

$$1. P_i \propto \Omega_i \Rightarrow \Omega_i = e^{\frac{s_i}{k}} \Rightarrow \bar{n} \Rightarrow dN \Rightarrow dE \Rightarrow dU$$

$$2. S \equiv k \ln \Omega$$

3. 열역학 제 1 법칙

$$\Delta U = T \Delta S - P \Delta V + \mu \Delta N$$

$$4. \begin{cases} P_n = c e^{-\beta n (\epsilon_s - \mu)} \\ \Omega_0 = c e^{-\beta (\Delta E + P \Delta V - \mu \Delta N)} \end{cases} \quad \beta = \frac{1}{kT}$$

$$5. \bar{n} = -\frac{\partial}{\partial x} (\ln \sum_n e^{-nx}) \Rightarrow \begin{cases} \bar{n} = \frac{1}{e^x + 1} & (\text{페르미온}) \\ \bar{n} = \frac{1}{e^x - 1} & (\text{보존}) \end{cases}$$

$x = \beta(\epsilon_s - \mu)$

$$6. dN = \frac{8\pi V \epsilon^2}{c^3 h^3} d\epsilon \cdot \bar{n}$$

$$dE = \epsilon \cdot dN$$

$$7. dU = \frac{dE}{V} = \frac{8\pi \epsilon^3}{c^3 h^3} d\epsilon \cdot \bar{n}$$

$$8. \frac{dU}{d\epsilon} = \left(\frac{8\pi}{c^3 h^3} \right) \frac{\epsilon^3}{e^{\beta\epsilon} - 1} \quad \text{흑체복사광자 총체복사광선}$$

$$9. u = \sigma T^4 \quad \text{스테판 볼츠만 공식} \quad \sigma = 5.67 \times 10^{-8} \text{ J s}^{-1} \text{ m}^{-2} \text{ K}^{-4}$$

$$10. p = \omega \rho c^2 \quad p = \frac{1}{3} a T^4 \quad \frac{\dot{r}}{r} = H \quad T = 1.5 \times 10^{10} \frac{1}{\sqrt{x}}$$

2강

$$1. \left(\frac{du}{d\varepsilon} = \frac{8\pi}{c^3 h^3} \frac{\varepsilon^3}{e^{\beta\varepsilon} - 1} \right.$$

$$E = h\nu$$

$$\frac{du}{d\lambda} = 8\pi ch \frac{\lambda^{-5}}{e^{\beta hc/\lambda} - 1}$$

$$\omega = 2\pi\nu$$

$$\frac{du}{d\omega} = \frac{h}{\pi^2 c^3} \frac{\omega^3}{e^{\beta h\omega} - 1}$$

$$\hbar = \frac{h}{2\pi}$$

$$\frac{du}{d\lambda} = 0$$

$$\lambda_{\max} T = 0.289 \text{ cm}^\circ\text{K} \text{ (빈의 변위법칙)}$$

2. Ideal gas

$$\left(\begin{array}{l} PV = NkT \\ u = \frac{3}{2} NkT \\ kT = \frac{1}{3} m\overline{v^2} \\ p = \frac{1}{3} \rho \overline{v^2} \end{array} \right.$$

$$\text{볼츠만상수 } k = 8.617 \times 10^{-5} \text{ eV/K}$$

$$w = \frac{v^2}{3c^2}$$

$$\left(\begin{array}{ll} Rdu & w = \frac{1}{3} \\ Mdu & w = 0 \\ \lambda du & w = -1 \end{array} \right.$$

$$3. \text{유체방정식} \quad \frac{\dot{\rho}}{\rho} = -3(1+w) \frac{\dot{R}}{R}$$

4. 프리즈만 방정식

$$\left(\frac{\dot{R}}{R} \right)^2 = \frac{8\pi G}{3} \rho - \frac{kc^2}{R^2}$$

$$5. R(t) = \left(\frac{\Omega_{m0}}{\Omega_{\Lambda 0}} \right)^{\frac{1}{3}} \sinh^{\frac{2}{3}} \left(\frac{3}{2} H_0 t \sqrt{\Omega_{\Lambda 0}} \right)$$

$$H_0 = 3.24 \times 10^{-18} h / \text{sec} \quad h = 0.71$$

3강

1. 특수상대성 이론

$$\text{길이 } l = l_0 \sqrt{1 - \left(\frac{v}{c}\right)^2}$$

$$\text{질량 } m = \frac{m_0}{\sqrt{1 - \left(\frac{v}{c}\right)^2}}$$

$$\gamma = \frac{1}{\sqrt{1 - \left(\frac{v}{c}\right)^2}} = \frac{1}{\sqrt{1 - \beta^2}}, \quad \text{로런츠 인자}$$

$$\text{시간 } t = \frac{\tau}{\sqrt{1 - \left(\frac{v}{c}\right)^2}} = \gamma \tau \quad \tau: \text{고유시간}$$

