J00E.2—Pitching Pennies into a Magnet

Problem

If one pitches a penny into a large magnet, eddy currents are induced in the penny, and their interaction with the magnetic field results in a repulsive force, according to Lenz' law. Estimate the minimum velocity needed for a penny to enter a long, solenoid magnet with central field $B = 1$ T and diameter $D = 0.1$ m.

You may suppose that the "penny" is actually a thin ring (torus) of radius a, cross-section area πb^2 where $b \ll a$, mass density ρ and conductivity σ. The "penny" moves so that its axis always coincides with that of the magnet, as shown in the figure below. Ignore gravity. The speed of the "penny" is low enough that the magnetic field caused by the eddy currents may be neglected compared to that of the solenoid. Equivalently, you may assume that the magnetic diffusion time is small.