Student ID Number: _____

**PRELIMINARY EXAMINATION**

Department of Physics

University of Florida

Part D, January 4, 2020, 14:00–17:00

**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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D1. Consider a simple system of N particles for which each particle can have two non-degenerate quantum states with energies $+\epsilon$ and $-\epsilon$.

(a) **[1 points]** Write down the partition function for the system at temperature $T$.

(b) **[2 points]** Using the relation between the partition function and the Helmholtz free energy $F$, derive an expression for $F$ of the system in terms of $\epsilon, T$ and fundamental constants.

(c) **[2 points]** From the expression for $F$ show that the entropy $S$ can be written as

$$S = Nk_B \left\{ \ln 2 + \ln \left[ \cosh \left( \frac{E}{k_B T} \right) \right] - \frac{E}{k_B T} \tanh \left( \frac{E}{k_B T} \right) \right\} \tag{1}$$

where $k_B$ is Boltzmann's constant.

(d) **[2 points]** Calculate the value of $S$ as $T$ tends toward 0? Does your answer violate the third law of thermodynamics?

(e) **[2 points]** Show that the heat capacity at constant volume can be written as

$$C_V = Nk_B x^2 / \cosh^2(x) \tag{2}$$

and give an expression for $x$.

(f) **[1 points]** Draw a rough graph of $C_V$ as a function of temperature.

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D2. A particle of mass $M$ at rest decays into three particles A, B, and C of different masses $m_A$, $m_B$, $m_C$, where the masses are given. Consider the case when one of the the particles A has its minimum allowed energy.

(Note: 2 points for considerations within the correct framework.)

(a) **[2 points]** Draw the momenta of the particles A, B and C in this case. Explain.

(b) **[1 point]** What is this minimum energy for the particle A in this case?

(c) **[4 points]** What would be the formula for the energy of the particle B in this case?

(d) **[1 point]** What would be the formula for the energy of the particle C in this case?

**PRELIMINARY EXAMINATION**

DEPARTMENT OF PHYSICS

UNIVERSITY OF FLORIDA

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D3. (a) **[5 points]** Wall plug voltage in the USA is sinusoidal with a peak amplitude of 170 V at 60 Hz. However it is more commonly stated that the voltage standard in the USA is 120 V at 60 Hz. What characteristic of the voltage is being quoted when it is said to be 120V? Stating the answer gets you 1/2 credit, a detailed derivation of the answer gets full credit. For the latter you may find useful the trig identity:

$$\sin^2 A = \frac{1 - \cos 2A}{2}.$$

(b) **[5 points]** For the common emitter amplifier circuit below, what is the quiescent (DC) base bias voltage fed to the transistor?