$$\text{위치벡터 } \vec{x} = (ct, x)$$

$$\text{4차원 속도벡터 } \vec{u} = (c\gamma, v\gamma)$$

$$|\vec{u}| = \gamma \sqrt{c^2 - v^2} = c$$

$$\text{4차원 운동량벡터 } \vec{p} = m_0 \vec{u} \quad m_0: \text{정지질량}$$

$$E^2 = (cp)^2 + (mc^2)^2$$

4장

$$1. f \rightarrow \frac{df}{d\eta} \rightarrow c[f] \rightarrow \Theta(\eta_0) \rightarrow S \rightarrow \frac{\partial}{\partial \eta} (\Theta e^{ik_B \eta - \tau}) \rightarrow \bar{S} \rightarrow \dot{f}_e \rightarrow \Theta_e(\eta_0)$$

2. Boltzmann Equation

$$\frac{df}{dt} = c[f]$$

$$\frac{df}{d\eta} = ac[f] \quad c = h = k_B = 1$$

$$c[f] = -p \frac{\partial f_0}{\partial p} n_e \Gamma_T (\Theta_0 - \Theta + V_b \cdot \vec{n})$$

3. Geodesic Equation of γ (photon)

$$\frac{1}{p} \frac{dp}{d\eta} = -\gamma \left(-\frac{\partial \Phi}{\partial \eta} - \eta^i \frac{\partial \Psi}{\partial x^i} \right)$$

<f> 아인슈타인의 측지선방정식 . $\frac{du^\lambda}{ds} + \Gamma_{\mu\nu}^\lambda u^\mu u^\nu = 0$

4. FRW metric

$$ds^2 = a^2(\eta) [-(1+2\psi) d\eta^2 + (1+2\Phi) \delta_{ij} dx^i dx^j]$$

$$g_{00} = -(1+2\psi)$$

$$g_{ij} = 1+2\Phi$$

a. scale factor

$$g_{\mu\nu} = a^2(\eta) \text{diag}[+1, 1, 1, 1]$$

$$g_{\mu\nu} = \frac{1}{g^{\mu\nu}}$$

5. 중력장 방정식

$$R^{\mu\nu} - \frac{1}{2}g^{\mu\nu}R = \frac{8\pi G}{c^4}T^{\mu\nu}$$

6. First-order Boltzmann Σ_f for δ in Fourier space

$$\dot{\Theta} + i\mu k\Theta + \dot{\Phi} + ik\mu\psi = -\dot{\tau}(\Theta_0 - \Theta + \mu v_b)$$

$$7. \mu = \frac{1}{ik} \frac{\partial}{\partial \eta} \quad g \equiv -\dot{\tau} e^{-\tau} \quad \mu \equiv \frac{\vec{k} \cdot \vec{n}}{k}$$

$$8. \int_{-1}^1 d\mu P_l(\mu) e^{ikx} = \frac{2 j_l(x)}{(-i)^l}$$

$$9. \Theta_l(\eta_0) = [\Theta_0(\eta_*) + \psi(\eta_*)] j_l(k(\eta_0 - \eta_*)) + 3\Theta_1[j_{l-1}(k(\eta_0 - \eta_*)) \\ - \frac{l+1}{k(\eta_0 - \eta_*)} j_l(k(\eta_0 - \eta_*))] + \int_0^{\eta_0} d\eta e^{-\tau} (\dot{\psi} - \dot{\Phi}) j_l(k(\eta_0 - \eta))$$

10.

$$\mathcal{L} \rightarrow \ddot{\phi} \rightarrow \phi + \delta\phi \rightarrow \ddot{\delta\phi} \rightarrow \ddot{h} \rightarrow \delta\phi \\ \rightarrow \zeta \rightarrow \psi \rightarrow P_{\psi} \rightarrow \delta \rightarrow P(k)$$

$$11. C_{\ell}(\eta) = \frac{2}{\pi} \int_0^{\eta_0} dk k^2 P(k) \left| \frac{\Theta_{\ell}(k)}{\delta(k)} \right|^2$$

12. Lagrangian

$$\mathcal{L} = -\frac{1}{2} g^{\mu\nu} \frac{\partial \phi}{\partial x^{\mu}} \frac{\partial \phi}{\partial x^{\nu}} - V(\phi)$$

13. Euler-Lagrange Eq

$$\frac{\partial}{\partial x^{\mu}} \left(\frac{\partial \mathcal{L}}{\partial (\partial_{\mu} \phi)} \right) - \frac{\partial \mathcal{L}}{\partial \phi} = 0$$

$$14. P(k) = \langle \delta \cdot \delta^* \rangle = 2\pi^2 \int_H^2 \frac{k^n}{H_0^{n+3}} \left(\frac{D(a)}{D(a_0)} \right)^2 T^2(k)$$

$$15. \ell(\ell+1) C_{\ell}^{LS}(\eta) = \frac{\pi \Omega_{m0}^2}{2D^2(a_0)} \int_H^2$$