KOÇ UNIVERSITY
College of Sciences
PHYS 102 General Physics 2
Spring Semester 2014
Midterm2 Exam
April 24, 2014 Thursday, 18:30-20:00

Please read.

- Count to make sure that there are 5 pages in this question booklet
- Check your name, number, on front page, and student ID on each page.
- This examination is conducted with closed books and notes.
- Put all your personal belongings underneath your seat and make sure that pages of books or notebooks are not open.
- Absolutely no talking or exchanging anything (like rulers, erasers) during the exam.
- You must show all your work to get credit; you will not be given any points unless you show the details of your work (this applies even if your final answer is correct).
- Write neatly and clearly; unreadable answers will not be given any credit.
- If you need more writing space, use the backs of the question pages and put down the appropriate pointer marks.
- Make sure that you include units in your results.
- Make sure that you label the axis and have units in your plots.
- You are not allowed to use calculators during this exam.
- Turn off your mobile phones, and put away.
- You are not allowed to leave the class during the first 15 minutes, and last 15 minutes.

A railgun is an electrically powered electromagnetic projectile launcher based on similar principles to the homopolar motor. A railgun comprises a pair of parallel conducting rails, along which a sliding armature is accelerated by the electromagnetic effects of a current that flows down one rail, into the armature and then back along the other rail.
1-(25 Points) Assume that the capacitors are initially charge neutral and the switch $S$ is open. Then, the switch is closed at $t = 0$ and a battery with emf $V$ and two resistors are connected to the circuit.

a) Find the accumulated charge on the first capacitor ($C_1$) as a function of time.

b) Find the current passing through the third capacitor ($C_3$) as a function of time.
2-(25 Points) A rigid wire, carrying a current $I$, consists of a circular portion of radius $R$ and two straight portions. The wire lies in the xy plane perpendicular to an external magnetic field $\vec{B}$ which fills the space, as shown in the figure. The magnetic field varies as;

$$\vec{B} = B_0 \left( \frac{x}{L} \right) \hat{k} \text{ for } 0 \leq x \leq L \text{ and } \vec{B} = B_0 \hat{k} \text{ for } x > L$$

The straight portions each have length $L$ within the field. Neglect gravity. Express your answers in terms of some or all of the given quantities and appropriate constants, as needed.

a.) Find the magnetic force on the straight portion of the wire along the x axis, between $x=0$ and $x=L$. Express your answer in unit vectors.

b.) Find the magnetic force on the circular portion of the wire. Express your answer in unit vectors.

c.) Find the magnetic force on the straight portion of the wire parallel to the y axis. Express your answer in unit vectors.
3-(25 Points) a) Consider a very long (L >> R) homogeneous wire carrying current $i$ as shown below. Find the magnitude and direction of $\vec{B}$ at point A located at a distance $y$ from the right end of the wire. (Hint: You should consider the wire to be semi-infinite and apply Ampere’s Law.)

![Diagram of a long wire with current](image)

b) Figure below shows an idealized schematic drawing of a rail gun. A small conducting projectile P sits between two homogeneous wide rails of circular cross section; a source of current sends current through the rails and through the conducting projectile. Let $w$ be the distance between the rails, and $R$ the radius of each rail. Treat the rails as very long semi-infinite wires (L >> R, L >> w) and use Ampere’s Law to find the direction and magnitude of the magnetic field ($\vec{B}(y)$) at a point on the conducting projectile when it is located very close to the right end of the rails.

c) Find the total force acting on the projectile described in part b.

![Diagram of a rail gun](image)
4-(25 Points)
a) Show that the magnitude of the magnetic field of a straight conducting wire of length $2a$ with current $I$, at a distance $x$ from the midpoint of the wire is \( B = \frac{\mu_0 l}{4\pi} \frac{2a}{\sqrt{x^2 + a^2}} \). Show your calculation steps clearly.

b) A conducting wire of length $L$ is bent to form an equilateral polygon loop with $N$ edges of edge length $a = \frac{L}{N}$. \((N \geq 3)\). Use your result in part (a) to determine the magnetic field at the geometric center of the wire as a function of $N$ and $L$ (Note: The figure shows just an example with $N = 6$, your result should be general for any $N$).

c) Show that in the limit $N \to \infty$ part (b) gives the magnetic field of a circular loop $B = \frac{\mu_0 l}{2d}$ with radius $d = \frac{L}{2\pi}$.

(Hints: Biot and Savart law: \( dB = \frac{\mu_0 l dx}{4\pi r^2} \). Integral change of variable $y = \tan \alpha$. For part (c), use the approximations $\sin \theta = \theta$, $\cos \theta = 1$ when $\theta \approx 0$.)