Problem 2 (20 points) Lorentz-Force

The diagram below shows the trajectories of three charged particles moving in a uniform magnetic field of strength B. The field points into the plane of the paper. The particles are moving in the plane of the paper. The direction in which each particle is moving is shown by the arrows.

(a) For each particle, find if the charge is positive or negative (Q>0 or Q<0).

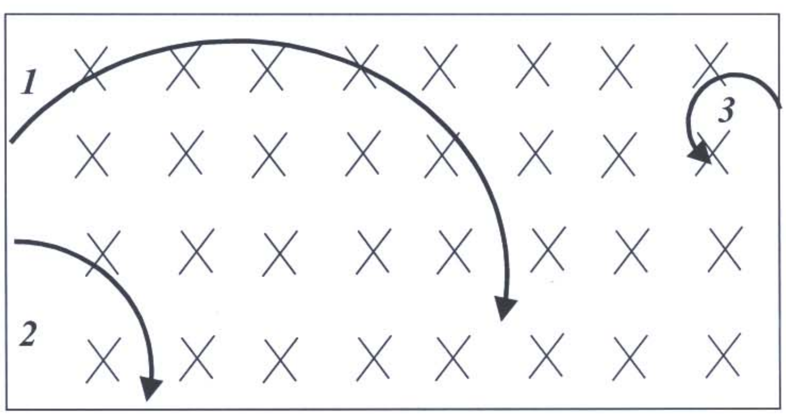
Q1: < 0 **Q2:** < 0 **Q3:** > 0

(b) Assume all particles have the same momentum. Which particle has the greatest magnitude of charge |Q|? Explain your answer in a few sentences.

Magnetic force $= qvB = \frac{mv^2}{R}$

The greater charge has a smaller bending radius.

$|Q_3|$ is the greatest



Problem 3 (20 points) Ampere, Biot-Savart

Shown below in fig. A, is a very long (assume infinite) thin wire carrying a current *I*.

(a) What is the direction of the magnetic field at point X_1 in the midplane of the wire, for the direction of I shown in the figure? Assume that both the wire and X_1 are in the plane of the paper and indicate the direction of the field on fig. A.

(b) Using Ampere's law, find the strength of the magnetic field created by the current I at point X_1, which is at a distance R_1 to the wire. Answers without work will not receive credit.

$$\oint B \cdot dl = B \cdot 2\pi R_1 = \mu_0 I$$

$$\boxed{B = \frac{\mu_0 I}{2\pi R_1}}$$

(c) Now assume that the wire, with the same current *I*, is bent by 90 degrees in the midplane (see fig. B). What is the magnitude of the magnetic field at the same point X_1 now? Explain in a few sentences. (Hint: The answer does not require any extensive calculation.**)**

Every contribution to B below the bend was matched by a current above the plane in Figure A. The bent wire does not contribute.

Therefore $B = \frac{1}{2} B_{\text{figure A}} = \boxed{\frac{\mu_0 I}{4\pi R_1}}$

Figure A

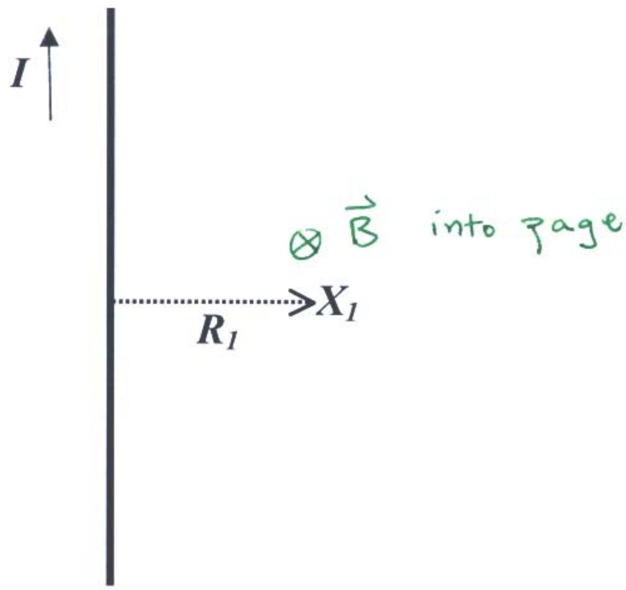
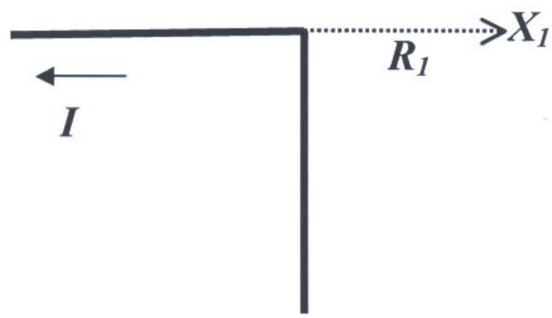


Figure B



Problem 4 (20 points) Lenz' Rule, Faradays Law

Shown below is a schematic view of a conducting loop falling through a uniform magnetic field. The field is pointing into the plane of the paper. The loop is located in the plane of the paper and is moving downward under the influence of gravity (neglect mechanical friction). The drawing shows three positions of the loop: (I) While it is entering the magnetic field, (II) while it is moving inside the magnetic field and (III) while it is exiting the magnetic field.

