
.075	7.5	.0246	-14.0	.1655	174.7	A
		.0298	-13.5	.1631	175.0	B
		.0206	-14.0	.1534	174.4	B1
		.0206	-13.7	.1770	174.0	B2
		.0188	-13.6	.1673	174.1	B3
		.0042	-33.0	.1760	5.9	C
		.0195	-167.3	.1722	5.5	D
		.0196	-166.8	.1720	5.6	F
		.0200	-12.4	.1607	175.3	H
		.0193	14.4	.1780	-173.7	I
		.0289	12.8	.1719	-174.2	I1
.10	7.5	.0139	-14.4	.1449	175.5	A
		.0220	-14.3	.1421	175.7	B
		.0163	-13.7	.1296	175.8	B1
		.0119	-13.7	.1448	175.7	B2
		.0106	-13.5	.1371	175.8	B3
		.0078	-9.8	.1440	4.3	C
		.0110	-166.8	.1404	3.8	D
		.0110	-166.8	.1403	3.8	F
		.0152	-12.3	.1374	176.6	H
		.0085	14.3	.1396	-175.9	I
		.0156	13.8	.1486	-175.5	I1
.15	7.5	.0062	-14.5	.1224	177.4	A
		.0096	-14.3	.1213	177.5	B
		.0058	-13.6	.1077	177.8	B1
		.0052	-13.7	.1211	177.6	B2
		.0047	-13.5	.1147	177.7	B3
		.0109	-2.8	.1205	2.4	C
		.0049	-166.8	.1179	2.0	D
		.0049	-166.8	.1179	2.0	F
		.0073	-12.3	.1147	178.4	H
		.0042	14.3	.1198	-177.6	I
		.0072	13.8	.1221	-177.5	I1
.20	7.5	.0034	-14.5	.1130	178.2	A
		.0050	-14.3	.1126	178.4	B
		.0030	-13.6	.1008	178.5	B1
		.0029	-13.7	.1128	178.4	B2
		.0026	-13.5	.1071	178.5	B3
		.0119	-1.3	.1115	1.5	C
		.0028	-166.8	.1100	1.2	D
		.0028	-166.8	.1100	1.2	F
		.0035	-12.4	.1072	179.2	H
		.0025	14.3	.1125	-178.4	I
		.0039	13.8	.1113	-178.6	I1

Table 2.3 Field Points Inside of Elements, R>0.07 (Continued)

R [m]	ϕ [Deg]	B_x [T]	θ_x [Deg]	B_y [T]	θ_y [Deg]	PROG.
.25	7.5	.0020	-14.5	.1092	178.8	A
		.0031	-14.3	.1088	178.8	B
		.0018	-13.8	.0976	179.0	B1
		.0018	-13.7	.1090	178.8	B2
		.0017	-13.5	.1035	178.9	B3
		.0125	-0.7	.1077	1.1	C
		.0017	-166.8	.1064	0.8	D
		.0018	-166.8	.1064	0.8	F
		.0021	-12.2	.1038	179.6	H
		.0017	14.3	.1090	-178.8	I
		.0026	13.8	.1083	-178.9	I1
.30	7.5	.0012	-14.5	.1075	179.0	A
		.0021	-14.3	.1069	179.1	B
		.0008	-19.8	.0966	179.2	B1
		.0013	-13.7	.1070	179.1	B2
		.0012	-13.5	.1016	179.1	B3
		.0127	-0.4	.1054	0.8	C
		.0012	-166.8	.1045	0.6	D
		.0012	-166.8	.1045	0.6	F
		.0013	-12.0	.1019	179.8	H
		.0012	14.3	.1070	-179.0	I
		.0018	13.8	.1066	-179.1	I1
.35	7.5	.0006	-14.5	.1062	179.1	A
		.0015	-14.3	.1057	179.2	B
		.0040	-177.8	.1060	179.9	B1
		.0009	-13.7	.1058	179.2	B2
		.0012	-9.9	.1007	179.3	B3
		.0128	-0.2	.1042	0.7	C
		.0009	-166.8	.1033	0.4	D
		.0009	-166.8	.1033	0.4	F
		.0009	-12.0	.1008	179.9	H
		.0009	14.3	.1058	-179.2	I
		.0013	13.8	.1056	-179.3	I1
.40	7.5	.0002	-14.5	.1059	179.2	A
		-----	------	-----	179.8	B
		-----	180.0	-----	179.9	B1
		.0007	-13.7	.0987	179.3	B2
		-----	-1.0	.1109	179.4	B3
		.0129	-0.1	.1032	0.6	C
		.0007	-166.8	.1025	0.3	D
		.0007	-166.8	.1025	0.3	F
		.0008	-12.0	.1002	180.0	H
		.0007	14.1	.1051	-179.3	I
		.0011	13.6	.1048	-179.4	I1

