

Faraday's law

Reading assignment

Ulaby, 6-1, 6-2, 6-4, 6-6

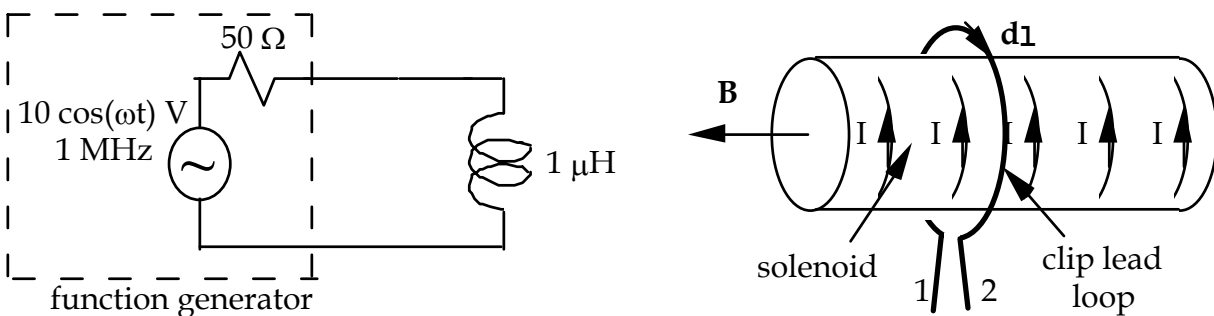
Connor and Salon VIII-1 6 VIII-3

Experiment 1 - Faraday's law for fixed loops (part 1)

a. Hook up the circuit shown on the left. The $1\ \mu\text{H}$ inductor is a solenoid. Take a pair of clip leads connected to a coax cable and wrap them around the solenoid as shown on the right. Try to minimize open space in the clip leads' loop.

(Note: The function generator's amplitude readout assumes a $50\ \Omega$ load which we don't have. A 10 V Peak-to-Peak setting is really a 20 V Peak-to-Peak on the ideal source).

What do you measure on the oscilloscope?

**Problem 1 - Faraday's law for fixed loops**

For a solenoid, $\mathbf{B} = \mu_0 n I \mathbf{a}_z$ inside the solenoid and 0 outside where n is the number of turns per unit length.

- a. Circuit analysis. What are the current I and voltage V through the inductor? b. What is the flux, $\psi = \int \mathbf{B} \cdot d\mathbf{s}$, through the clip lead loop? I and B directions at $t=0$ are shown. Do this analytically and then obtain a numerical value for $n = 1560$ and solenoid radius $a = 2.5\ \text{mm}$. Pay attention to the signs/direction of $d\mathbf{l}$ and $d\mathbf{s}$.
- c. What is the emf induced around the loop? Again do an analytical calculation, but then plug in the numbers from above.
- 1) At $t=0^+$, $I > 0$ and $dI/dt < 0$; does a scope read $V_1 - V_2 > 0$ or $V_1 - V_2 < 0$?
 - 2) If the clip leads were connected through a low impedance, which way would current flow at $t=0^+$?
- d. Sketch emf and ψ vs time. What is the flux when the emf is largest?
- e. In the absence of the clip lead loop, what is \mathbf{E} ?

Experiment 1 - Faraday's law for fixed loops (part 2)

- b. Try various orientations and positions for the loops. Look at signal strengths and phase shifts vs. the inductor voltage. Some suggested experiments:
- 1) Put the loop at the end of the solenoid and compare signal vs the center.
 - 2) Include a lot of open space in the clip lead loop.

Faraday's law

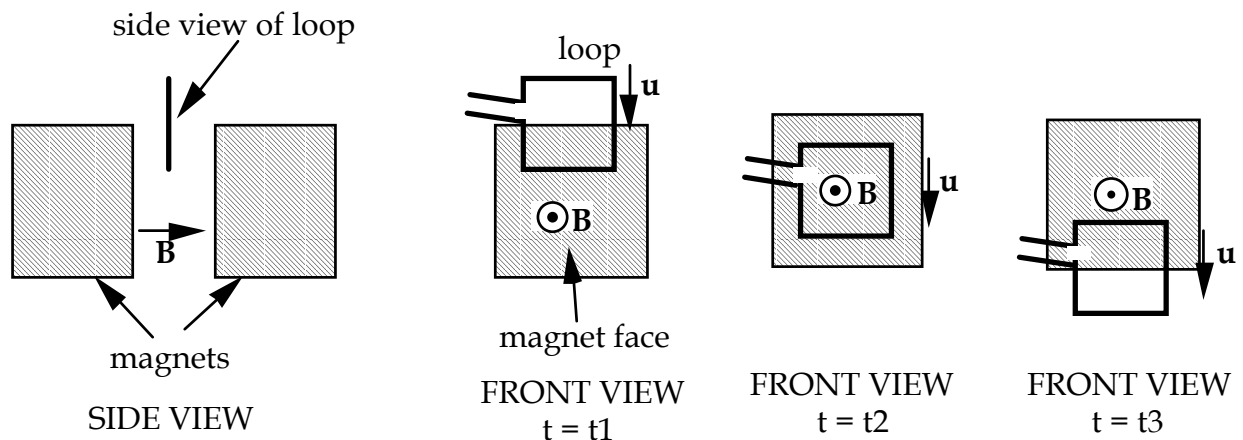
- 3) Connect the clip lead loop so that it does not encircle the solenoid (ala Fig. 5.6). Move it around and change orientation. Also vary the loop size.
- c. Estimate the electric field associated with various noise sources in the room by measuring $\oint \mathbf{E} \cdot d\mathbf{l}$ in the room at various positions. Then estimate \mathbf{B} .

Experiment 2 - Generators and Motors

- a. Connect the coil leads of a balance arm to the oscilloscope. Tap the balance arm and observe the signal produced. Estimate the change in flux linkage due to the vibrating arm. Estimate the resonance frequency of the arm.
- b. Set the function generator amplitude to 1.0 V P-P and the frequency to the resonance frequency of the arm. Connect the function generator output to the balance arm's coil. Vary the frequency and observe the motion of the arm. Try harmonics and sub-harmonics.

Problem 2 - Faraday's law for moving loops

A loop falls through the magnetic field between two pole faces at a constant velocity, u_0 . Assume that the magnetic field is B_0 between the pole faces and that the fringe fields are 0.



- a. Plot the flux through the loop, $\psi = \int \mathbf{B} \cdot d\mathbf{s}$, as a function of time.
- b. Calculate the emf around the loop using 6.40 for all times.
- c. Calculate the emf around the loop using 6.24 for the 3 times indicated.
- d. If the loop is connected across a low impedance output, will the current be in the clockwise direction, 0, or in the counter-clockwise direction? (Give a separate answer for each of the 3 times).

Faraday's law

A square loop with side length s , is spinning at a frequency ω in a DC magnetic field produced by a magnet. We'll use a very rough approximation that $\mathbf{B} = B_0 \mathbf{a}_z$ is a constant over the loop cross-sectional area. The center of the loop is at $(x,y) = (0,d)$. At $t = 0$, the loop lies in the x - y plane.

- Calculate the emf induced around the coil using Faraday's law as expressed in Eq. 6.40.
- Repeat part a. using Faraday's law as expressed in Eq. 6.24.
- What is the loop orientation when the emf is greatest? What is the flux through the loop at this time?
- Calculate the magnetic force on an electron that is sitting in the upper arm. What is the electric field that the electron sees in its frame of reference? What is the magnitude of the field for parameters, $s = 1$ cm, $B = 0.1$ T and 10 Hz rotation.

