Oppgave 1a)

$$Z_{rot} = \frac{1}{N!}\left[\frac{2Ik_BT}{\hbar^2}\frac{sinh\beta\mu E}{\beta\mu E}\right]^N$$

$$G(T,N,E) = -k_BTlnZ_{rot}$$

Oppgave 1b)

$$S = -\frac{G}{T} + Nk_B\left[2 - \frac{\mu E}{k_BT}coth(\frac{\mu E}{k_BT})\right]$$

Oppgave 1c)

$$P = -\frac{N\mu}{V}\left[\frac{k_BT}{\mu E} - coth(\frac{\mu E}{k_BT})\right]$$

Oppgave 3a)

$$Q = \left\{\begin{array}{ccc} 0 & 2/3 & 1/3 \\ 2/3 & 0 & 1/3 \\ 1/2 & 1/2 & 0 \end{array}\right\}.$$

Oppgave 3b)

$$t_A = t_B = 3/8 \quad t_C = 1/4$$

Oppgave 3c)

$$Q = \left\{\begin{array}{cccc} 0 & 1/2 & 1/4 & 1/4 \\ 2/3 & 0 & 1/3 & 0 \\ 1/2 & 1/2 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{array}\right\}.$$

$$1/6$$

1990

Oppgave 1b)

$$U = -\frac{4\epsilon(e^{4\beta\epsilon} - e^{-4\beta\epsilon})}{e^{4\beta\epsilon} + e^{-4\beta\epsilon} + 6}$$

$$C = 16k_B(\epsilon\beta)^2\frac{3cosh(4\beta\epsilon) + 1}{(cosh(4\beta\epsilon) + 3)^2}$$

Oppgave 1c)

$$< \sigma_1 >= 0 \qquad < \sigma_1\sigma_2 >= 4sinh(4\beta\epsilon)$$

Oppgave 2c)

$$\mu = k_BT\left(ln\frac{N}{N_0 - N} - lnq\right)$$

Oppgave 3a)

$$\mu_0 = (3\pi^2\rho)^{\frac{1}{3}}\hbar c$$

$$\epsilon = U/N = \frac{3}{4}\mu_0$$

Oppgave 3b)

$$\mu = \mu_0\left(1 - \frac{\pi^2(k_BT)^2}{3\mu_0^2} + \ldots\right)$$

1991

Oppgave 1a)

$$C_V = Nk_B$$

Oppgave 1b)

$$q = \sum_{j=0}^{\infty}(2j+1)e^{-\frac{\beta\hbar^2}{2I}j(j+1)}$$

$$< \epsilon >= \frac{\sum_{j=0}^{\infty}\frac{\hbar^2}{2I}j(j+1)(2j+1)e^{-\frac{\beta\hbar^2}{2I}j(j+1)}}{\sum_{j=0}^{\infty}(2j+1)e^{-\frac{\beta\hbar^2}{2I}j(j+1)}}$$

Oppgave 1c)
Ved lav temperatur

$$C_V \approx 3\frac{\hbar^4}{k_BT^2I^2}e^{\frac{-\beta\hbar^2}{I}},$$

og ved høg temperatur

$$C_V = Nk_B.$$

Oppgave 3a)

$$C_V = \sum_{n=-N/2}^{N/2}\frac{(\hbar\omega_n)^2e^{\beta\hbar\omega_n}}{k_BT^2(e^{\beta\hbar\omega_n}-1)^2}$$

Oppgave 3c)

$$\alpha = \gamma = 1$$

1992

Oppgave 1a)

$$T \to 0 : U = N\epsilon_0$$

$$T \to \infty : U = \frac{N}{2}(\epsilon_0 + \epsilon_1)$$

Oppgave 1d)

$$T \to 0 : S = 0$$

$$T \to \infty : S = Nk_B ln2$$

Oppgave 1e)

$$S = Nk_B \left[ln(1 + e^{-\theta/T}) + \frac{\theta/T}{1 + e^{\theta/T}} \right]$$

