Physics 208 Group Problem

In class tomorrow we will demonstrate how strong magnets can slow down a guillotine blade of falling copper so that it doesn't fall with enough momentum to do any damage. This can be explained using the Faraday effect and Lenz' law.

To make the problem simpler, think of a 20cm X 30 cm rectangular loop of copper wire instead of a solid sheet of copper. Gravity causes this loop to fall vertically into the field. The loop has a resistance of 0.5mΩ (0.5x10^{-3} Ω), and the loop has mass 1 kg.

Also to make the problem easier, think of a uniform magnetic field of strength 1 T that has a finite spatial extent. In this problem, we only consider the situation when the loop is partially in the field. This model system is illustrated below.

The loop is shown after it has entered 5 cm into the magnetic field.
A) What is the value of the magnetic flux into the page through the loop?

B) The loop now moves an additional 5 cm in the direction shown. Has the magnetic flux through the loop into the page increased or decreased?

C) It took the loop 0.5 s to move the 5 cm in part B). According to Faraday’s law, what is the magnitude of the EMF induced around the loop?

D) What is the magnitude and direction of the current that results from the EMF in C)?

E) What is the magnitude and direction of the force on the loop from the magnetic field?

F) Would this force be greater or smaller when the loop is moving more slowly?

G) If the only other force acting on the loop is the force of gravity, does the loop speed up, slow down, or move at constant velocity as a result of interacting with the field?

H) At some particular speed, the net force on the loop is zero, and the loop moves at constant velocity. This is the terminal velocity. Calculate the terminal velocity of the loop. This is the speed of the guillotine blade slowed by the magnets.