Statistical Physics (3rd tierce exam)

Name:

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1. Ideal gas equation $PV = NKT$ is true when the system is in classical domain (high temperature). To understand this macroscopic phenomena, we have to consider microscopic statistical description : gas constituent particles with
(a) Maxwell-Boltzmann (MB) distribution function
(b) Bose-Einstein (BE) distribution function
(c) Fermi-Dirac (FD) distribution function
(d) none of the above

2. According to ideal gas equations $PV = NKT$, $U = \frac{3}{2}NKT$, at zero temperature ($T = 0$), pressure P and internal energy U will be zero but it is not true because low temperature is quantum domain, where gas constituent particles follow
(a) classical distribution - MB
(b) quantum distribution - FD/BE
(c) equipartition of energy law
(d) none of the above

3. Considering compact star like white dwarf as electron gas only (ignoring its other components), then for statistical mechanical description of white dwarf, which distribution is required?
(a) MB
(b) BE
(c) FD
(d) none of the above

4. Fermion with energy ϵ in a gas with temperature T and chemical potential/Fermi energy μ will follow FD distribution, whose mathematical form will be $f_{FD} =$
(a) $1/\{\exp(\frac{\epsilon-\mu}{KT}) + 1\}$
(b) $1/\{\exp(\frac{\epsilon-\mu}{KT}) - 1\}$
(c) $\exp(-\frac{\epsilon-\mu}{KT})$
(d) none of the above

5. At Fermi energy, i.e. $\epsilon = \mu$
(a) $f_{FD}(\epsilon = \mu) = 0$
(b) $f_{FD}(\epsilon = \mu) = 1/2$
(c) $f_{FD}(\epsilon = \mu) = 1$
(d) none of the above

6. At $\epsilon << \mu$ or $\epsilon \to 0$
(a) $f_{FD} = 0$
(b) $f_{FD} = 1/2$
(c) $f_{FD} = 1$
(d) none of the above

7. At $\epsilon >> \mu$ or $\epsilon \to \infty$
(a) $f_{FD} = 0$
(b) $f_{FD} = 1/2$
(c) $f_{FD} = 1$
(d) none of the above

8. At $T = 0$
(a) $f_{FD} = 0$ for $\epsilon < \mu$ and $f_{FD} = 1$ for $\epsilon > \mu$

(b) $f_{FD} = 1$ for $\epsilon < \mu$ and $f_{FD} = 0$ for $\epsilon > \mu$
(c) $f_{FD} = 1$
(d) none of the above

9. No of electrons N in metal can be expressed as

$$N = 2\int_0^\infty \frac{d^3x d^3p}{h^3} \frac{1}{e^{\beta(\epsilon-\mu)} + 1} \tag{1}$$

with electron's energy $\epsilon = \frac{p^2}{2m}$. Here $\beta = 1/(KT)$, $\mu = \frac{p_F^2}{2m}$. At $T = 0$ we get number density as
(a) $\frac{N}{V} = \frac{8\pi}{5h^3}(2m\mu)^{5/2}$
(b) $\frac{N}{V} = \frac{8\pi}{4h^3}(2m\mu)^{4/2}$
(c) $\frac{N}{V} = \frac{8\pi}{3h^3}(2m\mu)^{3/2}$
(d) none of the above

10. Total energy (internal energy) of electron gas can be expressed as

$$U = 2\int_0^\infty \frac{d^3x d^3p}{h^3} \frac{\epsilon}{e^{\beta(\epsilon-\mu)} + 1} \ . \tag{2}$$

In the same condition, described in earlier question, energy density of electron gas will be
(a) $\frac{U}{V} = \frac{8\pi}{5h^3}\frac{(2m\mu)^{5/2}}{2m}$
(b) $\frac{U}{V} = \frac{8\pi}{4h^3}\frac{(2m\mu)^{4/2}}{2m}$
(c) $\frac{U}{V} = \frac{8\pi}{3h^3}\frac{(2m\mu)^{3/2}}{2m}$
(d) none of the above

11. Average energy of non-relativistic fermion (or boson or any particle) in classical domain is $\epsilon_{av} = \frac{U}{N} = \frac{3}{2}KT$, according to which $\epsilon_{av} = 0$ at $T = 0$, but according quantum relations (discussed in earlier 2 questions), at $T = 0$, average energy of non-relativistic fermion is
(a) $\epsilon_{av} = \frac{5}{3}\mu$
(b) $\epsilon_{av} = \frac{3}{5}\mu$
(c) $\epsilon_{av} = \mu$
(d) none of the above

12. Grand canonical potential Φ or Pressure times volume of electron gas can be expressed as

$$-\Phi = PV = 2\int_0^\infty \frac{d^3x d^3p}{h^3} \frac{pv/3}{e^{\beta(\epsilon-\mu)} + 1} \ , \tag{3}$$

In the same condition, described in earlier questions, pressure of electron gas will be
(a) $P = \frac{8\pi}{15h^3}\frac{(2m\mu)^{5/2}}{m}$
(b) $P = \frac{8\pi}{12h^3}\frac{(2m\mu)^{4/2}}{m}$
(c) $P = \frac{8\pi}{9h^3}\frac{(2m\mu)^{3/2}}{m}$
(d) none of the above

13. For non-relativistic fermion (or boson or any particle) in classical domain, we get relation between internal energy density and pressure as $\frac{U}{V} = \frac{3}{2}P$ by fusing two equations $U = \frac{3}{2}NKT$ and $PV = NKT$. Similar kind of relation between internal energy density and pressure for degenerate (i.e. at $T = 0$) and non-relativistic electron gas will be

(a) $\frac{U}{V} = \frac{1}{3}P$
(b) $\frac{U}{V} = \frac{3}{2}P$
(c) $\frac{U}{V} = \frac{2}{3}P$
(d) none of the above

14. Example of degenerate and relativistic electron gas is
    (a) White dwarf
    (b) Neutron star
    (c) black hole
    (d) none of the above

15. Example of degenerate and relativistic neutron gas is
    (a) White dwarf
    (b) Neutron star
    (c) black hole
    (d) none of the above