

1 Electromagnetism

$$\begin{aligned}\sin \theta &\equiv \theta \\ \tan \theta &\equiv \sin \theta \\ \cos \theta &\equiv 1\end{aligned}$$

$$\begin{aligned}\nabla \cdot \mathbf{D} &= \rho_f \\ \nabla \cdot \mathbf{B} &= 0 \\ \nabla \times \mathbf{E} &= \frac{\partial \mathbf{B}}{\partial t} \\ \nabla \times \mathbf{H} &= \mathbf{J}_f + \frac{\partial \mathbf{D}}{\partial t}\end{aligned}$$

$$\begin{aligned}\mathbf{D} &= \epsilon_0 \mathbf{E} + \mathbf{P} \\ \mathbf{B} &= \mu_0 (\mathbf{H} + \mathbf{M})\end{aligned}$$

$$\begin{aligned}\oint \mathbf{D} \cdot d\mathbf{a} &= Q_{f,enc} \\ \oint \mathbf{H} \cdot d\mathbf{l} &= I_{f,enc}(t) + \frac{d\Phi_{\mathbf{D}}}{dt} \\ \oint \mathbf{B} \cdot d\mathbf{a} &= 0 \\ \oint \mathbf{E} \cdot d\mathbf{l} &= -\frac{d\Phi_{\mathbf{B}}}{dt}\end{aligned}$$

$$\begin{aligned}D_1^\perp - D_2^\perp &= \sigma_f \\ B_1^\perp - B_2^\perp &= 0 \\ \mathbf{E}_1^\parallel - \mathbf{E}_2^\parallel &= 0 \\ \mathbf{H}_1^\parallel - \mathbf{H}_2^\parallel &= \mathbf{K}_f \times \hat{n}\end{aligned}$$

$$\begin{aligned}\mathbf{S} &= \frac{1}{\mu} \mathbf{E} \times \mathbf{B} \\ u &= \frac{1}{2} \left(\epsilon_0 E^2 + \frac{1}{\mu_0} B^2 \right) \\ I &= \langle S \rangle = \frac{1}{2} v \epsilon E_0^2 \\ P &= \int \mathbf{S} \cdot d\mathbf{a}\end{aligned}$$

$$\begin{aligned}\beta &= \frac{v}{c} \\ \gamma &= \frac{1}{\sqrt{1 - \beta^2}}\end{aligned}$$

$$\Lambda = \begin{pmatrix} \gamma & -\beta\gamma & 0 & 0 \\ -\beta\gamma & \gamma & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

$$u' = \frac{u - v}{1 - \frac{uv}{c^2}}$$

$$\Lambda_{\alpha}^{\mu} g_{\mu\nu} \Lambda_{\beta}^{\nu} = g_{\alpha\beta}$$

$$I = s^2 = x_{\mu} x^{\mu} = c^2 t^2 - d^2$$

$$\begin{aligned}d\tau &= \frac{dt}{\gamma} && \text{(proper time)} \\ \eta^{\mu} &= \frac{dx^{\mu}}{d\tau} = \begin{pmatrix} \gamma c \\ \gamma \mathbf{u} \end{pmatrix} && \text{(proper velocity)} \\ \eta^{\mu} &= m \eta^{\mu} = \begin{pmatrix} E/c \\ \mathbf{p} \end{pmatrix} && \text{(proper velocity)}\end{aligned}$$

$$\begin{aligned}\eta_{\mu} \eta^{\mu} &= c^2 \\ p_{\mu} p^{\mu} &= E^2/c^2 - \mathbf{p}^2 = m^2 c^2\end{aligned}$$

$$F^{\mu\nu} = \begin{pmatrix} 0 & -E_x/c & -E_y/c & -E_z/c \\ E_x/c & 0 & -B_z & B_y \\ E_y/c & B_z & 0 & -B_x \\ E_z/c & -B_y & B_x & 0 \end{pmatrix}$$

$$K^{\mu} = q F^{\mu\nu} g_{\nu\alpha} \eta^{\alpha}$$

$$J^{\mu} = \begin{pmatrix} c\rho \\ \mathbf{J} \end{pmatrix}$$

$$\partial_{\mu} J^{\mu} = 0$$

$$\mathbf{A}(\mathbf{x}) = \frac{1}{4\pi} \int \frac{\nabla' \times \mathbf{J}(\mathbf{x}')}{|\mathbf{x} - \mathbf{x}'|} d\mathbf{x}$$

$$\mathbf{B} = \nabla \times \mathbf{A}$$

$$\mathbf{E} = -\nabla V - \frac{\partial \mathbf{A}}{\partial t}$$

$$A_{\text{ret}}^{\mu}(\mathbf{x}) = \frac{\mu_0}{4\pi} \int d^3 x' \frac{J'(x^0 - |\mathbf{x} - \mathbf{x}'|, \mathbf{x}')}{|\mathbf{x} - \mathbf{x}'|}$$