(a) For each step, state whether the magnitude of the magnetic flux through the loop, $|\Phi_B|$, is increasing, constant or decreasing.

(I): increasing
(II): constant
(III): decreasing

(b) For each step, indicate on the drawing whether the induced current is clockwise, counter-clockwise or zero.

(c) How does the velocity of the loop change, while it is completely inside the field (e.g. position II) ? Explain in a few sentences. Consider which forces are acting on the loop in this case.

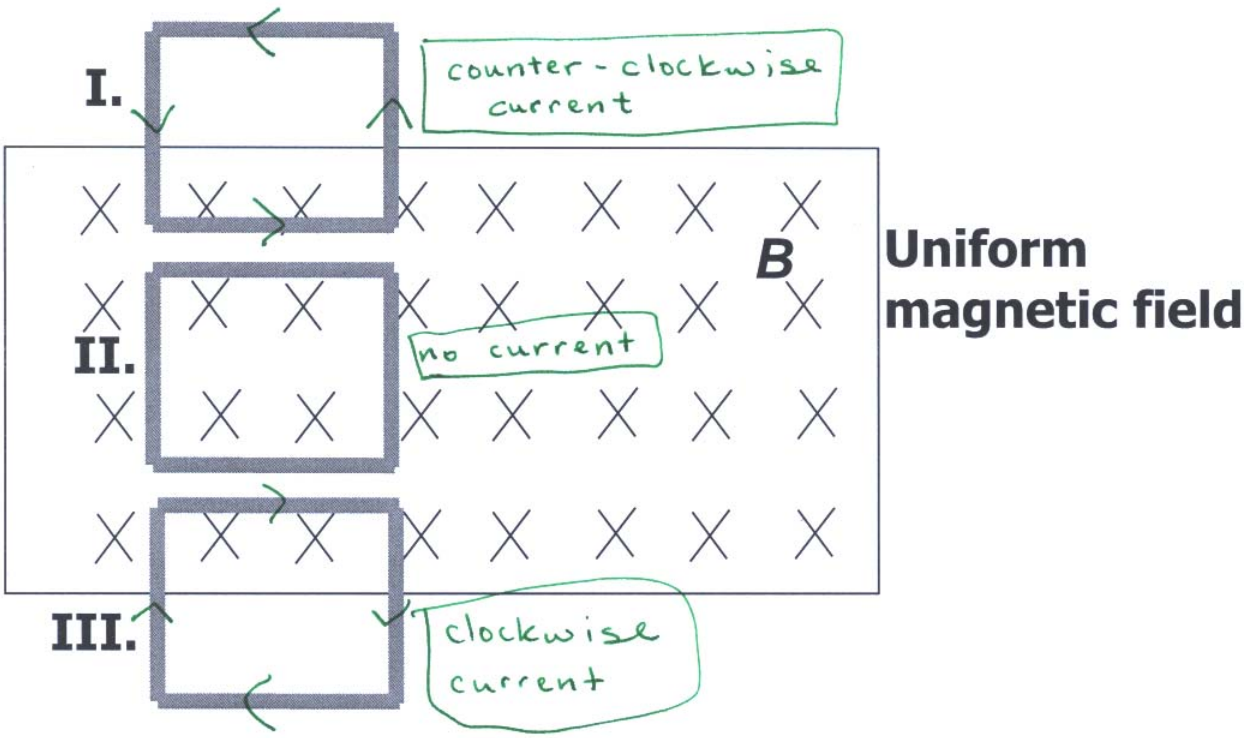
When completely inside the field

current = 0

so the only acting force is gravity.

the velocity increases.

Falling conducting loop



Problem 5 (20 points) Experiment MF

Shown below is a schematic view of the two coils in experiment MF. The currents in both coils are clockwise, as shown on the drawing, and the coils are centered on top of each other. The distance between the coils is small compared to their radius

(a) Indicate on the figure the direction of the field due to coil 2 at point X_1.

(b) Indicate on the figure the direction of the force on coil 1 at point X_1, due to the field from coil 2. Is the experiment set up for attraction or repulsion between the coils?

Attraction