Problem 4
The FELIX Brick Experiment

1. General Description

A rectangular aluminum brick with a rectangular hole through it is placed in a uniform magnetic field. The magnetic field is perpendicular to the faces with the hole, and decays exponentially with time. The problem is to calculate the total circulating current and the magnetic field at various positions. Global quantities such as power should also be calculated.

2. Mesh and Geometry Description

The brick, shown in Fig. 1, is made of aluminum alloy 6061, of resistivity $\rho = 3.94 \times 10^{-8}\ \Omega m$. The brick is 0.1524 m x 0.1016 m x 0.0508 m. A rectangular hole 0.0889 m x 0.0381 m penetrates the brick through the centers of the large (0.1524 m x 0.1016 m) faces.

2a. Specific Mesh.

The problem should be solved using the mesh shown in Figs. 2 and 3. By symmetry, only one-eighth of the brick need be modelled. The mesh is rectangular, with mesh planes at x = 0, 2, 4, 5, 6, 7, 8, 9, 10, 12, 20, 32, 48, and 80 x 0.00635 m, y = 0, 1, 2, 3, 4, 5, 6, 8, 16, 28, 44, and 80 x 0.00635 m, and z = 0, 2, 3, 4, 12, 24, 40, and 80 x 0.00635 m. The mesh includes 1344 nodes and 1001 hexahedral elements.

If the user's mesh generator prevents him from employing this mesh exactly, he should use one as close to it as possible.

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 or degrees of freedom. 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

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

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

where $B_o = 0.1$ T and $\tau = 0.0119$ s. This condition can be imposed by choosing the proper boundary conditions.

4. Quantities to be Calculated and Presented

For each of the following quantities, a), b) and c), the peak value and the time at which the peak value occurs should be presented. Plots of the quantities as a function of time are desirable but optional.

a) The total circulating current.

b) The induced magnetic field (total field minus applied field) at different vertical (z) positions at the center of the hole ($x = y = 0$).

$z = 0.0$ m (center of the brick)

$z = 0.0127$ m

$z = 0.0254$ m (in the plane of the face of the brick)

$z = 0.0508$ m (outside the brick)

c) The Joule heating rate P for the complete brick

$$P = \int J^2 \rho \, dV.$$

Here values tabulated or plotted against time are particularly valuable.

d) The total Joule heating: $\int_o^\infty P dt$.

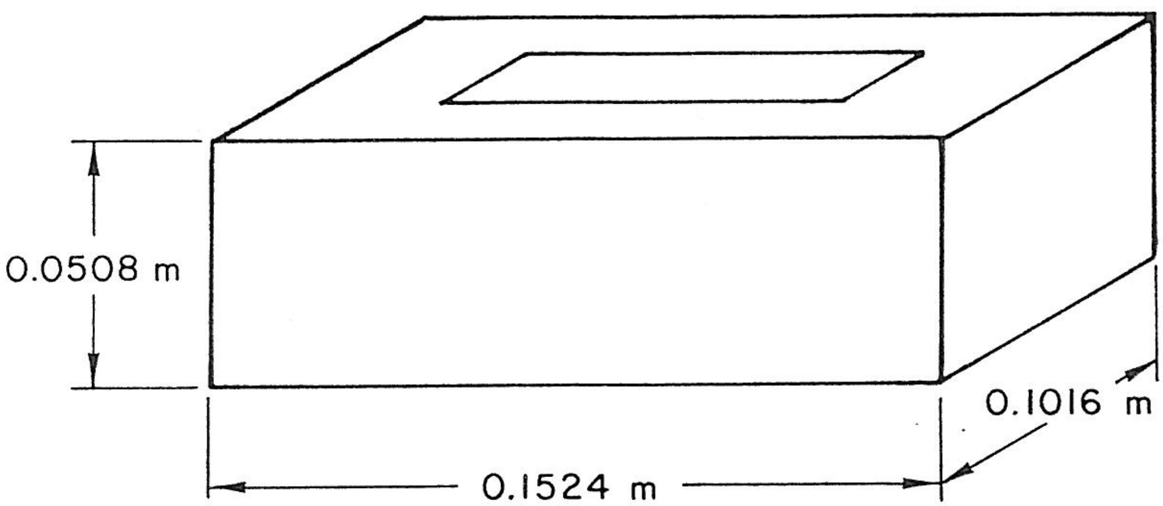

Fig. 1. The brick test piece. Through-hole 0.0889 m x 0.0381 m.

