Student ID Number: _____

PRELIMINARY EXAMINATION

Department of Physics

University of Florida

Part C, August, 2014, 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

PRELIMINARY EXAMINATION

DEPARTMENT OF PHYSICS

UNIVERSITY OF FLORIDA

Part C, August, 2014, 09:00–12:00

C1. Consider a solid material whose lattice consists of N atoms and n vacancies. A vacancy is a lattice site that does not contain an atom. Thus the total number of lattice sites is $N + n$.

(a) **[4 points]** Give an expression for the entropy S of the solid in terms of N, n and k_B. You may simplify your expression by assuming that N and n are both very large.

(b) **[3 points]** Suppose that each vacancy increases the energy of the solid by an amount ϵ. Find the Helmholtz free energy, F, as a function of T and n.

(c) **[3 points]** Show that if the solid is at thermal equilibrium (with a reservoir that has $\mu = 0$) the number of vacancies n is related to N by

$$n = \frac{1}{\exp(\epsilon/k_B T) - 1}$$

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C2. A Carnot cycle operates between two heat reservoirs at T = 300C and 20C.

(a) **[3 points]** What is the thermodynamic efficiency of the cycle?

(b) **[4 points]** If the net work output of each cycle is 500 J, what is the quantity of heat that must flow from the hot reservoir in each cycle? Give your answer in Joules.

(c) **[3 points]** How much heat flows into the cold reservoir in each cycle?

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C3. Consider a soap water bubble of radius R_0. The surface tension of the soap water (per one water-air surface) is λ.

(a) **[3 points]** Find pressure p inside the bubble with respect to the atmospheric pressure p_0.

(b) **[3 points]** If a small electric charge Q is uniformly deposited on the surface of the bubble, what is additional outward pressure that would be created by the electrostatic force of repulsion?

(c) **[4 points]** After depositing the charge Q, the radius of the bubble will change by ΔR. Assuming that the initial overpressure created by the water surface tension is much smaller than p_0, that the change in radius $\Delta R \ll R_0$, and that temperature of the system does not change, find ΔR.