Oppgave 2b)

$$U = Nk_BT$$

$$P = Nk_BT/V$$

$$\mu = -k_BTln\frac{k_BTm}{\rho\pi\hbar^2}$$

Oppgave 2c)
Kvanteeffekter viktigst når $\rho\Lambda^2 \geq 1$.
Oppgave 2e)

$$\mu = \epsilon_F = \frac{\pi\rho\hbar^2}{m}$$

$$U = N\epsilon_F/2$$

$$P = U/V = \frac{\pi\hbar^2}{2m}\rho^2$$

Oppgave 2f)

$$\mu = k_BTln(e^{\rho\Lambda^2} - 1)$$

Oppgave 3a)

$$Z_N = \left(4\pi\frac{k_BT}{BS}sinh\frac{BS}{k_BT}\right)$$

$$G = -Nk_BTln\left(4\pi\frac{k_BT}{BS}sinh\frac{BS}{k_BT}\right)$$

Oppgave 3b)

$$M = S\left(coth\frac{BS}{k_BT} - \frac{k_BT}{BS}\right)$$

Oppgave 3d)

$$T_C = 2JS^2/k_B$$

1993

Oppgave 1a)

$$T \to 0 : U = 0$$

$$T \to \infty : U = N\epsilon$$

Oppgave 1b)

$$N_3 = \frac{N}{1 + e^{\beta\epsilon} + e^{2\beta\epsilon}}$$

Oppgave 1c)

$$U = N\frac{\epsilon e^{-\beta\epsilon} + 2\epsilon e^{-2\beta\epsilon}}{1 + e^{-\beta\epsilon} + e^{-2\beta\epsilon}}$$

Oppgave 1d)

$$C_V = \frac{N\epsilon^2}{kT^2} \cdot \frac{e^{-\beta\epsilon} + 4e^{-2\beta\epsilon} + e^{-3\beta\epsilon}}{(1 + e^{-\beta\epsilon} + e^{-2\beta\epsilon})^2}$$

Oppgave 1e)

$$S = Nk\left[\ln(1 + e^{-\beta\epsilon} + e^{-2\beta\epsilon}) + \beta\epsilon\frac{e^{-\beta\epsilon} + 2e^{-2\beta\epsilon}}{1 + e^{-\beta\epsilon} + e^{-2\beta\epsilon}}\right]$$

Oppgave 2c)

$$S = \frac{3Vk}{2\pi^2 v^3}\int_0^{\omega_d} d\omega\omega^2\left[\ln(1 - e^{-\hbar\omega\beta}) + \frac{\hbar\omega\beta e^{-\hbar\omega\beta}}{1 - e^{-\hbar\omega\beta}}\right]$$

$$U = \frac{3V}{2\pi^2 v^3}\int_0^{\omega_d} \frac{d\omega\hbar\omega^3}{e^{\hbar\omega\beta} - 1}$$

Oppgave 2d)

$$\frac{U}{N} = \frac{3}{5}\pi^4 kT(\frac{T}{T_D})^3$$

Oppgave 3a)

$$Z = \frac{(2V\cosh(\beta\mu_B B))^N}{\Lambda^{3N}N!}$$

$$P = \frac{NkT}{V}$$

Oppgave 3b)

$$< H >= \frac{3}{2}kT - \mu_B B\tanh(\beta\mu_B B)$$

$$\mu = -kT\ln\left[\frac{2\cosh(\beta\mu_B B)}{\rho\Lambda^3}\right]$$

Oppgave 3c)

$$\lambda = \frac{\rho\Lambda^3}{2\cosh(\beta\mu_B B)}\left(1 + \frac{\rho\Lambda^3}{2\sqrt{2}} \cdot \frac{\cosh(2\beta\mu_B B)}{1 + \cosh(2\beta\mu_B B)}\right)$$

Oppgave 3d)

$$B_2 = \frac{\Lambda^3}{4\sqrt{2}} \cdot \frac{\cosh(2\beta\mu_B B)}{1 + \cosh(2\beta\mu_B B)}$$

1994

Oppgave 1a)

$$m = \mu\tanh\frac{\mu B}{2kT}$$