Student ID Number: ___________

PRELIMINARY EXAMINATION

Department of Physics
University of Florida
Part A, 21 Aug 2008, 09:00–12:00

Instructions

1. You may use a calculator and CRC Math tables or equivalent. No other tables or aids are allowed or required. You may **NOT** use programmable calculators to store formulae.
2. All of the problems will be graded and will be tabulated to generate a final score. Therefore, you should submit work for all of the problems.
3. For convenience in grading please write legibly, use only one side of each sheet of paper, and work different problems on separate sheets of paper. The sheets for each problem will be stapled together but separately from the other two problems.
4. Your assigned student **ID Number**, the **Problem Number**, and the **Page Number** should appear in the upper right hand corner of each sheet. Do **NOT** use your name anywhere on the Exam.
5. All work must be shown to receive full credit. Work must be clear and unambiguous. Be sure that you hand your completed work to the Proctor.
6. Each problem is worth 10 points.
7. Following the UF Honor Code, your work on this examination must reflect your own independent effort, and you must not have given, nor received, any unauthorized help or assistance. If you have any questions, ask the Proctor.

   University of Florida Honor Code: We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honesty and integrity. On all work submitted for credit by students at the University of Florida, the following pledge is either required or implied: *"On my honor, I have neither given nor received unauthorized aid in doing this assignment."*

DO NOT OPEN EXAM UNTIL INSTRUCTED

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A1. Consider a three-dimensional Hilbert space and the set of unit vectors

$$|\theta,\phi\rangle = \begin{pmatrix} \sin(\theta)\cos(\phi) \\ \sin(\theta)\sin(\phi) \\ \cos(\theta) \end{pmatrix}$$

for all $0 \le \theta \le \pi$ and $0 \le \phi < 2\pi$.

(a) (*1 point*) A general three-dimensional vector $|\psi\rangle$ may be taken as

$$|\psi\rangle = \begin{pmatrix} \psi_1 \\ \psi_2 \\ \psi_3 \end{pmatrix}$$

where ψ_j are arbitrary complex numbers. Show that the states $|\theta,\phi\rangle$ span the space by showing that if $\langle\theta,\phi|\psi\rangle = 0$ for all θ and ϕ, then $|\psi\rangle = 0$.

(b) (*3 points*) Evaluate the three-by-three matrix

$$M(\theta,\phi) = |\theta,\phi\rangle\langle\theta,\phi|.$$

Find $Tr[\,M(\theta,\phi)]$, where Tr denotes the trace of a matrix. Evaluate $[M(\theta,\phi)]^2$. What kind of matrix is $M(\theta,\phi)$?

(c) (*3 points*) Evaluate the three-by-three matrix K where

$$K = \frac{3}{4\pi}\int_0^{2\pi}\int_0^{\pi} M(\theta,\phi)\ \sin(\theta)\ d\theta\ d\phi\ .$$

(d) (*3 points*) Evaluate the three-by-three matrix L where

$$L = \frac{3}{4\pi}\int_0^{2\pi}\int_0^{\pi} M(\theta,\phi)\ \sin(\theta)\ \cos(\phi)\ \sin(\theta)\ d\theta\ d\phi\ .$$

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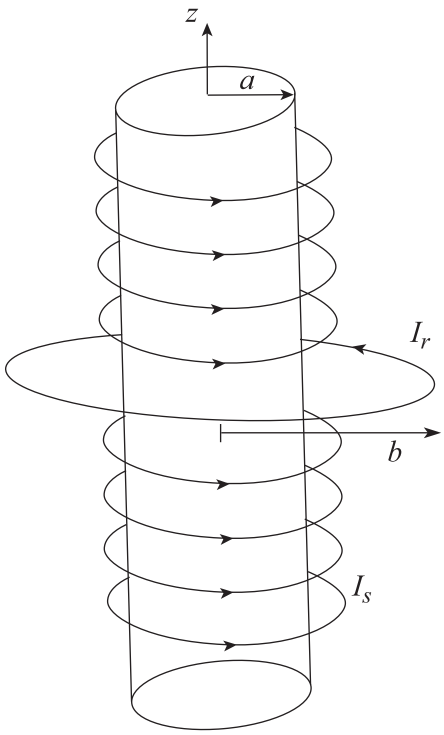
A2. A very long solenoid of radius a, with N turns per unit length, carries a current I_s. Coaxial with the solenoid, at radius $b >> a$, is a circular ring of wire, with resistance R. When the



current in the solenoid is (gradually) decreased, a current I_r is induced in the ring.

(a) (*2 points*) Calculate I_r, in terms of dI_s/dt.

(b) (*2 points*) Determine the power delivered to the ring from the solenoid.

(c) (*3 points*) Calculate the Poynting vector just outside the solenoid. (Use the electric field due to the changing flux in the solenoid and the magnetic field due to the current in the ring).

(d) (*3 points*) Determine the power transferred from solenoid to the ring using the Poynting vector obtained in (c).

Note: You may need the integral

$$\int \frac{dx}{(c^2 + x^2)^{3/2}} = \frac{x}{c^2(c^2 + x^2)^{1/2}}$$

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A3. An isolated nucleon N in the ground state can decay to produce a pion via

$$N \to N + \pi.$$

This decay does not change the state of the nucleon. The same pion is then re-absorbed some time later via

$$N + \pi \to N.$$

This process appears to violate conservation of energy.

(a) (*3 points*) Explain how this process can occur.

(b) (*2 points*) Calculate the maximum time in which this process can occur.

(c) (*3 points*) The maximum distance traveled by the pion is the range of the strong nuclear force ($\sim$1 fm = 10^{-15} m). Use this information to calculate the mass of the pion. Express your answer in MeV / c^2.

(d) (*2 points*) Use the mass calculated in part (c) to determine the maximum time in seconds for this process to occur.

Constants that may be of use:

$\hbar = 6.58 \times 10^{-16}$ eV· s; $\hbar c = 197$ MeV· fm.