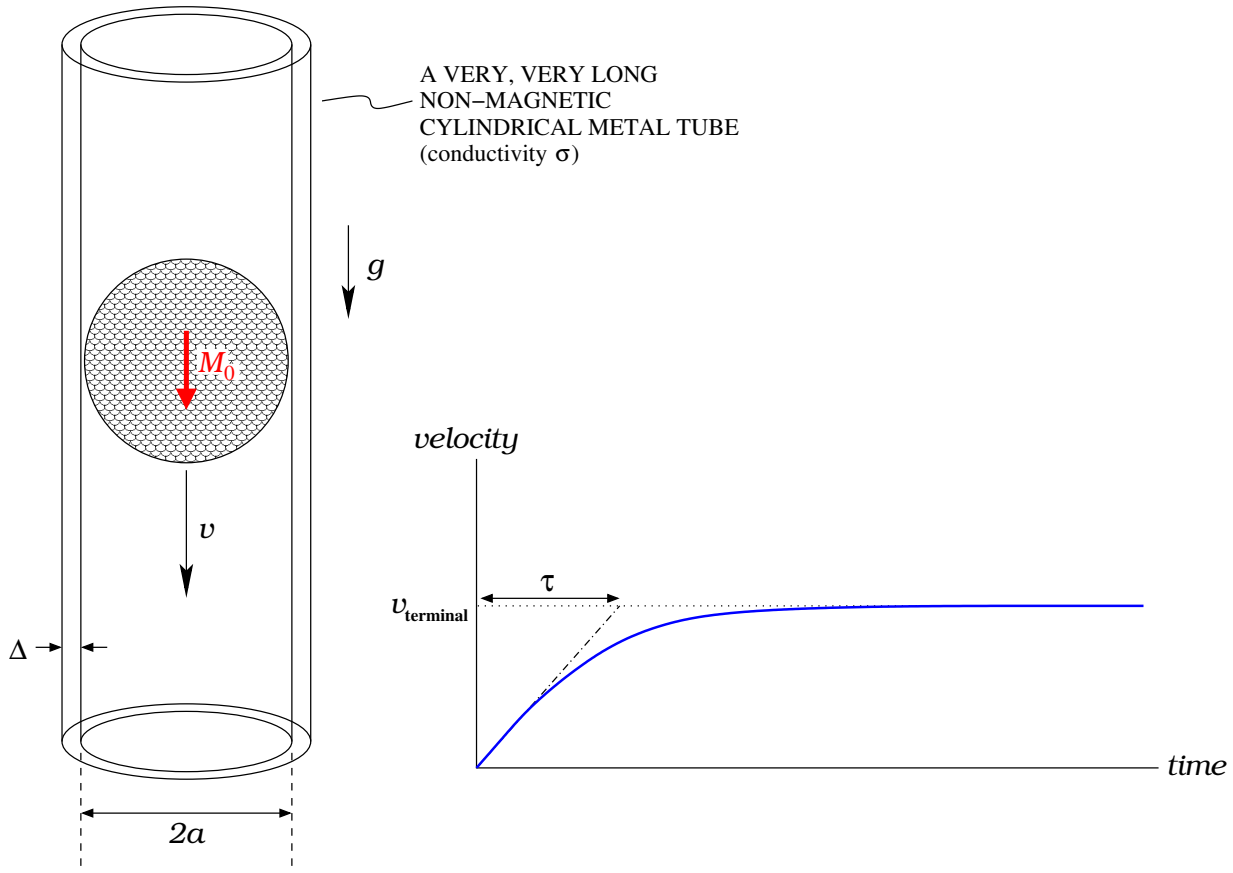
Problem 7 Falling Ball Magnet
Deadline June, 30 2012

A solid ball magnet (with uniform permanent magnetization $\mathbf{M}_0$) of mass m and radius a is dropped from the top of a metallic conducting tube (whose inner radius is a tiny bit larger than a and has thickness $\Delta \ll a$). Denote the conductivity of the metal by σ and the gravitational acceleration by g. As the ball magnet is released from rest, it will start falling and eventually it will reach a certain terminal velocity. Some details can be found in the schematics below, and several simplifying assumptions are as follows:

- Ignore air friction as well as friction between the ball and the tube.
- For simplicity, one may assume that the magnetization of the ball is oriented vertically down and the ball does not rotate as it falls down.



(a). Calculate the magnetic breaking force for the ball magnet in terms of the given quantities and relevant physical constants.

(b). Calculate the terminal velocity of the magnetic ball.

(c). Calculate the time scale τ for the magnetic ball to reach terminal velocity in terms of the given quantities and relevant physical constants.