Table 2.3 Field Points Inside of Elements, R>0.07 (Continued)

R [m]	ϕ [Deg]	B_x [T]	θ_x [Deg]	B_y [T]	θ_y [Deg]	PROG.
.075	14.0	.0335	-13.7	.1614	175.0	A
		.0360	-13.6	.1603	175.2	B
		.0325	-13.8	.1515	174.5	B1
		.0367	-13.7	.1700	174.3	B2
		.0342	-13.5	.1609	174.4	B3
		.0078	-33.0	.1727	5.9	C
		.0352	-166.0	.1647	5.9	D
		.0355	-166.8	.1657	5.3	F
		.0313	-12.4	.1557	175.5	H
		.0193	14.4	.1780	-173.7	I
		.0289	13.8	.1719	-174.2	I1
.10	14.0	.0206	-14.5	.1417	175.7	A
		.0244	-14.3	.1411	175.8	B
		.0206	-13.7	.1291	175.9	B1
		.0213	-13.7	.1408	176.0	B2
		.0196	-13.5	.1334	176.1	B3
		.0144	-9.8	.1340	4.3	C
		.0199	-166.8	.1369	3.6	D
		.0200	-166.8	.1369	3.6	F
		.0198	-12.3	.1354	176.8	H
		.0085	14.3	.1396	-175.9	I
		.0156	13.8	.1486	-175.5	I1
.15	14.0	.0088	-14.5	.1212	177.4	A
		.0109	-14.3	.1208	177.5	B
		.0082	-13.6	.1073	177.8	B1
		.0093	-13.7	.1193	177.7	B2
		.0085	-13.5	.1131	177.8	B3
		.0201	-2.8	.1180	2.4	C
		.0089	-166.8	.1163	1.9	D
		.0089	-166.8	.1162	1.9	F
		.0098	-12.3	.1136	178.5	H
		.0042	14.3	.1198	-177.6	I
		.0072	13.8	.1221	-177.5	I1
.20	14.0	.0047	-14.5	.1124	178.4	A
		.0059	-14.3	.1122	178.4	B
		.0046	-13.6	.1005	178.6	B1
		.0052	-13.7	.1118	178.5	B2
		.0048	-13.5	.1062	178.6	B3
		.0221	-1.3	.1094	1.5	C
		.0050	-166.8	.1092	1.1	D
		.0050	-166.8	.1092	1.1	F
		.0051	-12.3	.1065	179.2	H
		.0025	14.3	.1125	-178.4	I
		.0041	13.8	.1133	-178.4	I1

Table 2.3 Field Points Inside of Elements, R>0.07 (Continued)

R [m]	ϕ [Deg]	B_x [T]	θ_x [Deg]	B_y [T]	θ_y [Deg]	PROG.
.25	14.0	.0027	-14.5	.1087	178.8	A
		.0037	-14.3	.1086	178.9	B
		.0030	-13.4	.0974	179.0	B1
		.0033	-13.7	.1084	178.9	B2
		.0031	-13.5	.1030	179.0	B3
		.0229	-0.7	.1054	1.1	C
		.0032	-166.8	.1059	0.7	D
		.0032	-166.8	.1059	0.7	F
		.0032	-12.1	.1033	179.6	H
		.0017	14.3	.1090	-178.8	I
		.0026	13.8	.1083	-178.9	I1
.30	14.0	.0016	-14.5	.1069	179.0	A
		.0025	-14.3	.1067	179.1	B
		.0028	-10.0	.0960	179.2	B1
		.0023	-13.7	.1086	179.1	B2
		.0021	-13.5	.1012	179.2	B3
		.0235	-0.4	.1033	0.8	C
		.0022	-166.8	.1041	0.5	D
		.0022	-166.8	.1041	0.5	F
		.0022	-12.0	.1016	179.8	H
		.0012	14.3	.1070	-179.0	I
		.0018	13.8	.1066	-179.1	I1
.35	14.0	.0007	-14.5	.1059	179.2	A
		.0018	-14.3	.1055	179.2	B
		.0104	-2.4	.1004	179.4	B1
		.0017	-13.7	.1055	179.3	B2
		.0019	-11.2	.1004	179.3	B3
		.0238	-0.2	.1020	0.7	C
		.0016	-166.8	.1030	0.4	D
		.0016	-12.0	.1006	179.9	H
		.0016	-166.8	.1030	0.4	F
		.0009	14.3	.1058	-179.2	I
		.0012	13.7	.1054	-179.3	I1
.40	14.0	.0003	-14.5	.1055	179.2	A
		-----	------	-----	179.9	B
		-----	-179.9	-----	180.0	B1
		-----	-13.7	-----	179.6	B2
		-----	------	-----	179.8	B3
		.0239	-0.1	.1012	0.6	C
		.0013	-166.8	.1023	0.3	D
		.0012	-166.8	.1023	0.3	F
		.0014	-12.0	.1000	-180.0	H
		.0007	14.1	.1051	-179.3	I
		.0010	13.2	.1048	-179.4	I1

