Flipping Physics Lecture Notes:
Induced Forces on Current Carrying Loops
http://www.flippingphysics.com/induced-force-loops.html

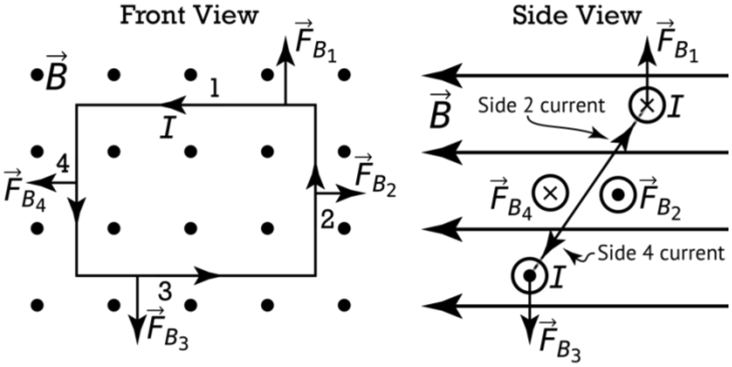
Next, let's look at a conductive loop which has a current induced in it, something we talked about previously[1], that induced current is now a bunch of charge carriers which are moving in a magnetic field. Those moving charges now have induced forces acting on them, again this is something we talked about quite a before now[2]. The following equations determine that magnetic force:

$$\vec{F}_B = I\vec{L} \times \vec{B} \Rightarrow \|F_B\| = ILB\sin\theta$$

Let's walk through an example.

Below is a front view and a side view of a conducting loop in the shape of a rectangle. Let's start by only looking at the front view. Again, all directions for now refer to the *front view only*.

- A uniform magnetic field is directed out of the page and is decreasing.
- That means the magnetic flux through the loop is decreasing.
- Lenz' law states the induced B field is out of the page to counteract the decreasing magnetic flux.



- Using the alternate right-hand rule
    - Fingers curl with the induced B field, out of the page.
    - Thumb points counterclockwise with induced current.
- The right-hand rule on the induced current in side 1 of the loop:
    - Fingers point to the left in the direction of the induced current.
    - Fingers curl out of the page in the direction of the original magnetic field.
    - Thumb points up in the direction of the induced magnetic force on side 1.
- For the remaining sides the right-hand rule shows the induced magnetic forces are:
    - To the right on side 2.
    - Down on side 3.
    - To the left on side 4.
- Notice that the net induced magnetic force on the loop equals zero!
    - The induced magnetic forces on sides 1 and 3 are equal and opposite.
    - The induced magnetic forces on sides 2 and 4 are equal and opposite.

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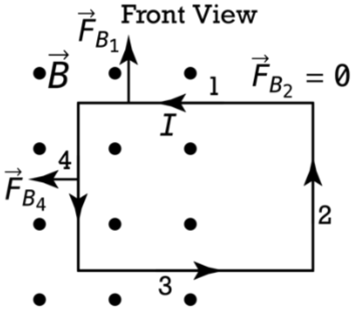
[1] Electromagnetic Induction

[2] Magnetic Force on Current

Now let’s switch to the side view. Again, all directions for now refer to the *side view only*.

- Side 1: The induced current is into the page, and the induced magnetic force is up.
- Side 2: The induced current is up and to the right, and the induced B force is out of the page.
- Side 3: The induced current is out of the page, and the induced magnetic force is down.
- Side 4: The induced current is down and to the left, and the induced B force is into the page.
- You can see the net induced magnetic force on the loop is still zero, however, …
- The induced magnetic forces cause a net torque on the loop! Net torque is not zero!
    - Assuming the loop is not attached to anything, the net torque on the loop would cause an angular acceleration around its center of mass which is counterclockwise at this specific moment in time.



Now let’s change the example by making it so the magnetic field abruptly ends partway through the loop.[3]

- Again, the magnetic field is uniform, directed out of the page, and is decreasing in magnitude.
- Lenz’ law gives us the same direction for the induced current in the loop; counterclockwise.
- Using the right-hand rule to determine the directions of the induced magnetic force:
    - Side 2: This entire side of the wire is not in the magnetic field, so there is *no induced magnetic force on side 2!*
    - Side 4: Everything is the same here. Induced magnetic force is to the left.
    - Sides 1 and 3: The directions are the same as before (1 is up, 3 is down), however, only the part of each side which is in the magnetic field will experience an induced magnetic force, therefore, the magnitudes of these induced magnetic forces are smaller than in the previous example.
- The net induced magnetic force on this loop *does not equal zero.*
    - The induced magnetic forces on sides 1 and 3 are equal and opposite.
    - The net force would accelerate the loop to the left.

In other words, the net induced magnetic force on a current carrying loop:

- Which is entirely in a uniform external magnetic field always equals zero.
    - (The induced magnetic forces can cause a net torque on the loop.)
- Which is only partially in a uniform magnetic field is nonzero.
    - This can cause a translational acceleration of the loop.

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[3] I would argue that creating a magnetic field which looks like this is impossible, however, it is helpful for learning. So, step off!