Physics PreLab 212-6

Generating Generators

Name ______________________________

Section ____________ **Date** ________

A Scientific Revolution

You have witnessed the fact that moving electric charges cause magnetic fields. Most readily this was seen in the magnetic fields around current-carrying wires. We next explore the symmetric question that can be stated, "Can magnetic fields cause charges to move?" or equivalently "Can magnetic fields cause electric fields?"

You will discover the answer in this week's lab, but let us start by tipping our hand. Michael Faraday, and independently Joseph Henry, discovered that *changing* magnetic fields could cause electricity to flow. Note that word, *changing.*

Consider the square loop of wire illustrated in Figure 1.

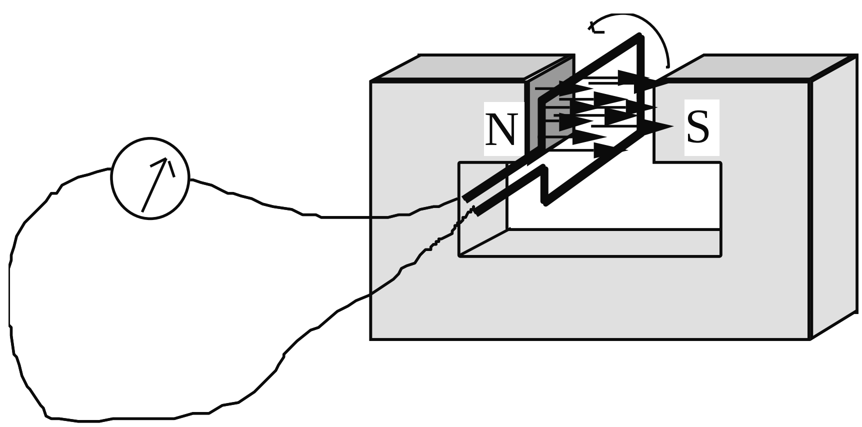

Figure 1. Rotating loop in uniform magnetic field

The *magnetic flux* through a loop of area A is defined to be the area of the loop times the component of the B field perpendicular to the plane of the loop. Since we are interested in the effects of a magnetic field on a loop of wire, the area A under consideration would be the surface enclosed by that loop. We can treat this area as a vector by assigning it a direction normal to the surface. Given this surface vector **A** and the magnetic field **B**, the magnetic flux Φ through the surface is given by

$$\Phi = \int \mathbf{B} \bullet d\mathbf{A} \qquad \text{(Eq. 1)}$$

For a flat surface in a constant field, this reduces to

$$\Phi = \boldsymbol{B} \bullet \boldsymbol{A} = B_{\perp}A = BA\cos\theta \qquad \text{(Eq. 2)}$$

where $B_{\perp}$ is the perpendicular component of the magnetic field lines plunging through the surface. It can be shown that Φ is proportional to the number of B-lines that pass through the loop.

In previous labs, you actually encountered the idea of magnetic flux when you examined how the magnetic field probe works. Recall the importance of the probe's correct orientation in a magnetic field for it to give the full field-strength reading. Your magnetic probe actually measured the *magnetic flux* through the Hall effect device. Once we know the magnetic flux (in G·m^2 or T·m^2) we can calculate the average magnetic field through the loop by dividing by the area the loop encloses. If the probe area is small enough, this value gives an accurate measure of the local field strength.

Imagine that we rotate the loop in Figure 1 at a uniform rate. Recall that the magnetic flux is proportional to the number of field lines you might have drawn to represent the field. There is a direction associated with the magnetic field and with the area of the loop. Consider the position of the loop in Figure 1. Imagine that in this position (at zero angle), the flux is at a maximum. For a reversed loop (180° flip), the flux magnitude is the same, but the direction of the area of the loop has reversed. This is just a statement that the dot product in Equation 1 has changed sign. What you will find out in this lab is that the changing magnetic flux will result in a current flow through the loop in Figure 1.

Q1[8'] Make a sketch of the magnetic flux passing through the area of the loop as a function of the rotation angle θ on the axes of Figure 2.

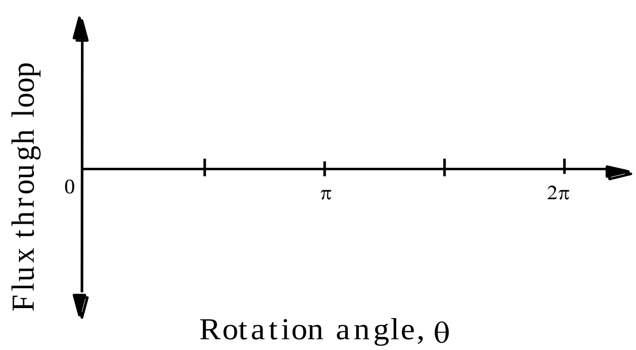

Figure 2. Flux through rotating loop in uniform magnetic field

Consider a bar magnet (north end on the right side) riding on a *frictionless* track as shown in Figure 3. Suppose the bar magnet has a mass of 3 kg and it starts at point a, at a height of 0.6 m above the lowest point of the track. For the moment, ignore those loops of wire at the track midpoint.

Q2[8'] What are the kinetic energy and the speed of the magnet at the lowest point on the track?