Table 2.3 Field Points Inside of Elements, R>0.07 (Continued)

R [m]	ϕ [Deg]	B_x [T]	θ_x [Deg]	B_y [T]	θ_y [Deg]	PROG.
.075	20.0	.0732	-13.9	.1526	175.5	A
		.0474	-13.5	.1486	175.8	B
		.0446	-13.7	.1396	175.2	B1
		.0498	-13.7	.1606	174.8	B2
		.0467	-13.5	.1521	174.9	B3
		.0112	-33.0	.1675	5.9	C
		.0486	-166.8	.1589	3.4	D
		.0446	13.7	.1623	3.5	E
		.0486	-166.8	.1570	4.8	F
		.0432	-12.3	.1435	176.2	H
		.0638	14.3	.1662	-174.3	I
		.0467	13.7	.1622	-174.7	I1
		.0483	13.8	.1576	5.0	J
.10	20.0	.0517	-14.4	.1390	175.9	A
		.0341	-14.3	.1312	176.6	B
		.0304	-13.6	.1198	176.6	B1
		.0291	-13.7	.1352	176.4	B2
		.0270	-13.5	.1282	176.5	B3
		.0208	-9.8	.1307	4.3	C
		.0273	-166.8	.1319	3.2	D
		.0268	13.8	.1333	2.1	E
		.0274	-166.8	.1319	3.2	F
		.0288	-12.4	.1264	177.4	H
		.0402	14.3	.1312	-176.6	I
		.0267	13.8	.1417	-175.9	I1
		.0230	13.6	.1286	3.0	J
.15	20.0	.0236	-14.5	.1202	177.5	A
		.0148	-14.3	.1165	177.9	B
		.0119	-13.6	.1040	178.2	B1
		.0127	-13.7	.1169	178.0	B2
		.0117	-13.5	.1109	178.1	B3
		.0291	-2.8	.1144	2.4	C
		.0121	-166.8	.1141	1.7	D
		.0133	13.7	.1138	1.7	E
		.0122	-166.8	.1142	1.7	F
		.0135	-12.4	.1097	178.9	H
		.0170	14.3	.1165	-177.9	I
		.0120	13.8	.1191	-177.8	I1
		.0134	13.6	.1178	2.1	J
.20	20.0	.0141	-14.5	.1117	178.4	A
		.0078	-14.3	.1101	178.7	B
		.0065	-13.6	.0987	178.8	B1
		.0070	-13.7	.1105	178.7	B2
		.0065	-13.5	.1050	178.7	B3
		.0319	-1.3	.1060	1.5	C
		.0068	-166.8	.1079	1.0	D
		.0081	13.7	.1036	0.9	E
		.0068	-166.8	.1080	1.0	F

Table 2.3 Field Points Inside of Elements, R>0.07 (Continued)

R [m]	ϕ [Deg]	B_x [T]	θ_x [Deg]	B_y [T]	θ_y [Deg]	PROG.
		.0070	-12.4	.1045	179.5	H
		.0094	14.3	.1107	-178.6	I
		.0062	13.8	.1102	-178.7	I1
		.0063	13.6	.1095	1.2	J
.25	20.0	.0082	-14.5	.1083	178.9	A
		.0049	-14.3	.1073	179.0	B
		.0042	-13.4	.0963	179.1	B1
		.0045	-13.7	.1076	179.0	B2
		.0042	-13.5	.1022	179.1	B3
		.0333	-0.7	.1022	1.1	C
		.0043	-166.8	.1051	0.6	D
		.0044	13.7	.1024	0.6	E
		.0044	-166.8	.1051	0.7	F
		.0043	-12.2	.1021	179.7	H
		.0059	14.3	.1079	-178.9	I
		.0041	13.7	.1076	-179.0	I1
		.0046	13.6	.1077	1.0	J
.30	20.0	.0052	-14.5	.1065	179.1	A
		.0033	-14.3	.1058	179.2	B
		.0038	-10.2	.0952	179.3	B1
		.0031	-13.7	.1060	179.2	B2
		.0029	-13.5	.1007	179.3	B3
		.0339	-0.4	.1003	0.8	C
		.0030	-166.8	.1035	0.4	D
		.0038	13.7	.1008	0.5	E
		.0030	-166.8	.1035	0.5	F
		.0029	-12.2	.1008	179.9	H
		.0041	14.3	.1063	-179.1	I
		.0029	13.8	.1061	-179.2	I1
		.0026	13.6	.1057	0.7	J
.35	20.0	.0036	-14.5	.1056	179.2	A
		.0024	-14.3	.1049	179.3	B
		.0138	-2.5	.0993	179.4	B1
		.0023	-13.7	.1050	179.3	B2
		.0025	-11.5	.0999	179.4	B3
		.0344	-0.2	.0990	0.7	C
		.0022	-166.8	.1026	0.3	D
		.0025	13.7	.1008	0.4	E
		.0022	-166.8	.1026	0.3	F
		.0021	-12.2	.1000	-180.0	H
		.0030	14.3	.1053	-179.3	I
		.0022	13.8	.1052	-179.3	I1
		.0019	13.6	.1051	0.7	J

