

Lab 4. Magnetic Measurements and Faraday's Law

Name: _____ Date: _____

1 Introduction

Faraday's law states that a voltage $e(t)$ is induced at the terminals of a coil that "sees" a time-varying magnetic flux $\Phi(t)$

$$e(t) = -\frac{d\Phi(t)}{dt} \quad (1)$$

For an N turn coil, each turn having an area A , the magnetic flux is $\Phi(t) = B(t)NA$, where B is the magnetic flux density. If the coil voltage $e(t)$ is electronically integrated through an integrator as shown in Figure 2, then

$$V_{out}(t) = -\frac{1}{RC} \int_0^t e(t') dt' \quad (2)$$

where RC is the time constant of the integrator. Combining (1) and (2), we obtain

$$V_{out}(t) = -\frac{1}{RC} NA [B(t) - B(0)] \quad (3)$$

If $B(0)=0$, then

$$B(t) = -\frac{RCV_{out}(t)}{NA} \quad (4)$$

In this demonstration you will insert a coil into the static magnetic field of a solenoid (or turn on the magnetic field with the coil in place) and use (4) to determine the magnetic induction $B(t)$ along the solenoid axis. You will compare to measurements made using a Bell Gaussmeter.

2 Procedure

1. Connect the coil to the Tektronix 7854 storage oscilloscope. The observing procedures are:
 - Triggering Setting: A trigger mode = auto, coupling=AC, source = line. Horizontal display: Time base A at 50ms/div, vertical display: 10mV/div.
 - Push the *stored* button.
 - Push the *agr* button and swing the coil fast through the magnet right after the push. Observe the waveform on the oscilloscope.

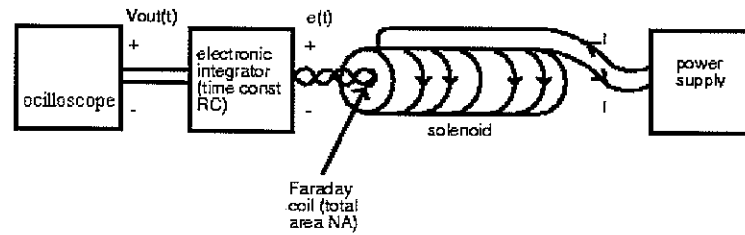


Figure 1:

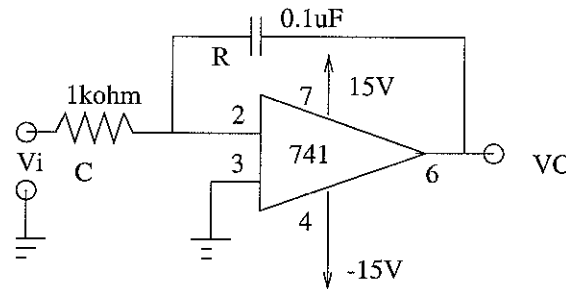


Figure 2:

- Repeat the above step until you can get the same waveform everytime.
- Record the waveform here. Mark the vertical and horizontal scales.

2. Calculate the estimated average voltage by

$$V = -2 * \frac{d\Phi(t)}{dt} = -2 * \frac{\Delta\Phi}{\Delta t} = -\frac{2BNA}{\Delta t} \quad (5)$$

The radius of the coil is _____

B at the gap measured by the Gauss Meter is _____ T

number of turns of the coil is _____

Δt read from the waveform is _____

The calculated V from measured B is _____ T

3. A schematic of the apparatus is shown in Figure 1. Make sure that the solenoid current is off. Insert the multiturn Faraday measurement coil into the center of the solenoid. Place the coil so that the coupling between the coil and the solenoid is maximum. Connect the coil to the electronic integrator input. The circuit of the integrator is

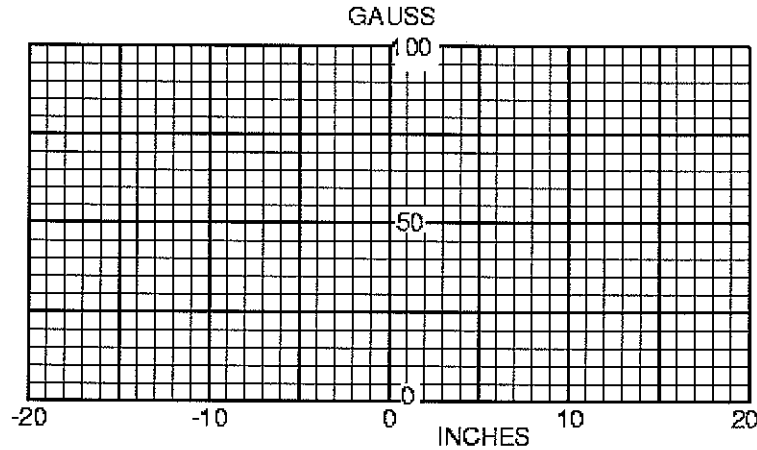


Figure 3:

shown in Figure 2. Connect the integrator output to the digital voltmeter. Zero the integrator when necessary. Then turn up the solenoid current to 3 amperes. Estimate the peak voltage swing from the oscilloscope.

$$V_{out} = \underline{\hspace{2cm}} V.$$

4. Using the Bell Gaussmeter, measure the axial magnetic induction $B(z)$ in the solenoid for a solenoid current of 3 amperes. Record the changes in magnetic field along the axis in Figure 3. Compare the measured magnetic induction in the center of the solenoid to the measured value from Faraday's law. Note: 1 gauss = 10^{-4} tesla.

The magnetic field B_1 at the end of the solenoid measured by the Gaussmeter is _____ Gauss

The magnetic field B_2 at the center of the solenoid measured by the Gaussmeter is _____ Gauss

Is B_1 approximately one half of B_2 ? Explain why.

Number of turns/m of the solenoid = _____ turns/m.

Area of the cross section of the coil = _____ m^2

R = _____

C = _____

Bell Gaussmeter measured _____ tesla

The result from Example 7.4 on page 300 of the textbook calculated _____ tesla

Faraday's law using (4) gives _____ tesla

5. From your measurements, estimate the external inductance L of the solenoid by

$$L = \frac{1}{I} \int_S B \cdot dS \quad (6)$$

$L =$ _____ mH