Student ID Number: ________

PRELIMINARY EXAMINATION

Department of Physics
University of Florida

Part D, August 16, 2019, 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. A system can be in N possible states, with energies E_j $(j = 1, 2, ...N)$. The system is in contact with a thermal bath at temperature T and has reached thermal equilibrium.

(a) [**3 points**] What is the probability P_j that the system in state j?

(b) [**3 points**] Consider a system whose energies are equally spaced: $E_n = n\,\epsilon$ $(n = 0, 1, 2, ..., N-1)$. Show that in this case

$$P_n = \frac{e^{-\beta\epsilon n}(1 - e^{-\beta\epsilon})}{1 - e^{-\beta\epsilon N}}$$

where $\beta = \frac{1}{k_B T}$.

(c) [**1 point**] A quantum harmonic oscillator has equally spaced energy states but an infinite number of such states. What is P_n in the limit $N \to \infty$?

(d) [**3 points**] What is the average energy of the system in the $N \to \infty$ limit?

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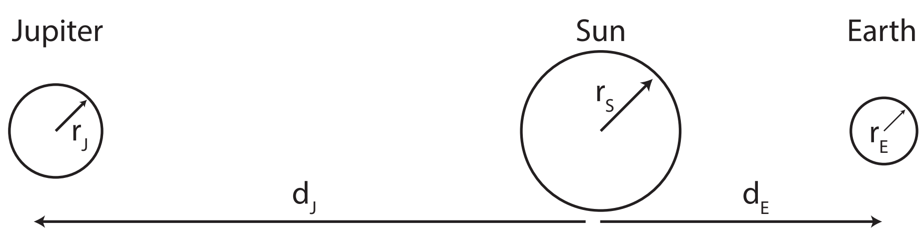
D2. This is a problem on black-body radiation.

(a) **[4 points]** The Stefan-Boltzman law relates the power radiated by an object to its physical properties. Write down the Stefan-Boltzman equation for the radiated power of an ideal black body in terms of the various relevant physical properties and an overall constant σ. What are the units of the constant σ?

(b) **[6 points]** For this question consider the Sun, Earth, and Jupiter as ideal black-bodies with uniform surface temperatures T_S, T_J, T_E. The radius of Jupiter's orbit is 5 times the radius of Earth's orbit, and the radius of Jupiter itself is 10 times the radius of Earth. Calculate the surface temperature of Jupiter T_J if only T_E is known. *Hint:* You can assume that the sun is the only source of heat for Earth and Jupiter (i.e. no internal heat source) and that both planets are in thermal equilibrium.



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D3. Neutrons and protons in atomic nuclei are confined within a region whose diameter is 1 fm.

(a) [**4 points**] At any given moment how fast might an individual proton be moving? Is it relativistic?

(b) [**3 points**] What is the approximate kinetic energy of an individual proton in this region?

(c) [**3 points**] If the nucleon is in a well of finite depth of 20 MeV can this nucleus spontaneously decay by emitting a proton? Why or why not?

Use 938 MeV/c^2 for the mass of the nucleon. $\hbar c = 197 \times 10^{-9}$ eV m