Table 2.3 Field Points Inside of Elements, R>0.07 (Continued)

R [m]	ϕ [Deg]	B_x [T]	θ_x [Deg]	B_y [T]	θ_y [Deg]	PROG.
.40	20.0	.0024	-14.5	.1051	179.3	A
		-----	------	-----	179.9	B
		-----	-180.0	-----	180.0	B1
		-----	-13.7	-----	179.8	B2
		-----	------	-----	189.9	B3
		.0346	-0.1	.0982	0.6	C
		.0017	-166.8	.1020	0.3	
		.0023	13.7	.1007	0.3	E
		.0017	-166.8	.1020	0.3	F
		.0018	-12.0	.0996	-179.9	H
		.0018	14.7	.1042	-179.4	I
		.0014	14.5	.1044	-179.4	I1
		.0008	13.7	.1044	0.6	J

A - PE2D, Chris Emson, Rutherford Laboratory.
B - PE2D, Robert Lari, Argonne National Laboratory.
B1 - PE2D, Robert Lari, Same as B but with Quadratic Triangular Elements.
B2 - PE2D, Robert Lari, 4 times the number of elements in B.
B3 - PE2D, Robert Lari, 4 times the number of elements in B1.
C - PROFI, Technische Hochschule, Darmstadt.
D - No Name, Toshiya Morisue, Tokushima University.
E - EDDYNDT, Nathan Ida, The University of Akron.
F - Analytical Solution, Oskar Biro, Technical University, Budapest.
G - ANSYS, Dale Ostergaard, Swanson Analysis Systems, Inc.
G1 - ANSYS, Dale Ostergaard, 4 times the number of elements in G.
G2 - ANSYS, Dale Ostergaard, 4 times the number of elements in G with modified boundary (outer boundary at 0.84m).
H - No name, E. M. Deeley, King's College, London.
I - FIELD/A2JW, T. Nakata, Okayama University.
I1 - Same as I but with four times the number of elements.
J - WEMAP, V. K. Garg, Westinghouse Electric Corporation.

Table 2.4 Comparison of global quantities.

	Time Average	Amplitude	Phase (Deg.)	PROG.
Total Eddy	.0	11385.5	166.4	A
Current in	.0	11239.0	166.5	B
1/4 Region	0.0	9664.0	167.2	B1
	0.0	10933.0	167.1	B2
[A]	0.0	10270.0	167.2	B3
	-------	10325.0		D
	-------	10511.0	-----	E
	.0	10569.0	12.4	F
	-------	10923.0	13.1	G
	-------	10851.0	12.8	G1
	-------	10648.0	12.6	G2
	0.	9819.0	169.1	H
	0.	11300.0	-166.4	I
	0.	10978.0	-167.0	I1
	0.	10730.0	14.28	J
Power Loss	2688.2	2412.7	-30.1	A
in 1/4	2613.0	2346.0	-29.6	B
Region	1933.0	1729.0	-28.4	B1
[Watt/m]	2454.0	2194.0	-28.6	B2
	2166.0	1935.0	-28.3	B3
	20578.0	-------	-----	C
	2177.0	1949.0	27.0	D
	-------	1912.4	-----	E
	2288.0	2043.0	27.6	F
	2445.0	2202.7	28.7	G
	2411.7	2158.1	28.4	G1
	2322.0	2078.0	27.9	G2
	2012.0	1771.0	-24.5	H
	2616.1	2360.1	29.6	I
	2467.4	2210.0	28.7	I1
	2389.0	------	-----	J
Stored	1.735	1.54	7.1	A
Energy in	1.69	1.49	7.5	B
1/4 Region	1.37	1.21	7.5	B1
	1.67	1.48	8.0	B2
.05717<r<	1.52	1.39	7.9	B3
.06985	.04	--------	-----	C
[Joule/m]	1.92	1.20	-27.7	D
	--------	1.25	-----	E
	1.60	1.41	-8.8	F
	1.6735	1.48	-8.0	G
	1.6749	1.482	-8.1	G1
	1.6128	1.4271	-8.6	G2
	1.42	1.26	8.8	H
	0	3.13	119.6	I *
	0	2.93	118.7	I1*
	1.75	1.54	-7.1	I**
	1.6975	1.50	-7.8	I1**
	1.629	-----	-----	J

