Student ID Number: ________

PRELIMINARY EXAMINATION

Department of Physics
University of Florida
Part C, January, 2013, 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.

   (a) 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.

   (b) 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.

   (c) 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.

   (d) 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.

   (e) Each problem is worth 10 points.

   (f) 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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C1. Find the net force that the southern hemisphere of a uniformly charged sphere exerts on the northern hemisphere. Express your answer in terms of the radius R and the total change Q.

(a) [**3 points**] Dimensional analysis gives you how the magnitude F of the force depends upon the parameters R, Q and ϵ_0, up to an overall constant. What is this form?

(b) [**3 points**] What is the magnitude and direction of the electric field everywhere within the sphere?

(c) [**4 points**] What is the exact formula for F?

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C2. Consider a quantum mechanical system. Let $\hat{A}$, $\hat{B}$, and $\hat{C}$ be three quantum mechanical Heisenberg operators which commute with the system Hamiltonian. (All commutators in this question refer to $[\hat{A}, \hat{B}] = \hat{A}\hat{B} - \hat{B}\hat{A}$.)

(a) [**3 points**] Express the commutator of the operator $\hat{A}$ with the product operator $\hat{B}\hat{C}$ in terms of the commutator of $\hat{A}$ with $\hat{B}$ and the commutator of $\hat{A}$ with $\hat{C}$.

(b) [**3 points**] Show that for the commutator of the sums of operators $\sum_i \hat{A}_i$ and $\sum_j \hat{B}_j$, the distributive law holds and yields a sum of commutators.

(c) [**4 points**] For a system described by a wavefunction Ψ and a Hamiltonian $\mathcal{H}$, find the time derivative of the operator product $\hat{A}\hat{B}$.

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C3. A ball of mass m, radius R, and rotational inertia $I = 2mR^2/5$ is at rest on a table. It is then suddenly hit with a horizontal force lined up with its center of mass, and it is initially sliding *without rotating* with an initial speed v_i. The coefficient of kinetic friction of the tabletop is μ_k. The force of friction slows the ball down and also changes the ball's angular velocity.

(a) [**2 points**] Find v as a function of the time t while the ball is partially sliding on the table top.

(b) [**2 points**] Find the angular velocity ω of the ball, about its center of mass, as a function of the time t while it is still partially sliding.

(c) [**3 points**] At what time t does the ball begin rolling without sliding?

(d) [**3 points**] How far did the ball travel in that amount of time t?