Problem 1B
The FELIX short Cylinder Experiment

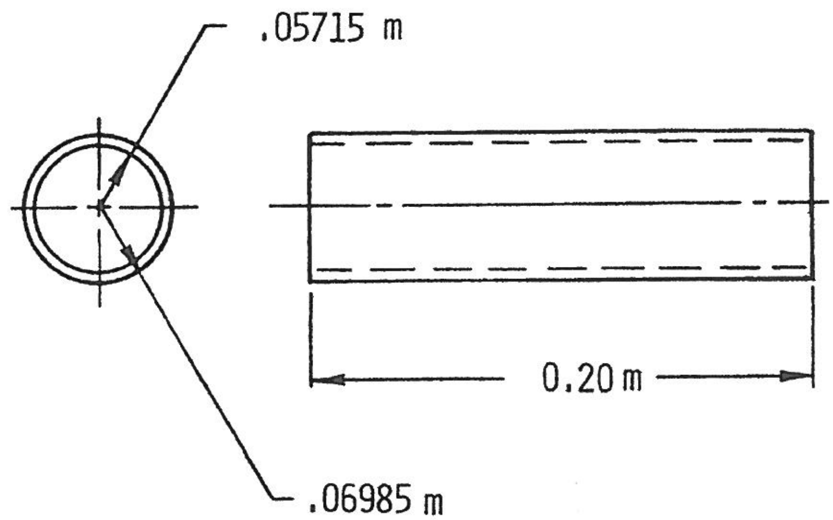
1. General Description of the Problem

This problem consists of a hollow aluminum cylinder placed in a uniform magnetic field. The magnetic field is perpendicular to the axis of the cylinder and decays exponentially with time. The problem is to calculate the induced eddy currents in the aluminum and the magnetic field both inside and outside the cylinder at various axial positions. Global quantities such as power losses, stored energy, forces, etc. should also be calculated. If capability for 3D calculations is not available, 2D calculations may be attempted.

2a. Specific Mesh Description

Cylinder geometry:

Length:	0.20 m
Inner radius:	.05715 m
Outer radius:	.06985 m



The cylinder material is aluminum alloy 6061 of resistivity $\rho = 3.94 \times 10^{-8}$ ohm-m. The nodes that form the specified mesh are shown in Fig. 1.a,b for the x-y plane, and Fig. 2.a,b for the x-z plane. The finite elements need not be triangles as shown. In Fig. 1.b, the mesh has nodes at .01 m spacing in the region $0 \le x \le .03$, $0 \le y \le .03$ m. In the regions surrounding this square, the nodes on the inner radius of .05715 m are spaced 15 degrees apart. The nodes on the other three boundaries are spaced equidistant apart. Straight lines are drawn connecting the nodes on y = .03 (or x = .03) to the nodes on r = .05715. These lines have nodes equidistantly spaced. In the cylindrical region, nodes are placed at r = .05715, .06138, .06562, .06985, and .080 m at θ = 0, 15, 30, 45, 60, 75, and 90 degrees. The outer regions have nodes spaced (or x = .42). These lines have nodes equidistant apart. The total number of nodes is 114 and there are 93 quadrilateral elements in this x-y plane.

This mesh is extended in the z direction as shown in Fig. 2a. and 2b. The nodes are spaced .02 m apart for $0 \leq z \leq .20$. The spacing is .04 m for $.20 \leq z \leq .40$ m.

There are 16 planes each having 114 nodes for a total of 1824 nodes. The 15 block layers have 93 hexahedral elements per block layer and a total of 1395 hexahedral elements.

If the user's mesh generator prevents generating this mesh exactly, a mesh as close to it as possible should be used.

2b. User Defined Mesh

The user is free to place the nodes as desired but should try to maintain the same total number of nodes. Adaptive mesh generators may be used here.

2c. Other Techniques

Solutions obtained using integral techniques should use matrices that have roughly the same number of non-zero elements as those meshes defined above or that have a similar mesh over the conducting region.

3. The Applied Magnetic Field and Boundary Conditions

The applied magnetic field in the y direction is uniform in space and decays exponentially with time as

$$B_y = B_o \, e^{-t/\tau}$$

where B_o= 0.1 T and τ = .0069 s. This condition can be imposed by choosing the proper initial boundary conditions.