Table 2.4 Comparison of global quantities. (Continued)

	Time Average	Amplitude	Phase (Deg.)	PROG.
Stored Energy in 1/4 Region r<.05715 [Joule/m]	.275	.270	-176.6	A
	.270	.260	-175.8	B
	0.2	0.19	-171.8	B1
	0.25	0.25	-171.9	B2
	0.22	0.22	-170.8	B3
	2.130	---------	-----	C
	.229	.229	169.9	D
	---------	.230	-----	E
	.228	.228	170.0	F
	0.25023	0.25023	171.2	G
	0.2418	0.2418	170.8	G1
	.2323	0.2328	170.3	G2
	0.202	0.202	-165.9	H
	0.268	0.268	172.7	I
	0.2475	0.2475	171.3	I1
	0.2406	-------	-----	J
Stored Energy in 1/4 Region r>.06985 [Joule/m]	363.0	362.2	-1.0	A
	265.0	264.0	-1.3	B
	232.0	232.0	-1.1	B1
	277.0	276.0	-1.2	B2
	261.0	260.0	-1.1	B3
	2365.0	--------	-----	C
	273.5	273.8	.6	D
	-------	286.2	-----	E
	273.6	273.1	.5	F
	283.6	282.5	1.2	G
	286.1	285.4	1.2	G1
	259.0	258.0	0.1	H
	284.1	283.4	1.28	I
	286.3	285.6	1.2	I1
	361.8	--------	-----	J
Stored Energy of Induced Field in 1/4 Region	-------	11.0	-----	A
	12.3	10.9	-1.2	B
	9.2	8.1	-1.1	B1
	12.8	11.4	-1.2	B2
	11.3	10.1	-1.1	B3
	.0	2.6	117.0	D
	-------	2.8	-----	E
	-294.0	305.0	174.9	H
	13.7	13.6	27.1	I
	13.4	13.3	26.0	I1

Table 2.4 Comparison of global quantities. (Continued)

	Time Average	Amplitude	Phase (Deg.)	PROG.
Force on 1/4 Region [N/m] Fx	-385.9	407.0	171.5	A
	-375.0	396.0	172.0	B
	287.0	302.0	172.6	B1
	-356.0	376.0	172.6	B2
	-287.0	302.0	172.6	B3
	-314.0	348.0	-175.0	D
	-------	-343.7	-----	E
	-333.4	351.6	-173.6	F
	-353.7	375.0	-173.0	G
	-350.8	370.5	-173.0	G1
	-337.8	356.7	-173.5	G2
	-294.0	305.0	174.9	H
	-390.1	393.5	-172.5	I
	-373.5	376.4	-172.8	I1
	345.1	-------	-----	J
Force on 1/4 Region [N/m] Fy	-196.0	375.0	163.1	A
	-190.0	363.0	163.6	B
	-143.0	274.0	164.7	B1
	-179.0	343.0	164.6	B2
	-143.0	274.0	164.0	B3
	-157.0	164.0	-158.0	D
	-------	155.7	-----	E
	-166.7	165.7	-155.8	F
	-178.4	177.7	-154.8	G
	-175.8	174.8	-155.1	G1
	-169.3	168.3	-155.6	G2
	-146.0	143.0	157.4	H
	-169.6	188.7	-154.0	I
	-161.2	178.2	-154.8	I1
	172.1	-------	------	J

A - PE2D, Chris Emson, Rutherford Laboratory.
B - PE2D, Robert Lari, Argonne National Laboratory.
B1 - PE2D, Robert Lari, Same as B but with Quadratic Triangular Elements
B2 - PE2D, Robert Lari, 4 times the number of elements in B.
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I - FIELD/A2JW, T. Nakata, Okayama University.
I1 - Same as I but with four times the number of elements.
J - WEMAP, V. K. Garg, Westinghouse Electric Corporation.
* - Method A (see [16]).
** - Method B (see [16]).

