

8.02X Electricity and Magnetism

Problem Set 9

Issued: Wed, Apr 7

Due: Fri, Apr 15, 4PM <- note Date + Time!

Reading suggestions (from Young&Freedman)

Mon: Quiz 3

Wed: Faradays Law, Transformer Action, Inductance: 29-5, 31-6, 30-1 to 30-3

Fri: AC Circuits, 31-1 to 31-3 (Note: You can ignore phasor diagrams)

Homework Problems (30 points total)

Problem 1 (20 points) The 1200 dipole magnets of the LHC accelerator at CERN will have a field of 8 Tesla. Approximate the magnet as two square loops of dimension 14m x 0.3 m, with a distance of 10cm between the two loops (similar to the arrangement in question 4 of quiz 3).

- (a) What direction should the field have to keep protons going clockwise on a circular trajectory?
- (b) What is the current in each loop needed to create a field of 8T in the midplane of the two loops?
- (c) Again using pictures and words show that you get repulsion if the currents in the two wires run anti-parallel
- (d) . Assume that the field is homogenous at 8T over a cross-section of 200 cm². What is the total energy stored in the magnetic field of all dipoles combined?

Problem 2 (10 points) Explain why power is transformed to high voltages to be transported over power lines

Experiment AMP (Amplifier) (20 points total)

Note that check-off and experiment write-up for experiment 'Amplifier (AMP)' are due on Fri, 4/29. AMP questions are provided below. There will be 4 bonus points for MF check-off on or before 4/15, three bonus point for check-off on or before 4/22, two bonus points on 4/25 and 1 bonus point on 4/26.

The lab hours are Mon 3-5, Tues. 7:30-9:30 pm, Wed 7:30-9:30 pm, Thur 3-5, Fri 12-3.

You will be graded according to the following criteria:

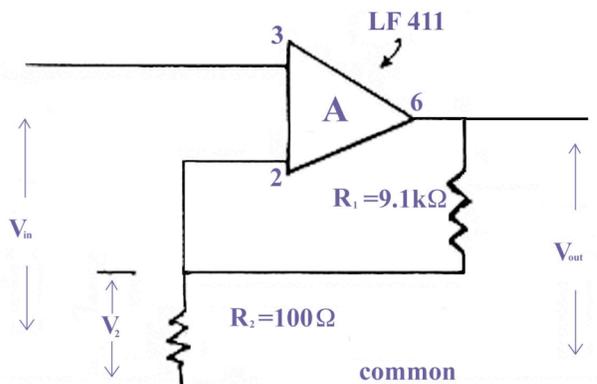
1. Your Experiment: Amplifier apparatus works (you will need to demonstrate a trial run during the check-off).
2. Your understanding of how to zero and calibrate your amplifier.
3. You may be asked a question during the check-off about how to calculate the gain of your amplifier.

Problem 1: Data Analysis

After you have made and tabulated your measurements of input and output voltages for the amplifier, plot the output voltage as a function of input voltage. Determine the gain of the amplifier in the region where the response is linear and compare your value with the theoretical expectation. Does the gain remain constant over the whole range of input voltages?

Problem 2: Amplification

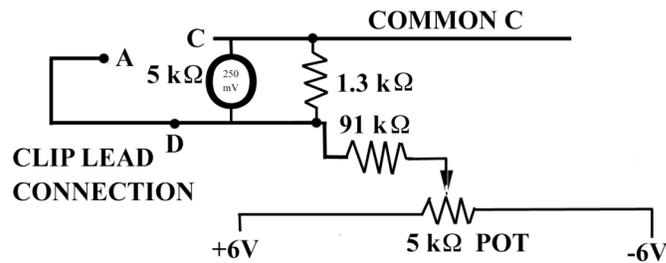
A negative feedback circuit in an amplifier circuit is shown in the figure below. In this circuit, the resistors have the values $R_1 = 9.1k\Omega$, $R_2 = 100\Omega$, and the open loop amplification is $A \approx 10^5$. Pin 3 is non-inverting and pin 2 is inverting.



- What is the output voltage V_{out} of the op-amp in terms of the input voltage V_{in} to pin 3, and the voltage at pin 2, V_2 , and the amplification A ? (Note: all voltages are with respect to common).
- Derive an expression for the voltage at pin 2, in terms of R_1 and R_2 .
- Derive an expression for the closed loop gain $G = V_{out}/V_{in}$ in terms of R_1 , R_2 , and A .
- Calculate the value of the gain G , clearly indicating any approximations you have made.

Problem 3: Calibration

The calibration circuit for the amplifier is shown in the figure below. When the multi-meter is set on the 250 mV scale the multi-meter has a resistance of $5\text{ k}\Omega$.



- When the $5\text{ k}\Omega$ pot is turned $2/3$ of the way in the direction of the $+6\text{ V}$ line from the -6 V end, what is the voltage difference between common C and the $5\text{ k}\Omega$ pot slider?
- When the $5\text{ k}\Omega$ pot is set as in part a), calculate the voltage difference between the common C and point D which is connected via a clip lead to the input A?
- What output voltage did you read when your pot was set as in part a) while you were calibrating your amplifier?