Vector potentials may be specified on the left and right boundary to give the desired field. If 0.0 vector potential is specified on the x = 0 plane, and (0.1) (.42) T-m is specified on the x = .42 m plane, the field will be a uniform .1 T with no conducting cylinder. The boundary planes y = 0 and y -0.42 m are flux normal boundaries. The plane z = 0 is a symmetry plane and has no flux crossing it. The plane z = .40 m also has no flux crossing it.

Scalar potentials may be specified on the y = 0 plane as 0.0 and on the y = .42 m plane as (0.1) (.42) T-m. The boundary planes x = 0 and x = .42 m have no flux crossing them. The $z = 0$ and $z = .40$ m planes are the same as above.

4. Presentation of Results

The following quantities in Table 1 should be calculated and presented. Some have been experimentally determined.

Table 1.

Quantity	Time (s)	Calculated
Total eddy current (ampere) crossing the plane z = 0 m.	.000	
	.002	
	.004	
	.006	
	.008	
	.010	
	.020	
Time of peak current and the value		
Total eddy current (ampere) crossing the plane z = 0.06 m.	.000	
	.002	
	.004	
	.006	
	.008	
	.010	
	.020	
Magnetic fields (tesla)		
B_y along the z axis at: z(m)		
0.0	.000	
	.002	
	.004	
	.006	
	.008	
	.010	
	.020	
.05	''	
.10	''	
.15	''	

Table 1. (Continued)

Quantity	Time (s)	Calculated
Global Quantities:		
Power losses in the cylinder	.000	
$\iint J^2 \rho \, dS \, dz$ (watts)	.002	
	.004	
	.006	
	.008	
	.010	
	.020	
Stored energy in the cylinder walls,	.000	
$\iint \frac{A \bullet J}{2} dS \, dz$ (joule)	.002	
	.004	
	.006	
	.008	
	.010	
	.020	
Stored energy in the volume	.000	
$r \leq 0.1317$, $z \leq 1.30$	.002	
$\iint \frac{BH}{2} dS \, dz$ (joule)	.004	
	.006	
	.008	
	.010	
	.020	
Stored energy in the volume	.000	
$r \geq .06985$, $z \leq 0.40$	.002	
$\iint \frac{BH}{2} dS \, dz$ (joule)	.004	
	.006	
	.008	
	.010	
	.020	
Force on one octant of the cylinder	.000	
$F_x = \iint J_z B_y \, dS \, dz$ (newton)	.002	
	.004	
$F_y = \iint J_z B_x \, dS \, dz$	.006	
	.008	
$F_z = \iint (J_x B_y - J_y B_x) \, dS \, dz$	.010	
	.020	
Time at which each component of force peaks, and the peak value.		

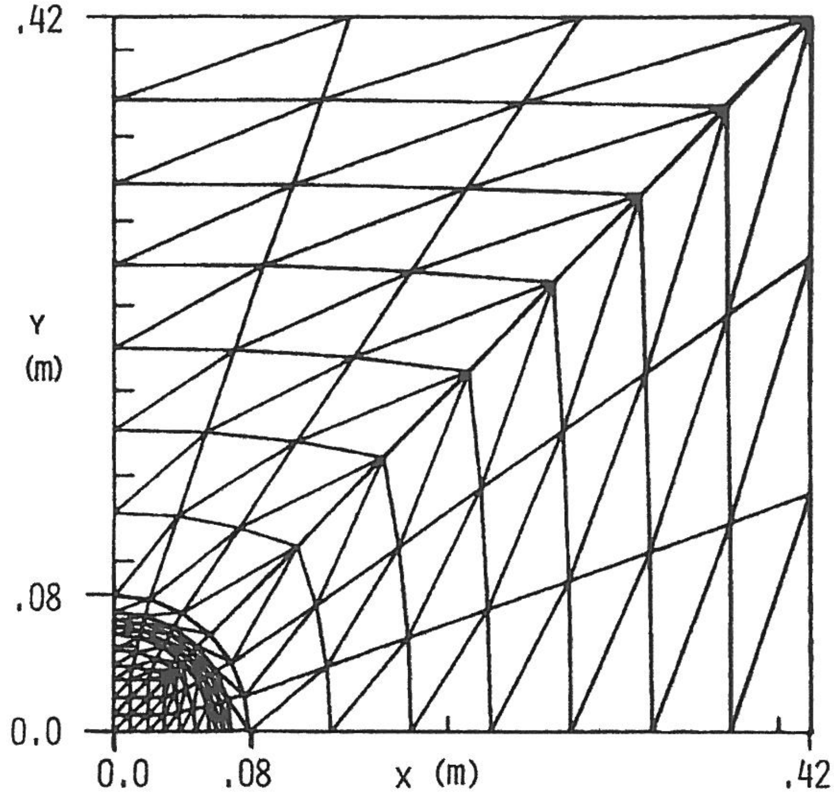


Figure 1a.

