PHY1308 - Homework 7

Expectations for the quality of your handed-in homework are available at http://www.physics.smu.edu/sekula/phy1308/homework.pdf. Failure to meet these guidelines will result in loss of points as detailed in that document. **This assignment is due on Tuesday, Mar. 29 by 9:30am.**

Reading Assignment

- Chapter 26.1-26.5

Practice Problems

These are not required; they are odd-numbered problems from Wolfson that may help you to warm up for the required problems.

- CH26-17
- CH26-19
- CH26-25
- Try working Example 26.5 on your own.

A Note on Significant Figures

Wolfson's representation of numbers can often make interpreting the number of significant figures very difficult. Here are some rules you can follow and to which the solutions will adhere:

1. If an integer number has a trailing zero (e.g. 50 or 100), but no decimal point to indicate that zero is significant, TREAT THE TRAILING ZEROS AS SIGNIFICANT.
    a) Example: 100 will have three significant figures. 50 will have two.
2. If an integer less than 10 is given, assume it is INFINITELY SIGNIFICANT
    a) Example: 2 has infinite precision, and should be treated like 2.0000000...

Required Problems

- SS-10 (See Below) [10 Points]
- CH26-18 [10 Points]
- SS-11 (See Below) [10 Points]
- CH26-62 [20 Points]
- SS-12 (See Below) [20 Points]

Problem SS-10: Practice with the Cross Product

1. Consider two vectors, $\vec{a}=6.0\,\hat{i}$ and $\vec{b}=-4.0\,\hat{k}$. Write the cross-product of these vectors, $\vec{a}\times\vec{b}=\vec{c}$.

2. Consider two different vectors, $\vec{a}=2.0\,\hat{i}-4.0\,\hat{j}$ and $\vec{b}=-6.0\,\hat{i}+1.0\,\hat{j}$. Write the cross-product of these vectors, $\vec{a}\times\vec{b}=\vec{c}$.

3. Consider a proton moving with velocity $\vec{v}=(5.0\times10^{4}\,\text{m/s})\,\hat{j}$. If the proton suddenly enters a region of magnetic field, and the force on the proton is $\vec{F}_B=(4.0\times10^{-5}\,\text{N})\,\hat{k}$, what is the vector that describes the magnetic field, $\vec{B}$?

Problem SS-11: The Design of the Large Hadron Collider

The Large Hadron Collider (LHC) is a subatomic particle physics experiment designed to recreate the universe as it existed about 10^{-15} seconds after it was created in the Big Bang. The goal of the LHC is to try to better understand why we exist at all by recreating a moment after the birth of the universe. SMU has four professors and about 6 students working on projects at the LHC. The experiment is international in scope, consisting of over 7000 physicists (students, scientists, and professors) from across the globe, and cost over $10 billion to build. The LHC recreates the very early universe by smashing together protons at the highest energies ever directly created by humans.

The protons, with electric charge $q=+1.6\times10^{-19}\,\text{C}$, are currently accelerated by electric fields up to speeds approaching that of light; this represents a momentum, in "particle physics units", of $p=3.5\,\text{TeV/c}$, where *c* is the speed of light, $c=2.998\times10^{8}\,\text{m/s}$ and $1\,\text{TeV}=1.0\times10^{12}\,\text{eV}$. The protons are maintained in a circular orbit using strong magnetic fields that are perpendicular to the direction of proton motion; that orbit has a circumference of 26.0 km.

1. Convert the momentum of the protons from "particle physics units" of TeV/c to MKS units (kg m/s).

2. Calculate the magnetic field strength required to maintain the protons in their 26.0 km circumference orbit in the LHC. *HINT: to remain in a circular orbit, there must be a centripetal force that balances the magnetic force.*

Problem SS-12: Magnetic Fields from the Brain

The brain is an incredibly complex electric circuit. As a result of all that moving electric charge, the brain generates very weak magnetic fields which can be detected by sensors placed directly on the scalp. These magnetic fields are EXTREMELY weak compared to, say, the earth's magnetic field; the strongest biological magnetic fields have strengths of only $1.0\times10^{-12}\,\mathrm{T}$ (or 1.0 picoTesla). Let us consider a special sensor, called a SQUID, placed on the surface of the head. SQUIDs are real, and are capable of measuring such a field.

Treat the magnetic field strength measured by the sensor as arising from a single, straight neuron in the brain located just inside brain surface, about 10.0 mm from the sensor (this corresponds to the combined thickness of the skull and scalp). Let's treat the neuronal current as flowing *perpendicular* to the direction between the neuron to the SQUID, and let the neuron be long compared to the distance between the sensor and the straight axon of the neuron, whose length is L = 4.0cm.

Calculate the current passing through the neuron that gives rise to a magnetic field of strength 1.0 pico-Tesla.