Student ID Number: _____

PRELIMINARY EXAMINATION

DEPARTMENT OF PHYSICS
UNIVERSITY OF FLORIDA
Part A, 14 August 2003, 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 quantum mechanical system which consists of two states, $|1\rangle$ and $|2\rangle$, that are not necessarily eigenstates of the Hamiltonian. The Hamiltonian of this system can be described by giving its matrix elements, $H_{ij} = \langle i|H|j\rangle$, for $i, j = 1, 2$.

(a) (3 points) What is the form of the most general Hamiltonian matrix, H_{ij}?

(b) (3 points) Show that the relative phase between the two states can be re-defined so as to make H_{ij} completely real.

(c) (4 points) Find H_{ij} given the following information:

i. $H_{22} = 0$.

ii. The probability of a state which is initially pure $|1\rangle$, becoming pure $|2\rangle$, oscillates between 0 and 0.7 with a period of 10^{-8} seconds.

A2. A polymer chain is made from $N = 100$ monomers, each $\ell = 10$ nm long, linked together. Assume the orientation of each monomer is completely random and independent from the orientation of the other monomers.

(a) (6 points) Find the distribution function for the distance between the endpoints of such a polymer chain (in three dimensional space).

(b) (4 points) Consider the position of one end of the chain to be fixed. The other end is attached to a speckle of dust with mass $m = 1.3 \times 10^{-15}$ kg. Find the average displacement of the end of the chain due to the weight of the dust particle.

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A3. A brilliant physics student thinks that our transportation problems can be solved by digging a network of underground tunnels connecting the major cities. The idea is to use the gravitational attraction supplied by the Earth to accelerate trainloads of passengers or cargo from one point on the Earth's surface to another. Let's idealize the situation and neglect air resistance and any friction which the trains might encounter within the tunnel. Consider a pilot project of such a tunnel between New York and Los Angeles, where the distance is 2450 mi **along a geodesic on the surface of the Earth.** (For comparison, the minimum distance along paved roads between New York and Los Angeles quoted in a road atlas is 2780 mi.) Now imagine we build an underground tunnel which connects New York and Los Angeles along a straight line as shown in the figure, and regularly scheduled trains make the trip between the two cities powered only by the gravitational force of the Earth. The radius of the Earth is $R = 3970$ mi.

(a) (1 point) Find the length h of the tunnel.

(b) (3 points) Assuming that the train starts from rest at the Earth's surface, find its maximum speed (in mph) during such a trip.

(c) (3 points) Find the maximum acceleration felt by a person on the train, in terms of g, the Earth's acceleration. Is the trip safe? (For example, NASA's safety standards allow for g-forces of up to $4g$ in the course of 30 min.)

(d) (3 points) Find the total time of the trip.