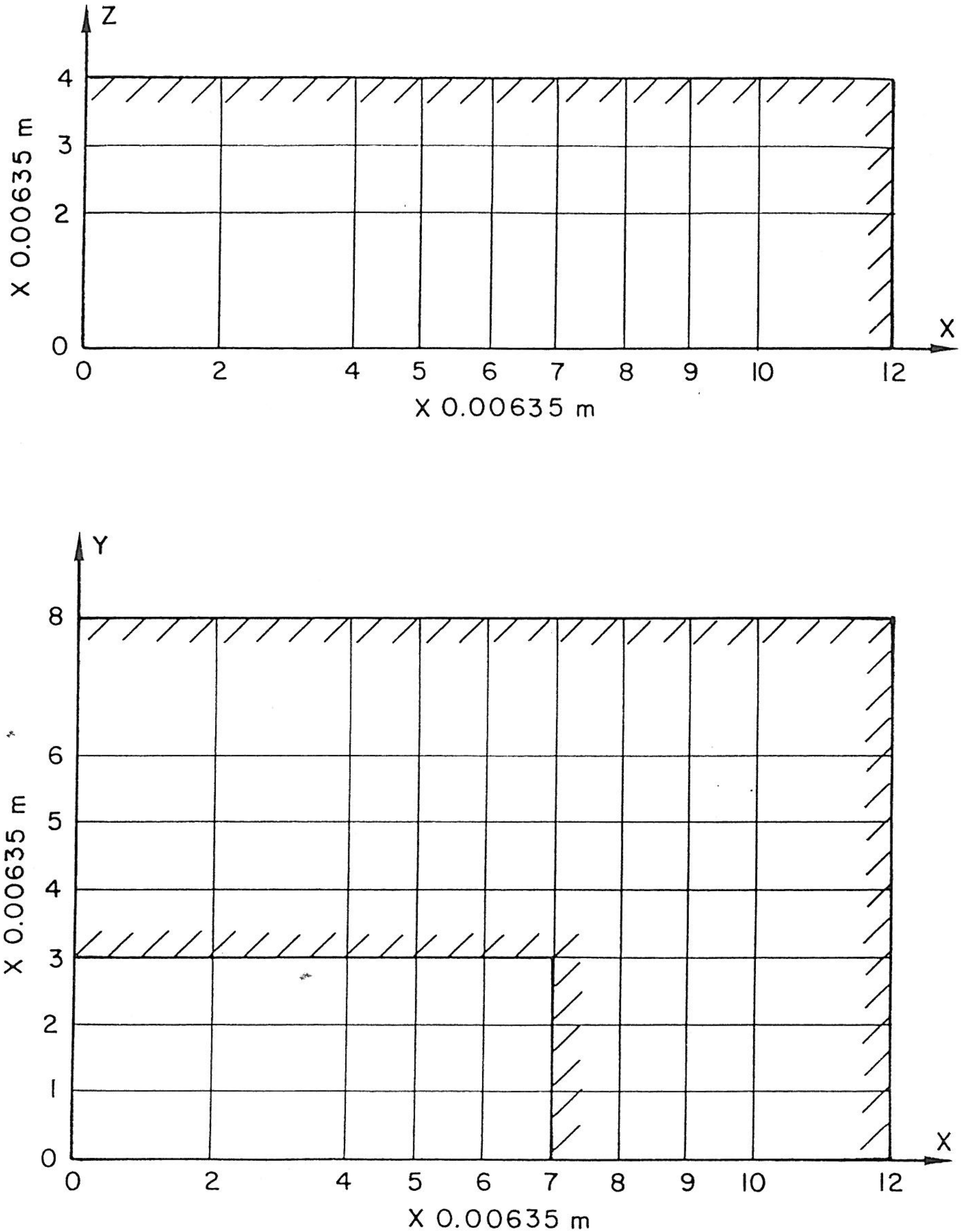

Fig. 2. Detail of mesh, showing extent of brick.