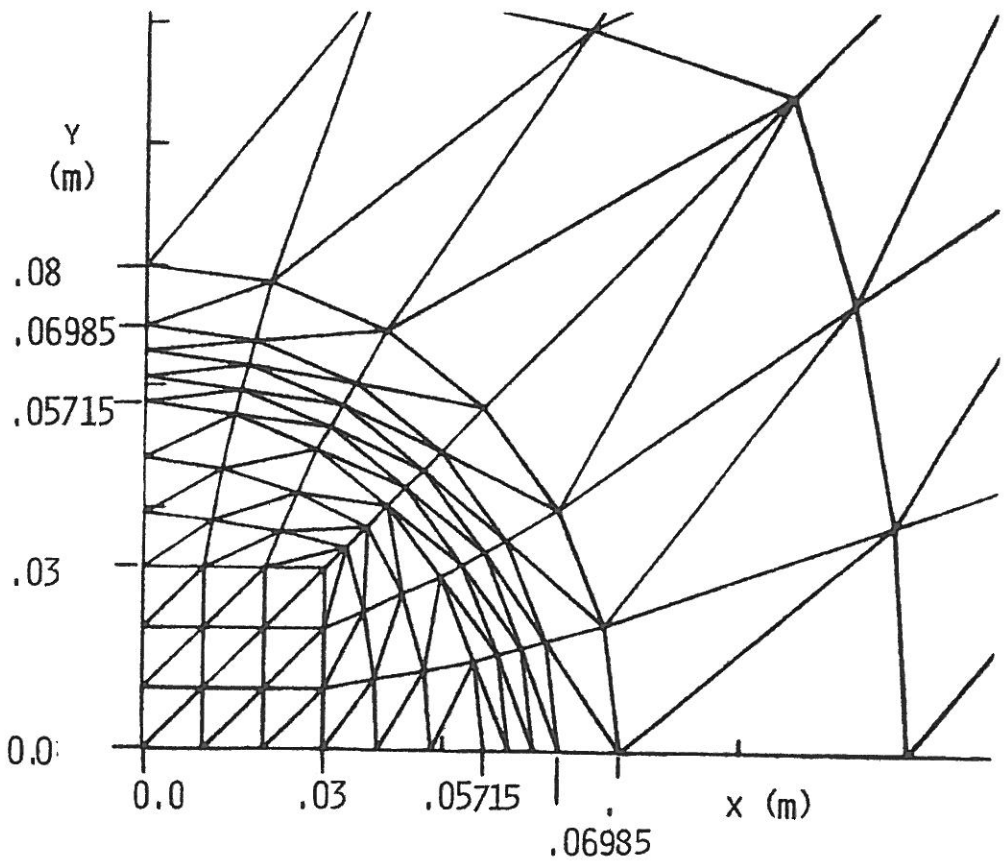


Figure 1b.