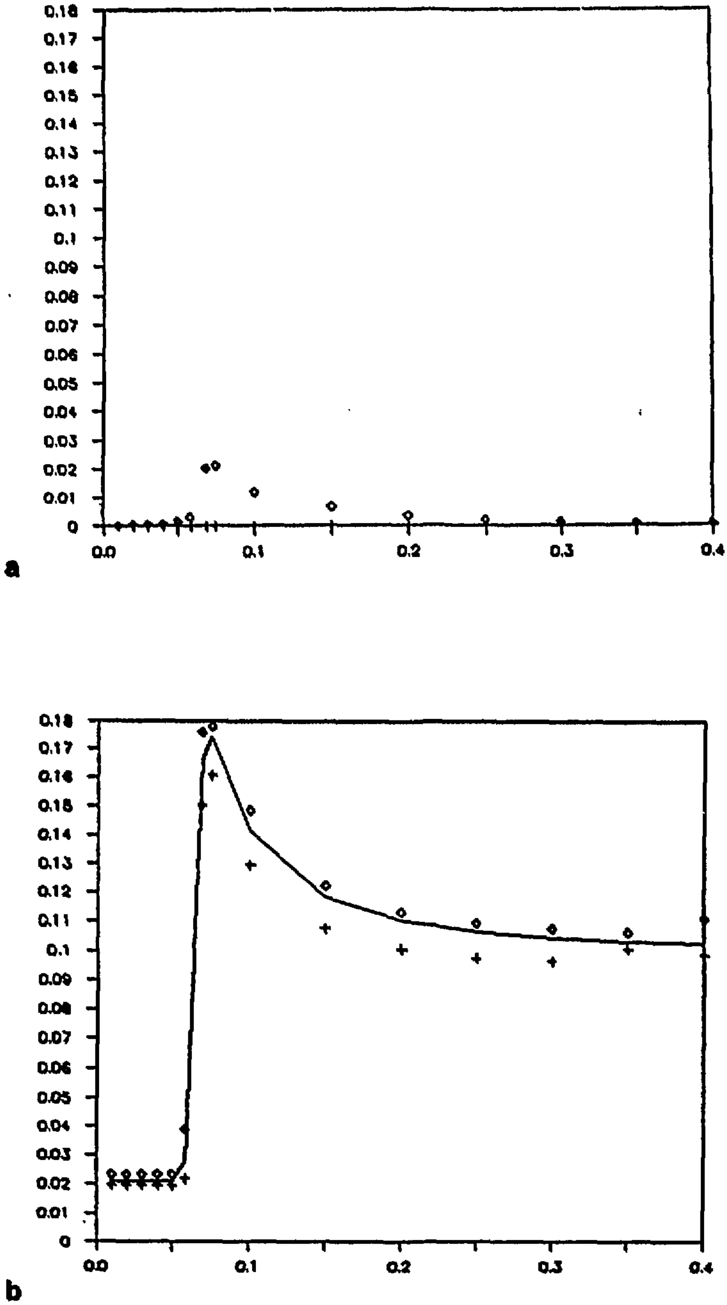
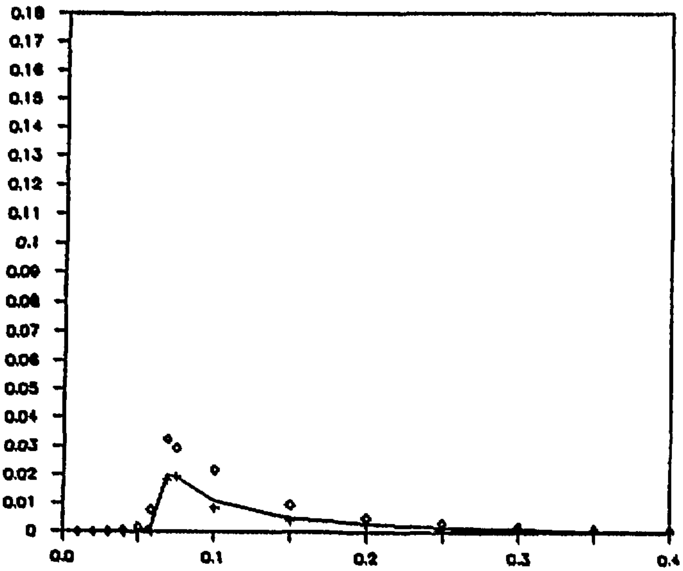
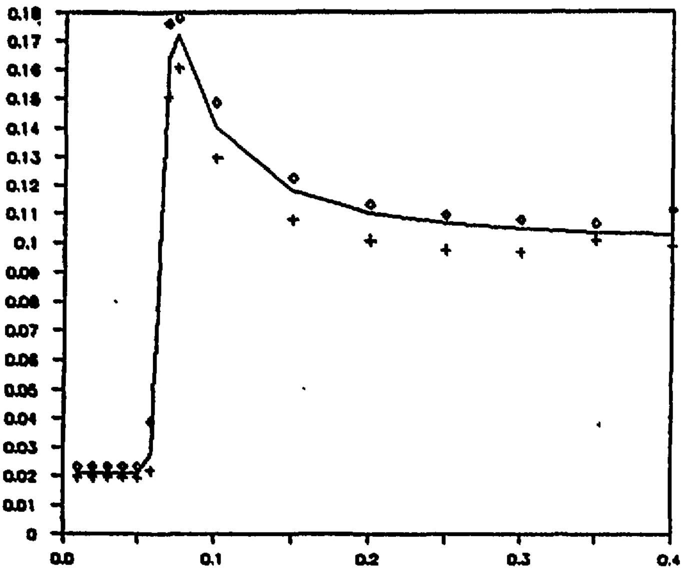


Figure 3. Flux density versus position at 0.0 degrees.
a. B_x.
b. B_y.