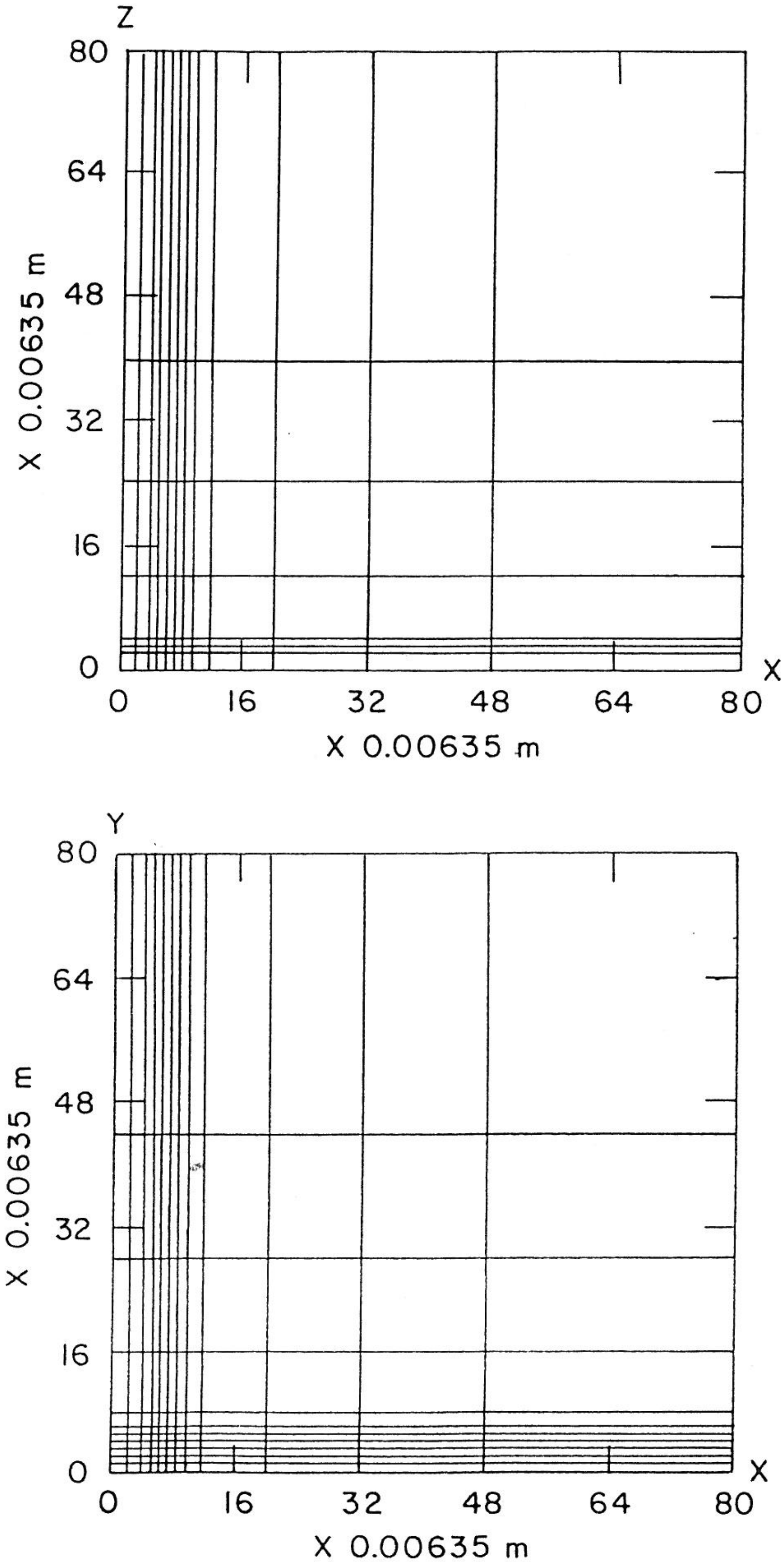

Figure 3. Full mesh.