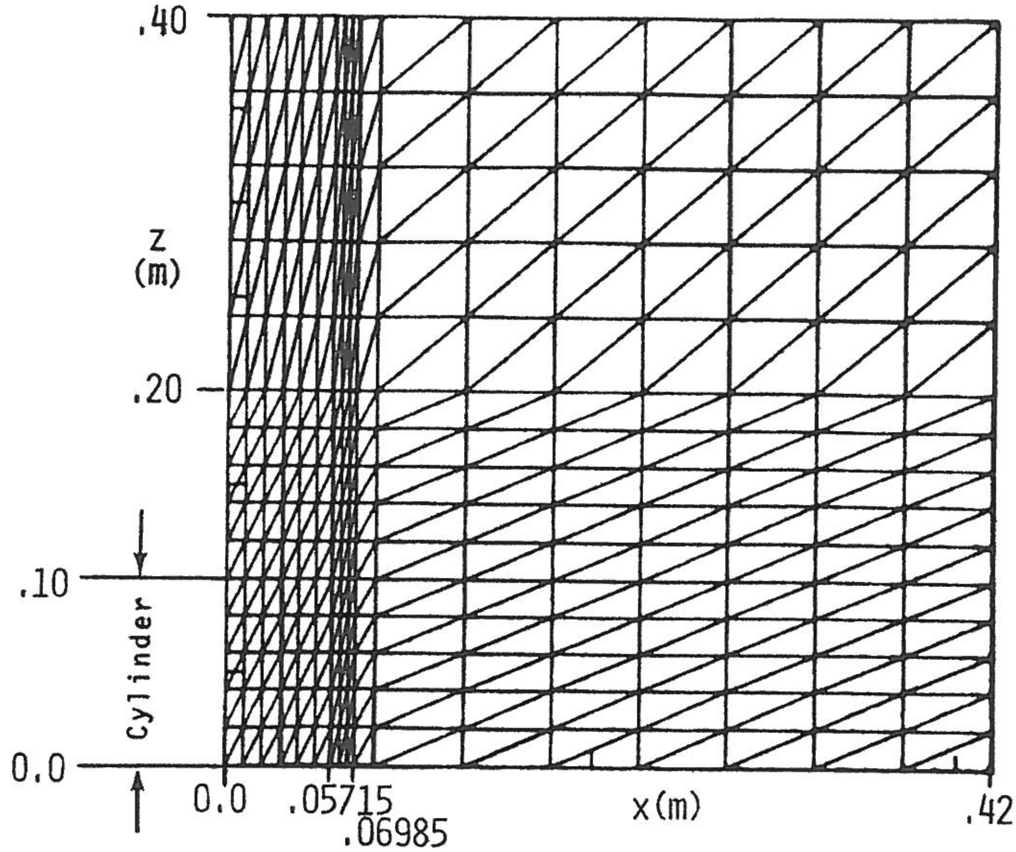


Figure 2a.

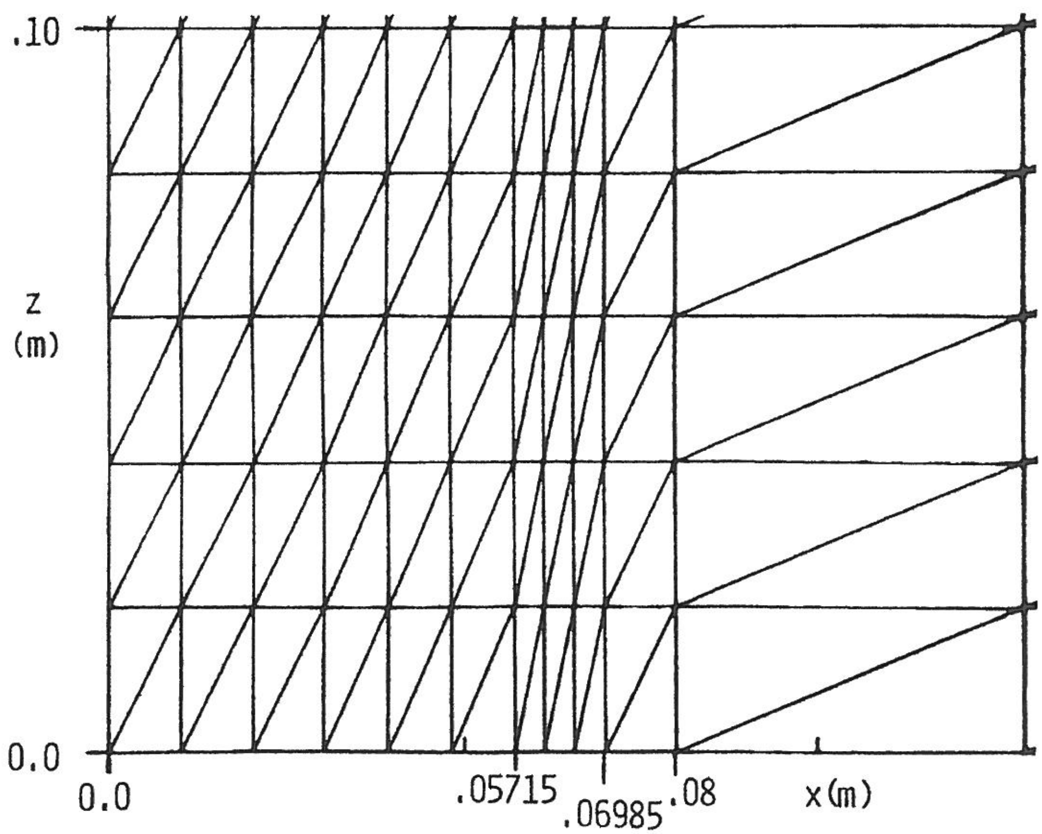


Figure 2b.