◇ Maximum calculated result.
—— Analytic solution.
\+ Minimum Calculated result.



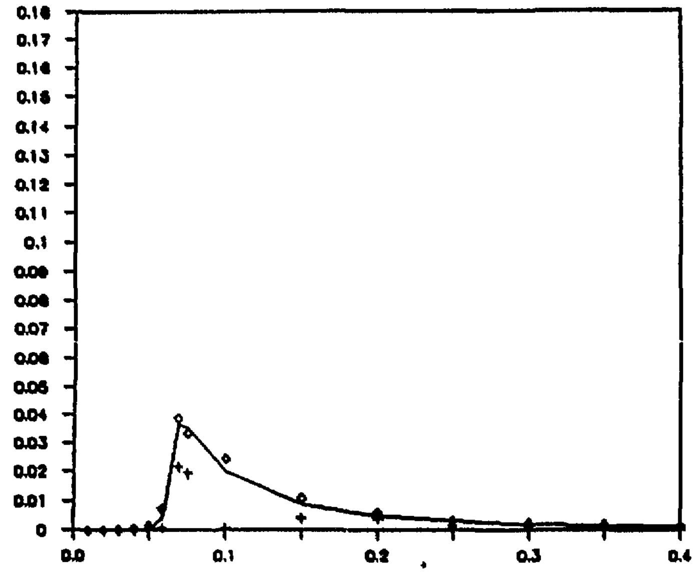
a



b

Figure 4. Flux density versus position at 7.5 degrees.
a. B_x.
b. B_y.

◇ Maximum calculated result.
____ Analytic solution.
+ Minimum Calculated result.



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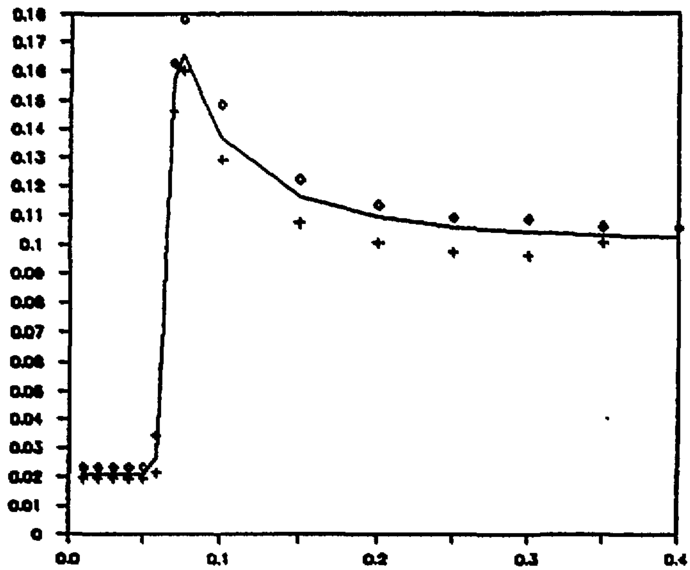

b

Figure 5. Flux density versus position at 14.0 degrees.
a. B_x.
b. B_y.

◇ Maximum calculated result.
—— Analytic solution.
\+ Minimum Calculated result.

