PHYS 2140

Midterm exam
March 21, 2024

1. Relativistic particles move with the speed of light, c, in one dimension from left to right. The energy of a particle $\epsilon = cp$, where $p > 0$ is its momentum. The particles do not interact. Derive a kinetic equation for a one-particle distribution function $f_1(x, p, t)$. Show that any function of $(x - ct)$ and p is a solution of the kinetic equation.

2. A tunneling current flows between two electrodes. It is carried by particles of two charges, q_1 and q_2, which can tunnel from the left electrode to the right electrode but cannot tunnel in the opposite direction. Particles of charge q_1 tunnel with rate r_1, and particles of charge q_2 tunnel with rate r_2. Each tunneling event is instantaneous. All tunneling events are uncorrelated with each other, that is, we deal with two independent Poisson random processes for the two types of the particles. Find the average current. Compute the noise $S = 2\int_{-\infty}^{\infty} dt[\langle I(t)I(0)\rangle - \langle I(0)\rangle^2]$, where $I(t)$ is the current at the moment of time t and the angular brackets denote averaging over all realizations of the random process. What effective charge q will be extracted from the Schottky formula $S = 2q\langle I(0)\rangle$?

3. In this problem the pressure is fixed and does not play any role in the solution. We consider a system with two phases so that the thermodynamic potential $G = N\mu_1(T)$ in the first phase and $G = N\mu_2(T)$ in the second phase. The particle number N is constant. The chemical potential $\mu_1 = -AT^3$, where $A > 0$ is a constant. The chemical potential $\mu_2 = BT^3 - CT^4$, where $B > 0$ and $C > 0$ are constants.

a) Compare G_1 and G_2 and find the transition temperature between the two phases.

b) Compute the entropy as a function of the temperature.

c) Compute the heat capacity as a function of the temperature.

d) Compute the latent heat of the phase transition.