1. (25 points) A conducting layer occupying \(-a < x < a\), but infinite in the \(y\) and \(z\) directions, contains a uniform current density \(J = J_0 \hat{z}\), while \(J = 0\) elsewhere. The permeability \(\mu = \mu_0\) everywhere. Use Ampère's law and symmetry to find an expression for the magnetic field \(B\) at any value of \(x\).

2. (25 points) A toroidal core made of two different materials with permeabilities \(\mu_0\) and \(\mu_1\) as shown in the figure is tightly wound with \(N\) turns of wire.

If a current \(I\) flows in the wire, obtain expressions for the \(H\) and \(B\) field at all points in space, using Ampère's law and symmetry.
3. (25 points) Find an expression for the resistance between two rectangular electrodes of dimensions \(a\) and \(b\), separated by a conducting medium of \(z\)-dependent resistivity

\[ \rho(z) = \rho_0 \left( 1 + \frac{z}{l} \right) \]

and length \(l\) as shown below. If \(a = 2\) mm, \(b = 5\) mm, \(l = 2\) cm and \(\rho_0 = 40\) \(\Omega\) m, determine the resistance between the two electrodes.

![Diagram of two rectangular electrodes separated by a conducting medium with a \(z\)-dependent resistivity](image)

The following question needs little or no math; mark your answer directly on the exam page.

4. (25 points) A long (not necessarily straight) wire lying in a plane carries a constant (DC) current \(I_1\) as shown below. If a wire loop lying in the same plane as the wire moves away from the wire with a constant velocity \(v\), which of the following is true (choose one answer from each column)? Give reasons for your answers.

![Diagram of a long wire and a wire loop in the same plane](image)

(i) A current \(I_2\) flowing clockwise is induced in the loop (mark the direction on the figure to make your intention clear).

(ii) A current \(I_2\) flowing counterclockwise is induced in the loop (mark the direction on the figure to make your intention clear).

(iii) No current is induced in the loop.

(a) An attractive horizontal force exists on the loop.

(b) A repulsive horizontal force exists on the loop.

(c) A vertical force exists on the loop.

(d) No net force exists on the loop.