Examination 3 for PHYS 6450/7450 29th April 2026

Student Name: First Last

Instructions: This test is worth 24 points which will be scaled to be 24% of the final letter grade.

In this test the Bolztmann's constant, temperature, volume, the Helmholtz free energy, the specific heats at constant pressure and at constant volume, entropy, fugacity, the Fermi functions and the chemical potential are k, T, V, H, $C_P(T)$, $C_v(T)$, S, z and $f_\nu(z)$, μ respectively.

[1] A small sphere, with initial temperature T, is immersed in an ideal Boltzmannian gas at temperature T_0. Assuming that the molecule incident on the sphere is first absorbed and then reemitted with the temperature of the sphere. Determine the variation of the temperature of the sphere with time. The radius of the sphere may be assumed to be much smaller than the mean free path of the molecules.
(a) Use Newtons law of radiation. [**4 points**]
(b) Use Stafan's law of radiation. [**4 points**]

[2] The velocity of sound in a fluid is given by the formula, $w = \sqrt{(\partial P/\partial \rho)_S}$, where ρ the mass density of the fluid. Show that for an ideal Bose gas $w^2 = (5kTg_{5/2}(z))/(3mg_{3/2}(z)) = (5\langle u^2\rangle)/9$, where $\langle u^2\rangle$ the mean-square speed of the particles in the gas. Given $\gamma = 5/3$. [**6 points**]

[3] The volume of a sample of helium gas is increased by withdrawing the piston of the containing cylinder. The final pressure P_f is found to be equal to the initial pressure P_i times $(V_i/V_f)^{1.2}$, V_i and V_f being the initial and final volumes.
[a] Assuming that the product PV is always equal to (2U)/3. will (i) the energy and (ii) the entropy of the gas increase, remain constant, or decrease during the process? [**4 points**]
[b] If the process were reversible, how much work would be done and how much heat would be added to doubling the volume of the gas? Take P_i = 1 atm and $V_i = 1 m^3$. [**2 points**]

[4] For a Fermi–Dirac gas, we may define a temperature T_0 at which the chemical potential of the gas is zero (z = 1). Express T_0 in terms of the Fermi temperature T_F of the gas. Give a numerical result. [**4 points**]