Formula sheet for Final PHYS 3113

First law of thermodynamics: $\Delta U = Q + W, \;\; W = -\int PdV$

Thermodynamic identity: $dU = TdS - PdV$

Ideal gas: $PV = NkT, \;\; U = \dfrac{f}{2}NkT$

Heat capacity: $C = \dfrac{\partial U}{\partial T}$

Boltzmann statistics: $Z = \sum e^{-\beta E_n}, \;\; \beta = \dfrac{1}{kT} \qquad \langle E \rangle = -\dfrac{1}{Z}\dfrac{\partial Z}{\partial \beta} \qquad U = N\langle E \rangle$

Fermi gas of electrons in solids: $\epsilon_F = \dfrac{h^2}{8m}\left(\dfrac{3N}{\pi V}\right)^{2/3}$

internal energy at low T: $U = \dfrac{3}{5}N\epsilon_F + \dfrac{\pi^2}{4}N\dfrac{(kT)^2}{\epsilon_F}$

Debye theory of solids (lattice vibrations): $T_D = \dfrac{hc_S}{2k}\left(\dfrac{6N}{\pi V}\right)^{1/3}$

internal energy at low T: $U = \dfrac{3\pi^4}{5}\dfrac{NkT^4}{T_D^3}$

Bose-Einstein condensation: $T_c = \gamma\dfrac{h^2}{2\pi mk}\left(\dfrac{N}{V}\right)^{2/3}, \; \gamma = 0.527$

$N_0 = N - N_{\text{excited}} = \left[1 - \left(\dfrac{T}{T_c}\right)^{3/2}\right]N$

Useful constants:

$k = 1.38 \times 10^{-23}$ J/K $\qquad$ 1 eV=1.602×10^{-19} J $\qquad$ $kT = 0.026 \text{ eV}\left(\dfrac{T}{300 \text{ K}}\right)$