Physics 333 – Fall 2021
Due November 12.

Homework 10 - REV A

Instructions:

Each problem should begin at the top of a new sheet of paper. The final answer (numerical or symbolic) should be boxed or written in a different color. Each problem should have your name on the left and, below it, the *SPN*, circled. Problems should (usually) include a 3x3 inch sketch and begin with the general equations and the assumptions you make.

SPN 10–01 Do Griffiths Problem 5.9 (– *Using the Biot-Savart Law.*)

SPN 10–02. (– *e/m for an electron*) In class we did the e/m experiment. Here were our measurements:

B: 1150 μT (Magnetic field in apparatus measured by cell phone)
2z: 15 cm (distance between the Helmholtz coils).
b: 14 cm (diameter of the Helmholtz coils).
N: 2×140 (Each coil has 140 turns of wire).
I: 0.55 $Amps$ (Current through each coil).
r: 6.2 cm (Radius of circle of electron beam).
V: 120 $Volts$ (Accelerating voltage on electron beam).

a: Use the Biot-Savart law (you don't have to rederive it) to calculate the magnetic field based on these figures and compare it to what we measured.

b: Use the formula for field of a solenoid to estimate the magnetic field. Decide how to estimate N/L. Explain your choice and then do the calculation.

c: You can do the q/m calculation so that the only parameters you need are V, B and r. Derive a formula for q/m that only uses these factors. Then plug in the values above and $q = 1.6 \times 10^{-19}\ C$ and see what you get for m.

SPN 10–03. A plate is 10 cm wide (along z-axis), 100 m tall (along y-axis) and 1 mm thick (along x-axis). It has a uniform current density $\vec{J} = 20000\ A/m^2\ \ \hat{y}$. The plate is centered at the origin. In answering the questions below, be sure to show any Amperian loops you use.

a: Sketch the setup. Make is clear how coordinates and currents and fields are oriented. (You might show sketches from a couple of viewpoints.)
b: Because of an externally applied magnetic field, at the point $\vec{r}_1 = -2\ mm\ \hat{x}, B(\vec{r}_1) = 20\ \mu T\ \hat{x}$. What is the vector form and magnitude of the field at $\vec{r}_2 = +2\ mm\ \hat{x}$?.
c: What is the field at $\vec{r}_3 = 10\ m\ \hat{x}$? Assume at this point that the contribution from the external field is negligible.

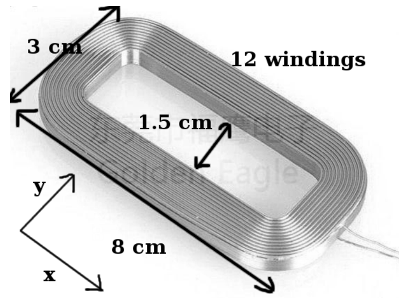
SPN 10–04. – *Ampere's law for a solenoid.*

a: Sketch a cross section of an "infinite" solenoid and use Ampere's law to derive the field inside the solenoid. Your sketch should include your Amperian loop and an indication of what direction the current is flowing in the wires and what direction the B-field is in.
b: We will measure a solenoid in class. There were 3400 turns in all and the solenoid was 3.5 inches long. Our measured current was (TBA) and the estimated B-field is (TBA). Calculate what the B-field "should have been", and give your views about why the result is not quite the same as what was measured.

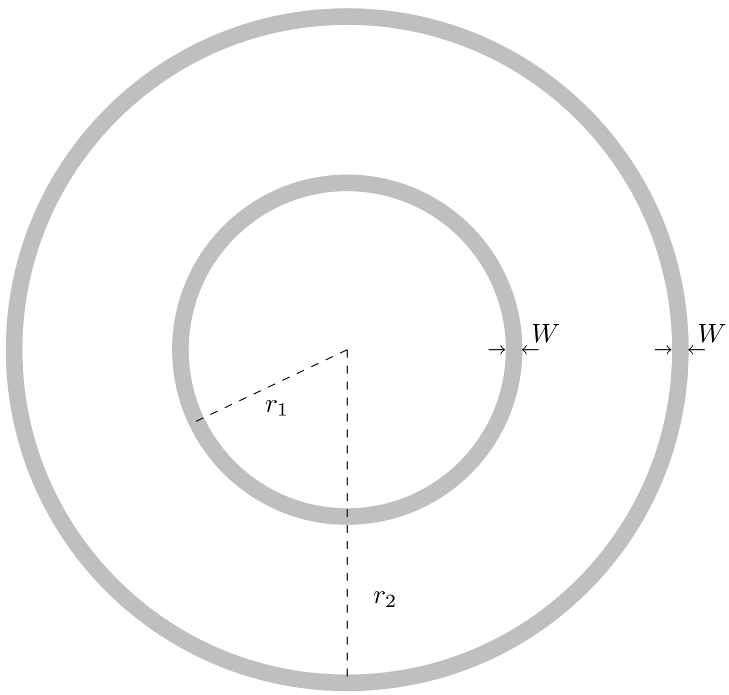
SPN 10–05. A rotor for a simple motor is being advertised on Alibaba.

a: You will operate the motor at 300 mA with a constant magnetic field $\vec{B} = 0.2\ T\ \hat{x}$. What is the torque on the coil at the instant shown?
b: What if $\vec{B} = 0.2\ T\ \hat{z}$?
c: What if $\vec{B} = 0.2\ T\ \hat{y}$?

Note: Because the area of the windings is not constant (they make concentric rectangles), each one provides a somewhat different torque. I do not want you to assume they are all the same area, but you may still approximate. You can solve this either by doing an appropriate integral or by summing the individual torques numerically.



Problem 5: A rotor for a motor.



Problem 6, 7: Two concentric flat narrow hoops lay in the $x-y$ plane. The outer hoop has radius $r_2 = 2r_1$. Both have the same width W. Note that $W << r_1$ just as shown in the sketch.

SPN 10–06. The two hoops shown in the figure each have the same surface charge density σ. The are sitting on a turntable and both rotating with the same angular velocity Ω.

a: What is the charge of each ring?
b: What is the current represented by each ring?
c: What is the magnetic dipole moment $\vec{m}$ of each ring?

SPN 10–07. This is a continuation of problem 10–06.

a: Use the answer from part c of the previous problem to estimate the magnetic field magnitude and direction at $\vec{r}_3 = 2r_2\hat{x}$.
b: Do the same for $\vec{r}_4 = 2r_2\hat{z}$.

SPN 10–08. A 25 Ω resistor is connected across a 120 V DC power supply for one minute. What current does it carry? How many coulombs pass through it in a minute? How many electrons pass through it?

SPN 10–09. A square iron rod is 20 m long and 3.0 mm on edge. What is its end-to-end resistance? If the same 20 m long wire were made of copper, how much smaller could its cross-section be (to have the same resistance as the iron wire)?

SPN 10–10. The conduction electron density in iron is $n = 8.5 \times 10^{28}/m^3$. The mean time between collisions is $4.2 femtoseconds$. How much current is driven through a one millimeter diameter iron wire by a 50 milliVolt/meter electric field?

SPN 10-11. A 2.0 mV/m electric field creates a $100mA$ current in a 1.0 mm-diameter aluminum wire. What are the drift speed and the mean time between collisions for electrons in this wire? (Assume the conduction electron density of Aluminum is 80% that of iron.)

SPN 10-12. An 0.50 mm-diameter gold wire carries a 20 mA current.

(a) Look up the resistivity of pure gold at room temperature. Write it down. (Proper SI units)

(b) Determine the electric field needed to drive this current.

(c) What is the resistance of a one-kilometer length of this wire?