Student ID Number: ________

PRELIMINARY EXAMINATION

Department of Physics
University of Florida
Part C, August, 2015, 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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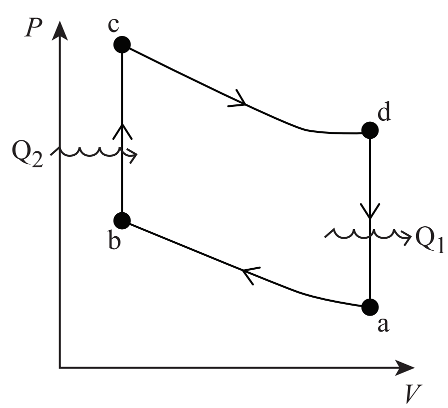
C1. **(Meisel)**

(a) [**5 points**] An ideal refrigerator (a Carnot engine running backwards) freezes liquid H_2O to form ice at a rate of 5 g/s when the sample is at its freezing point at 0°C. Energy is expelled to the room that is at 30°C. At what rate must electrical energy be supplied as work? At what rate is energy given off to the room?

You may or may not want to know that H^2O at 0°C and 1 bar has a heat of fusion (or enthalpy of fusion) of 334 J/g, a density of 999.8 kg/m^3, a heat capacity of 4.22 J/(g K), and a heat of vaporization of 45 kJ/mol.

(b) [**5 points**] An ideal gas with $\gamma = 1.4$ is used as the working substance in the cylinder of an engine. The temperature of the hot reservoir is 240°C while the cold reservoir is 50°C. The maximum and minimum volumes of the cycle are 1 liter and 2.5 liters. Compare the efficiency of this engine assuming it can be modeled by the Carnot cycle to the efficiency of it being modeled by the Otto cycle.



Consider an ideal gas as the working substance for the "Otto" cycle that is sketched on the P vs. V plot. As you may recall, a–b and c–d are adiabatic processes, while b–c and d–a are isochoric processes.

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C2. **(Hershfield)** In a two dimensional noninteracting degenerate Fermi gas the non-relativistic energy as a function of wave vector, k, is given by $\epsilon_k = \hbar^2 k^2/(2m)$. The density of the Fermi gas is fixed at n, and assume the particles do not have a spin degree of freedom.

(a) [**2 points**] Express the density, n, in terms of the Fermi energy.

(b) [**3 points**] What is the energy density of the Fermi gas at zero temperature? Express your answer in terms of the density and the Fermi energy.

(c) [**3 points**] What is the change in energy density as a function of temperature? To simplify the mathematics in this section you may approximate the Fermi function as 1 for $\epsilon < \mu - k_B T$, 0 for $\epsilon > \mu + k_B T$, and 1/2 in between.

(d) [**2 points**] Use the previous result to derive the specific heat as a function of temperature.

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C3. **(Ray)** A π^0 is produced with an energy of 0.5 GeV in the lab frame. The π^0 then decays into two photons via $\pi^0 \rightarrow \Upsilon_1 \Upsilon_2$. If the mass of the pion is 135 MeV and the lifetime is 8.4×10^{-17} seconds, what is the range of energies of the produced photons?