Kinetic energy ________ [J]

Speed ________ [m/s]

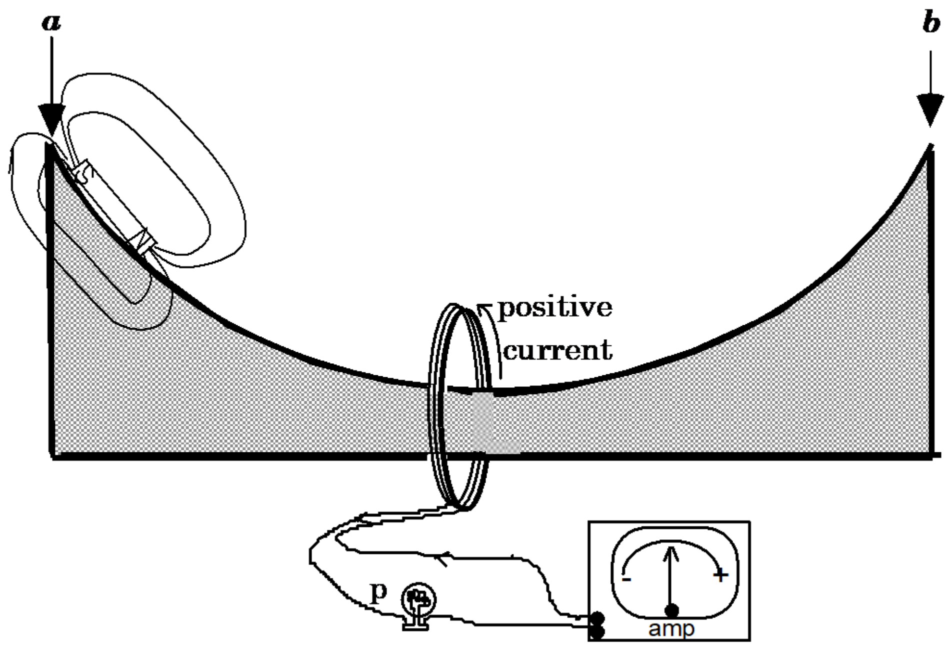

Figure 3. The magnet coaster

Carefully consider the flux through the loops as the magnet goes from position *a* to position *b* along with the track. Assume that at both position *a* and *b* the flux through the loop is zero. Keep the directions in mind as you go.

Q3[8'] Make a sketch of flux through the loop as a function of the cart position as it moves from *a* to *b* then back to *a* on the axes of Figure 4. (Hint: the flux depends <u>only</u> on the magnetic field (<u>always</u> basically to the right) and the area vector of the loop (assume that is also pointing to the right).

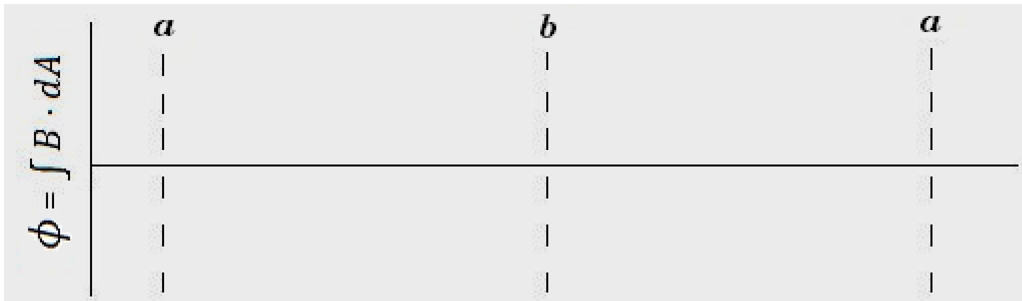

Figure 4. Flux through loop

Q4[8'] Make a sketch of the *rate of change* of flux through the loop as a function of the magnet position as it moves from *a* to *b* and back to *a* on the axes of Figure 5 based on your sketch in Figure 4.

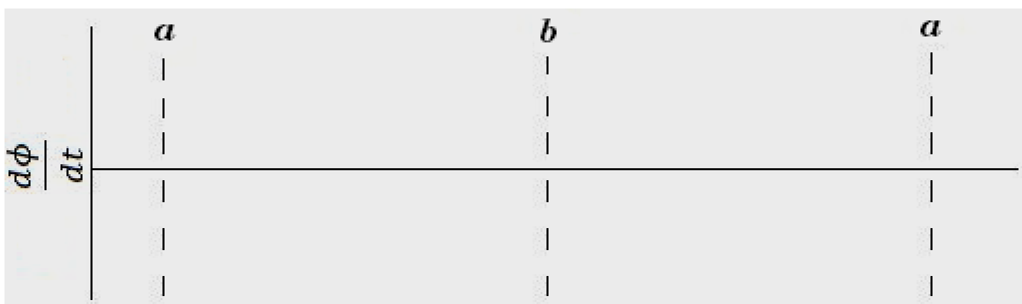

Figure 5. Rate of change of flux through loop

Let us put a bit of this together. As the flux *changes* through the surface defined by the loops, an EMF (<u>E</u>lectro<u>m</u>otive <u>F</u>orce) is generated there. This is true even if there are no wires there! But because there *are* wire loops there, the electrons in the wire can respond to this EMF, generating a current in the wire. In principle, the induced current could be sufficient to light the bulb shown in Figure 3. Assume that it is.

Q5[8'] How many times does the bulb blink (i.e. turn on) over the course of **three** complete ***round trips***?

Q6[5'] Where does the energy come from that lights the bulb?

Q7[5'] Continuing with the assumption that no friction exists, does the magnet reach the same peak height at the end of each return trip?[2'] Why?[3']

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In this lab you will be asked to determine the direction of induced currents. The easiest way to do this is to realize that induced currents create magnetic fields that oppose the motion of things causing a change in flux. For example, if you push a magnet into a coil, the induced currents will try to prevent the magnet from being pushed in. Similarly, if you pull a magnet out of a coil, the induced current will try to prevent the magnet from being pulled out.