

8.02X Electricity and Magnetism

Practice Quiz #3

Problem 1 (25 points)

In the EB experiment, you saw that as you slowly turned up the gap voltage V_G , at some point a spark between the two electrodes developed and a current started flowing in your circuit.

- (a) Describe the process that leads to the creation of free charge carriers (2-3 sentences) in the air gap.

- (b) Assume that the spark developed for a potential difference $V_G = 500V$ for a gap width of 0.05mm. How big is the critical field for the gas?

- (c) You see lightning between a cloud that is 1000m high and the ground. Estimate the potential difference between the cloud and ground before the lightning strike, assuming the same gas as used for part (b).

Problem 2 (25 points)

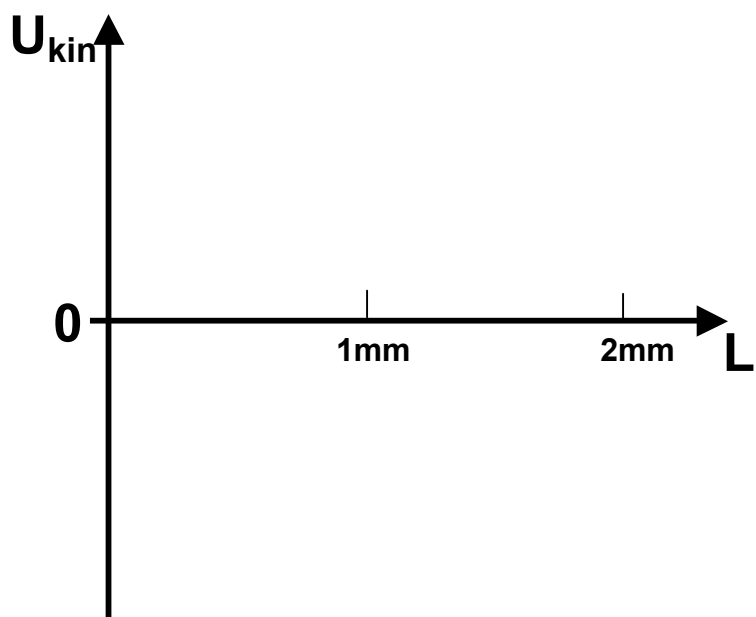
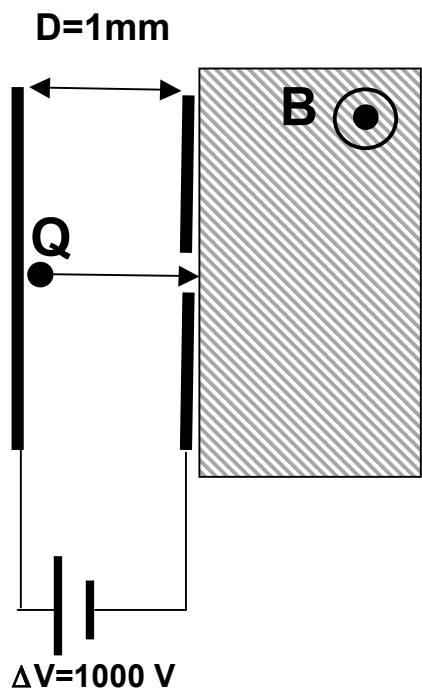
A particle with charge $Q > 0$ and mass m is released from the positive electrode of a parallel plate capacitor (see the cross-section shown below) and eventually passes through the small hole in the second electrode into a region of uniform magnetic field. The magnetic field is pointing out of the paper plane. The particle is non-relativistic, i.e. its kinetic energy and momentum are related by $U_{\text{kin}} = p^2/(2m)$.

- (a) On the drawing, sketch the electric field lines created by the capacitor. Neglect fringe effects.

- (b) On the picture, sketch the trajectory of the charged particle after it has entered the magnetic field.

- (c) On the graph, sketch how the kinetic energy U_{kin} of the particle changes, as it moves along its trajectory through the electric field and then the magnetic field. L is the path length along the trajectory of the particle, starting from the positive electrode. The distance between the capacitor plates is 1mm. Assume that the magnetic field is weak enough, such that the particle travels at least a distance $L > 1\text{mm}$ in the magnetic field.

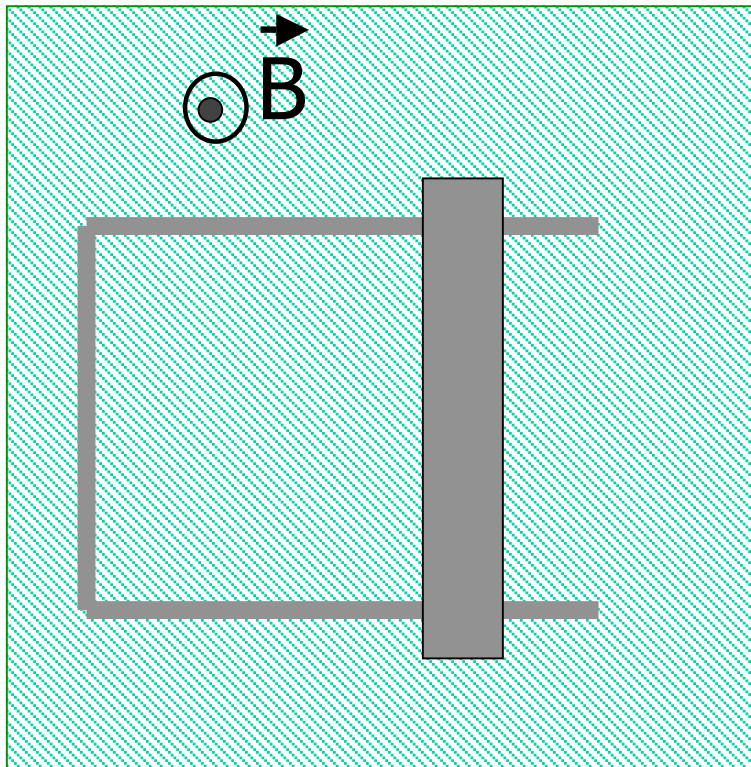
- (d) On the picture, draw the trajectory for a particle with charge $4*Q$, but the same mass m , assuming it starts from the same point as the first particle.



Problem 3 (25 points)

Shown below is a conducting rod that is movable on a U-shaped conducting rail. The rod and rail sit inside a uniform magnetic field created by an electromagnet. The magnetic field is pointing out of the paper plane. There is a constant, counter-clockwise current flowing in the loop formed by rod and rail, even though there is no battery or power supply connected to them.

- (a) Is the rod sitting still or moving? If it is moving, which direction is it moving in? If it is moving, is it moving at a constant velocity or accelerating? Explain your answers!
- (b) Suppose the rod was sitting still and there was no current in the loop formed by rod and rail. If then the electromagnet was switched off, such that the magnetic field rapidly dropped to 0, what would happen to the rod? Explain your answer.



Problem 4 (25 points)

Shown below are two current loops, each carrying a current I_0 . The current in loop 1 (top) is clockwise, the current in loop 2 (bottom) is counterclockwise. The distance d between the loops is small compared to their radius R , such that they can be approximated as two parallel “infinite” wires.

- (a) On the drawing, indicate the direction of the field created by the current in loop 1 at the right-most point of loop 2 .
- (b) Using Amperes law, find the magnitude of the field created by the current in loop1 at the location of loop 2 (recall the approximation suggested above!). Show your work!
- (c) Find the magnitude of the force exerted on loop 2 by loop 1 in terms of the current I_0 , distance d and radius R . Is the force attractive or repulsive?

