Student ID Number: __________

PRELIMINARY EXAMINATION

Department of Physics
University of Florida
Part C, 22 August 2007, 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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C1. Rutherford, using alpha particle scattering, was able to determine the radii of the nuclei of certain elements. Gold, chemical symbol Au, which has 79 protons and — in the naturally-occuring isotope — 118 neutrons, has a nuclear radius of about 10 fm (1×10^{-14} m). The binding energy per nucleon of Au is about 7.8 MeV.

(a) (*3 points*) Using the Heisenberg uncertainty principle, estimate the minimum kinetic energy of a nucleon (either proton or neutron) confined to this size nucleus.

(b) (*3 points*) Using your answer from part (a), estimate how many nucleon *states* (remember spin!) could be contained in an infinite square well potential before the energy of the next-to-be-occupied $(n + 1)$th state exceeds the binding energy/nucleon of 7.8 MeV. Ignore the Coulomb repulsion between the protons (which is only 1% of the nuclear force); ignore also any angular momentum corrections to the energy (i.e. assume everything is in an $l = 0$ state.)

(c) (*3 points*) Again using your answer from part (a) and the stated assumptions in part (b), estimate how many nucleon states could be contained in an harmonic oscillator potential before the energy of the next-to-be-occupied $(n + 1)$th state exceeds the binding energy/nucleon of 7.8 MeV.

(d) (*1 point*) Based on your results for (b) and (c), comment on which potential (infinite square well vs harmonic oscillator) best describes the reality of the Au nucleus. Recall that protons and neutrons are spin-$1/2$ Fermions and obey the Pauli principle.

C2. Consider a simple model of a paramagnetic salt, in which the magnetic moments are noninteracting, so that the only interaction is between the ionic moments and an externally applied magnetic field $\vec{H}$. The Hamiltonian is then

$$\mathcal{H} = -\gamma \sum_{i=1}^{N} \vec{J}_i \cdot \vec{H},$$

where $\gamma = g\mu_B$, with g the Landé g-factor and μ_B the Bohr magneton. The ions have angular momentum J (with $2J+1$ substates), and there are N identical ions in the salt. For simplicity, let's consider a spin-$1/2$ system with $J = 1/2$ (and therefore two sub-states).

(a) (*4 points*) Calculate the canonical partition function Z_N for the N ionic moments.

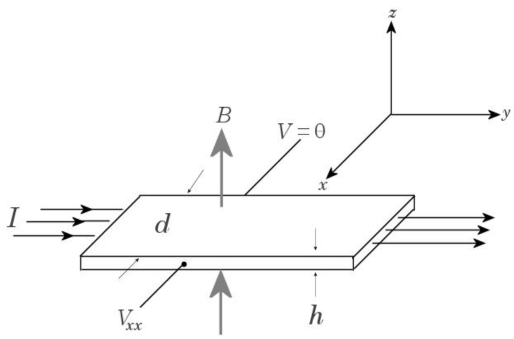
(b) (*3 points*) From the partition function Z_N, calculate the Helmholtz free energy F and the entropy S for the salt. [Note: even if you couldn't calculate the partition function in (a), at least write down the necessary relations between Z_N and F, and between F and S.]

(c) (*3 points*) Calculate the net magnetization in the applied field,

$$\vec{M} = \gamma \sum_{i=1}^{N} \langle \vec{J}_i \rangle,$$

and from the magnetization calculate the susceptibility $\chi_T = (\partial M/\partial H)_T$. Show that when $k_B T \gg \gamma H$, the susceptibility behaves as $\chi_T \sim 1/T$ (the Curie law).

C3. A copper strip 2.0 cm wide (d) and 1.0 mm thick (h) is placed in a magnetic field of 1.5 T as shown. A current of 200 A is set up in the strip, also as shown.



(a) (*2 points*) In what direction are the charge carriers deflected by the magnetic field?

(b) (*6 points*) Derive the formula for the Hall voltage in the $\hat{x}$ direction, including sign.

(c) (*2 points*) Calculate the numerical value of the Hall voltage, using the parameters given.

Hints: Density of copper $\rho_{Cu} = 9.0\ g/cm^3$; Atomic weight of copper is $64\ g/mole$. Avogadro's constant is $6.0 \times 10^{23}/mole$. Note that copper has 1 free electron /atom as its charge carriers.