I. Induced currents
A. A copper wire loop is placed in a uniform magnetic field as shown. Determine whether there would be a current through the wire of the loop in each case below. Explain in words your answer in terms of magnetic forces exerted on the charge carriers in the wire of the loop.

1. When the loop is stationary.

2. When the loop is moving to the left.

B. Suppose that the loop is now placed in the magnetic field of a bar magnet as shown.

1. On the diagram, label the north and south poles of the magnet.

2. Determine whether there would be a current through the wire of the loop in each case below. If so, draw the direction of the current. Explain in words your answer in terms of magnetic forces exerted on the charge carriers in the wire of the loop.

   a. When the loop is stationary.

   b. When the loop is moving away from the bar magnet.
3. Which side of the loop appears to be a *north magnetic pole*?
   a. When the loop is stationary.
   b. When the loop is moving away from the bar magnet.

4. Is the loop *attracted toward* or *repelled from* the bar magnet?
   a. When the loop is stationary.
   b. When the loop is moving away from the bar magnet.

5. Does the force exerted on the loop tend to complement or oppose the motion of the loop and bar magnet?
   a. When the loop is stationary.
   b. When the loop is moving away from the bar magnet.

II. **Lenz's Law**

A. To the right is a QR code that will open a simulation. If you don’t know how to open a QR code, ask your TA/LA. Or you can search for “faraday law phet”; it will be the first link. The direct URL to the simulation is: [https://phet.colorado.edu/sims/html/faradays-law/latest/faradays-law_en.html](https://phet.colorado.edu/sims/html/faradays-law/latest/faradays-law_en.html)

Once you have opened the simulation, play around with it to get a feeling for how everything works. Turn on the field lines so you can see how they pass through the loop.
1. When the magnet is stationary, is there a current through the loop? Does this match your results from section I.B.?

2. Now move the magnet towards the loop and watch how the ammeter and light bulb react. Is there a current through the loop? Does this match your results from section I.B.?

3. Think about how the field lines change through the loop. Explain in words how you could simulate a magnetic field decreasing with time.


To understand the interaction between the wire loop and bar magnet in section I, it is possible to predict the results using only the Lorentz force \( F_B = q\vec{v} \times \vec{B} \) and the motion of the charges in relation to the magnetic field lines. In each of those cases there was an induced current when there was relative motion between the bar magnet and the wire loop. In other situations such as the one in Part II, however, there is an induced current in the wire loop even though there is no relative motion between the wire loop and the bar magnet. There is a general rule called Lenz’s law that we can use in all cases to predict the direction of the induced current. Lenz’s law can be stated in different ways. One common way of stating Lenz’s law is:

*Current is induced in a conducting loop when the external magnetic flux through that loop is changing. The induced current creates a magnetic flux that opposes the change in external flux that created it.*
B. A wire loop moves from a region with no magnetic field into a region with a uniform magnetic field pointing into the page.

The loop is shown at two instants in time, \( t = t_0 \) and \( t = t_0 + \Delta t \).

1. For the time interval shown, does the magnetic flux through the loop due to the external field increase, decrease, or remain the same? Explain in words your reasoning.

2. Use Lenz’s law to determine whether the induced magnetic field at the center of the loop is into the page, out of the page, or zero. Explain your reasoning.

3. Based on the direction of the induced magnetic field, what is the direction of the induced current in the loop?

4. What is the induced emf in the loop? Your answer should be in terms of \( w, h, x, B, v_0, \) and \( \Delta t \).

5. If \( w = 3 \text{ m}, x = 0.3 \text{ m}, h = 1 \text{ m}, \Delta t = 0.5 \text{ s}, B = 1 \text{ T}, \) and \( v_0 = 2 \text{ m/s}, \) what is the magnitude of the induced emf in the wire loop?