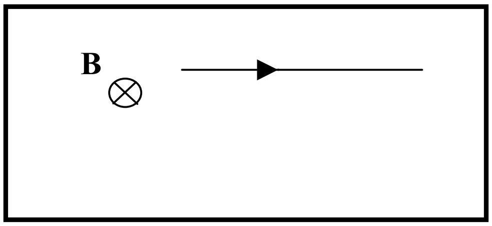
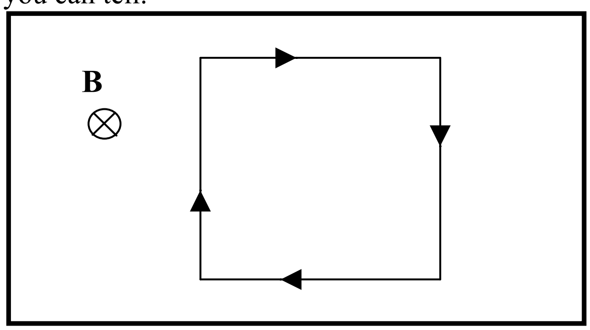
Torque on a Current Loop in a Magnetic Field

1. All ***throughout*** the boxed region below, there is a uniform magnetic field pointing ***into*** the page (as indicated by the cross). [This field is created by source currents outside of the region.] A wire segment carrying a current in the direction shown is placed inside the region. [Wires leading to the battery are not shown in this or in any subsequent figure.]

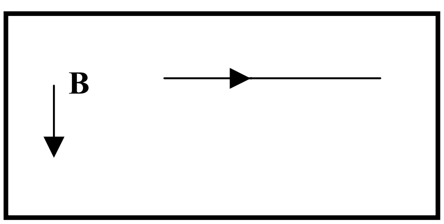


Indicate the direction of the force on the wire segment, using either arrows or the "dot" or "cross" symbols. If the force is zero, write "zero."

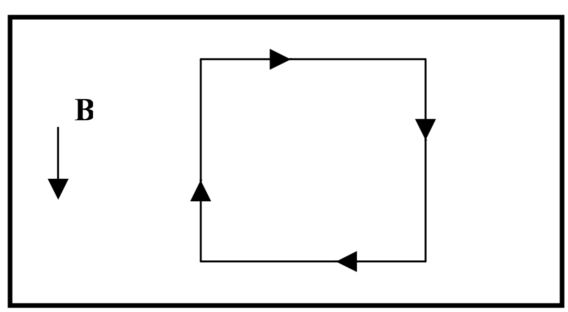
2. Now, a square wire loop carrying a steady clockwise current is placed in the region. (Current in each of the four sides is equal.) On each of the four sides of the loop, indicate the direction of the magnetic force (if there is one) or write "zero." Is there a ***net force*** acting on the loop as a whole? If so, state its direction. If not, explain how you can tell.



3. In this region, a uniform magnetic field is present that points toward the ***bottom*** of the page. A wire segment carrying a current in the direction shown is placed in the region. Indicate the direction of the force on the wire segment, using either arrows or the "dot" or "cross" symbols. If the force is zero, write "zero."



4. Now, a square wire loop carrying a clockwise current is placed in the region. On each of the four sides of the loop, indicate the direction of the magnetic force (if there is one.) Is there a ***net force*** acting on the loop as a whole? If so, state its direction. If not, explain how you can tell.



5. For the two cases of the square loops (i.e., in Questions #2 and #4), state whether you would expect there to be any motion of the loop at all that would move it away from its original position or orientation (assuming that it was free to move or twist). Explain your answer.

*Case I [figure in Question #2], magnetic field pointing **into** the page:*

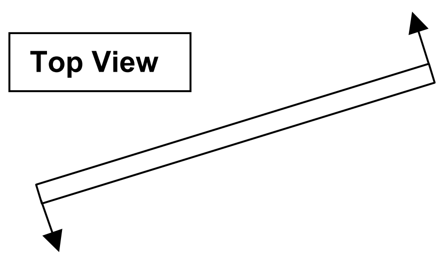
*Case II [figure in Question #4], magnetic field pointing toward the **bottom** of the page:*

6. Consider the case of a meter stick lying on a low-friction surface, with equal forces applied to the two ends in the directions shown.

a) Is there a net force on the meter stick? Explain.

b) Will the stick move in any way? Explain.

c) Check that your answers to #5 are consistent with your answer to this question about the meter stick.



7. When forces are applied to an object in such a way that the object would twist or rotate, we say that there is a net ***torque*** on the object. Suppose the direction of the current flow were reversed in the two cases where the current loops were present. (So, instead of flowing in a clockwise direction, the current now flows ***counterclockwise***.) For each case, state (a) whether there would be a ***net force*** on the loop, and (b) whether there would be a ***net torque*** on the loop.

I. *Magnetic field pointing **into** the page, current flowing counterclockwise in the loop:*

a) net force?

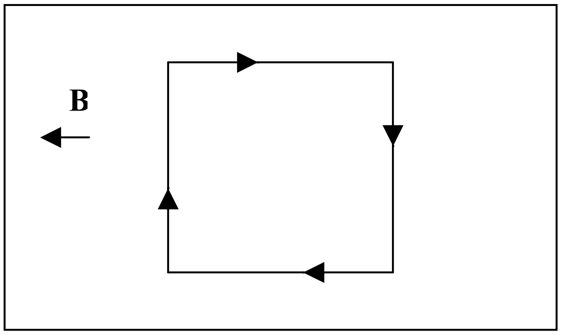
b) net torque?

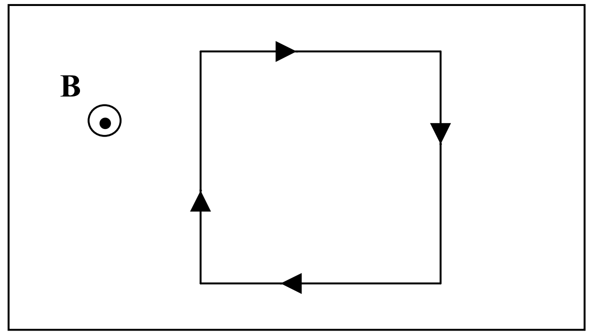
II. *Magnetic field pointing toward the **bottom** of the page, current flowing counterclockwise in the loop:*

b) net force?

b) net torque?

8. For the two cases below, again indicate the direction of the force (if any) on each side of the loop. State whether there is a net force on the loop, and whether there would be a net torque on it.





9. We can now see the importance of the relative orientation of ***(a) the "external" magnetic field*** and ***(b) the plane of the loop.*** (We have examined cases where the field is either ***perpendicular*** to the plane of the loop, or ***parallel*** to that plane.) Try to come up with a general rule that relates this relative orientation to the presence of either a net force, or a net torque, on the loop. [Although here we have been discussing a square loop only, it can be shown that these rules are true for ***any*** closed loop, of ***any*** shape.]

10. This is a ***side view*** of a square current-carrying loop that is free to move or rotate. The three boxes show three different orientations of the loop with respect to the external magnetic field. (In #1, the current flows up and toward the right on the long side shown, then ***into*** the paper, then down and toward the left on the "invisible" side, and then ***out*** of the paper.) The direction of the external uniform magnetic field is indicated. In all three cases, show the directions of the forces on the three "visible" sides of the loop, and indicate the direction of the force on the "invisible" (fourth) side.

Explain what will happen to this loop. Is there a net torque or net force acting on it:

i) In Case #1?

ii) In Case #2?

iii) In Case #3?