Experiments in Modern Physics
Introductory Lab: Magnetic Field Measurements
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Goal
Become familiar with operating the MPL 12-inch magnet and measuring and controlling the resulting magnetic field.

Introduction
The Modern Physics Lab (MPL) is the proud owner of an old, but hearty, regulated magnet capable of maintaining uniform magnetic fields up to about 15 kG. As this magnet (and others) will be used frequently in this class, you will learn how to operate this device and will map out the magnetic field.

Equipment
• 12-inch magnet with power supply and regulation apparatus: This device creates a magnetic field by maintaining a current in two coils. In between the coils, across the pole tips, the field is reasonably uniform (we will determine how uniform). The magnet may be run in "normal" (non-regulating) mode where a current is maintained through the coils. In regulating mode, a rotating probe is used to monitor the field, feedback to the power supply, and adjust the current to keep a fixed field.
• Hall-probe gaussmeter (Bell 610 or Walker MG-3A): This device uses the Hall effect[1] to measure the magnetic field.

Preparation
- Review your favorite E&M text to remind yourself of the derivation of the magnetic field from a solenoid and the concepts of magnetic saturation and hysteresis for a magnet with an iron core.
- Read Refs. [1,2] to understand the Hall effect.
- Read over the manuals for the magnet and control electronics and for the gaussmeter.

Task 1: Calibrate and position the Hall-probe gaussmeter.
- Following the instructions in the manual, zero and check the calibration of the gaussmeter. Keep the probe from the area of the magnet while calibrating (why?). Don't spend too much time calibrating with zero field as it is difficult to get the calibration precise at both low and high fields and you will be measuring high fields (several kG).
- Then, use the calibrated magnetic field box to calibrate the device. Think about errors at this step.
- Position the Hall-probe in the center of the air gap between the magnet pole tips. Remember that the Hall-probe is sensitive to a single component of the magnetic field vector, $\mathbf{B}$. 

Task 2: Start up the magnet in non-regulated mode.
- Turn on magnet cooling water.
- Make sure the current control switch (at bottom of control panel) is off and "mode select" switch is set to "field set"
- Turn control power on.
- Turn course current control knob (at bottom of control panel) all the way CCW and turn current control switch to "on".
- Press black "on" push button (lower right of control panel).
- Slowly turn course current control up and watch the magnet current. Be patient, the control circuits take a while to respond to any changes on control panel.
- Monitor the current to the magnet with a DVM on the current monitor point (above the current meter).

Task 3: Measure the magnetic field in the center of the magnet as a function of magnet current.
- Starting at zero current and working up, record the magnetic field as a function of current in ~10A steps up to a maximum current of ~100A. Repeat this working down from maximum current. Plot this data (with errors) and explain. Is the measured field zero at zero current? Does the measured field vary linearly with current?
- Using a value for the magnetic field from your measurements, the known current, and estimating the dimensions of the magnet, calculate the number of windings in magnet. Does it seem reasonable? How does the iron affect the field.

Task 4: Map the magnetic field across the gap of the magnet.
- At an intermediate value of the magnetic field (~6.5 kG), step the probe in x, y, or z to measure how the field changes with position. Pick a direction that has not been mapped by previous students so that we can achieve a fairly complete characterization of this magnet.

References