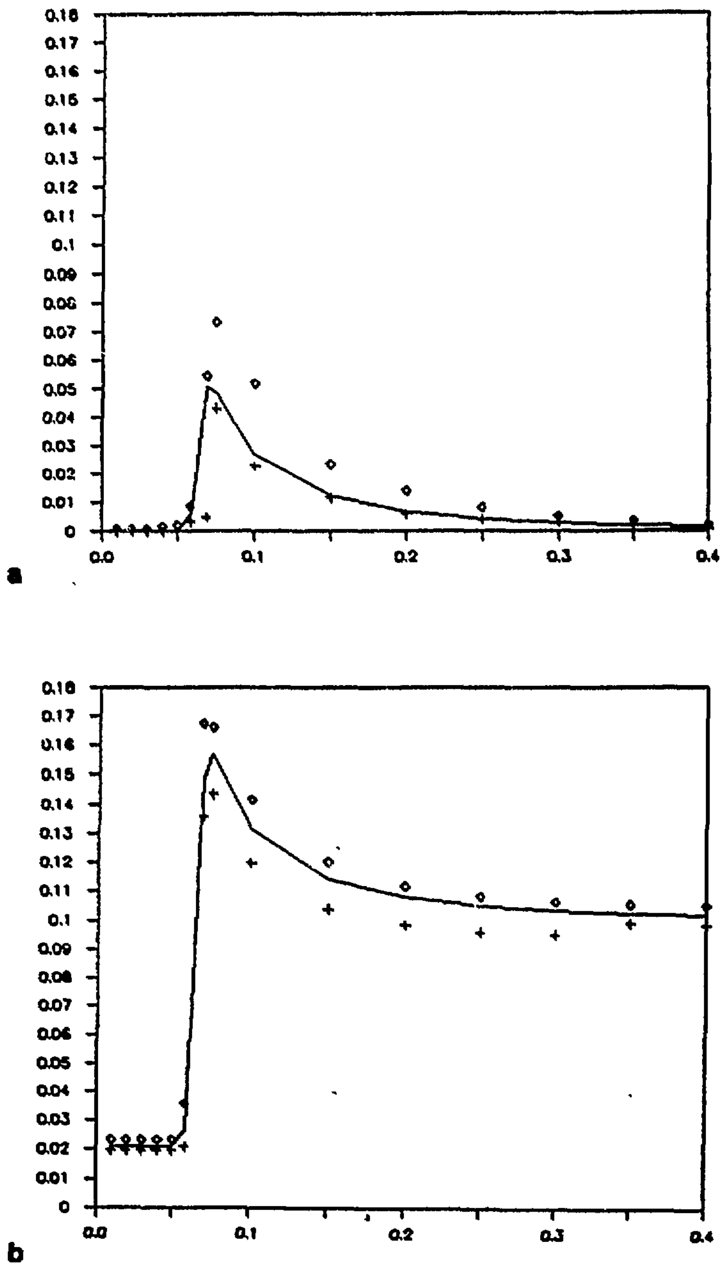

Figure 6. Flux density versus position at 20.0 degrees.

a. B_x.

b. B_y.

◇ Maximum calculated result.

___ Analytic solution.

+ Minimum Calculated result.

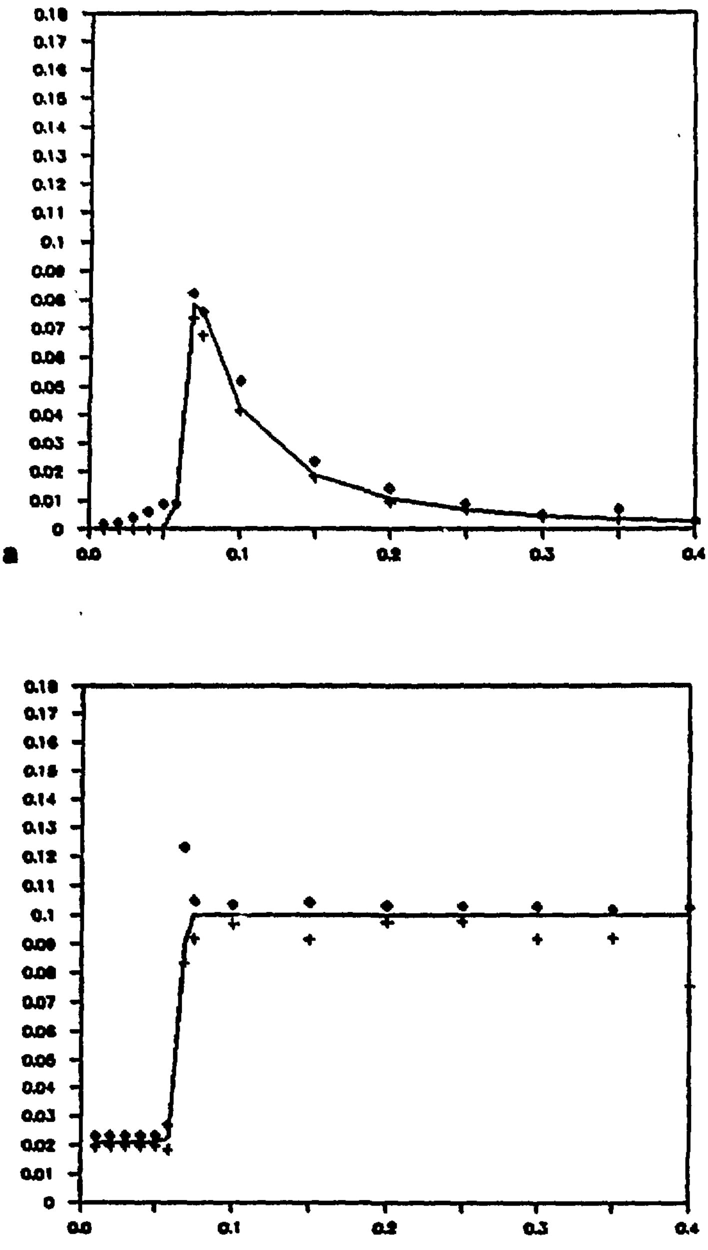

Figure 7. Flux density versus position at 45.0 degrees.
a. B_x.
b. B_y.

◇ **Maximum calculated result.**
___ **Analytic solution.**
\+ **Minimum Calculated result.**

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