1.2 Radiation

$$\mathbf{E} = \frac{q}{4\pi\epsilon} \left(\frac{\hat{\mathbf{r}} - \boldsymbol{\beta}}{\gamma^2(1 - \boldsymbol{\beta} \cdot \hat{\mathbf{r}})^3 |\mathbf{r}|^2} + \frac{\hat{\mathbf{r}} \times ((\hat{\mathbf{r}} - \boldsymbol{\beta}) \times \dot{\boldsymbol{\beta}})}{(1 - \boldsymbol{\beta} \cdot \hat{\mathbf{r}})^3 c |\mathbf{r}|} \right) \quad (\text{for point charge})$$

$$\mathbf{E} = \frac{q}{4\pi\epsilon_0} \frac{\hat{\mathbf{r}} - \boldsymbol{\beta}}{\gamma^2(1 - \boldsymbol{\beta} \cdot \hat{\mathbf{r}})^3 |\mathbf{r}|^2} \quad (\text{constant velocity})$$

$$\frac{dP}{d\Omega} = \frac{\mu_0 q^2}{16\pi c} \frac{(\hat{\mathbf{r}} \times ((\hat{\mathbf{r}} - \boldsymbol{\beta}) \times \mathbf{a}))^2}{(1 - \boldsymbol{\beta} \cdot \hat{\mathbf{r}})^5}$$

$$\begin{aligned} \frac{dP}{d\Omega} &= \frac{\mu_0 q^2 a^2}{16\pi^2 c} \sin^2 \theta & (\text{non-rel. limit}) \\ P &= \frac{\mu_0 q^2 a^2}{6\pi c} \end{aligned}$$

$$P = \frac{\mu_0 q^2 \gamma^2}{6\pi c} (a^2 - |\boldsymbol{\beta} \times \mathbf{a}|^2) \quad (\text{rel. generalisation})$$

todo Maybe do dipole stuff?

1.3 Radiation of dipole

$$\mathbf{p}(t) = e^{-i\omega t} \int \rho \mathbf{x}' d^3x' \quad (\text{dipole moment})$$

2 Nuclear Physics

$$\Delta M(Z, A) = M(Z, A) - [Z(M_p + m_e) + NM_n]$$

$$B(A, Z) = -\Delta M(Z, A)c^2 \quad (\text{Binding energy})$$

$$\begin{aligned} Q &= [(M_i + M_I) - (M_f + M_F)]c^2 \\ Q &= B(f) + B(F) - B(i) + B(I) \end{aligned}$$

$$T_{1/2} = \frac{\ln 2}{\lambda}$$

$$\begin{aligned} -\frac{dN(t)}{dt} &= \lambda N(t) \\ N(t) &= N(0)e^{-\lambda N(t)} \end{aligned}$$

$$\begin{aligned} R(t) &= -\frac{dN(t)}{dt} \\ R(t) &= \lambda N(0)e^{-\lambda N(t)} \end{aligned}$$

$$I(x) = I_0 e^{-\mu x} \quad (\text{Intensity loss of } \gamma)$$

$$I(x) = I_0 e^{-N\sigma x} \quad (\text{Neutron absorption})$$

$$D_{\text{tissue}} = \frac{E_{\text{deposited}}}{m_{\text{tissue}}}$$

$$H_{\text{tissue}} = \sum_R W_R D_{\text{tissue}, R} \quad (\text{Equivalent Dose})$$

$$\begin{aligned} N &= In\Delta x\sigma \\ I &= I_0 e^{-n\sigma t} & (\text{For a thick target}) \end{aligned}$$

$$\frac{d\sigma}{d\Sigma}$$

maybe include SEMF?

$$(n\ell_j)^k \quad (\text{Labeling states } [k = 2j + 1])$$

$$S, P, D, F, G, \dots \implies \ell = 0, 1, 2, 3, 4, \dots$$

$$P = (-1)^\ell \quad (\text{for single particle state})$$

3 Atomic Physics

$$-i\hbar \frac{d}{dt} |\Psi(t)\rangle = \hat{H} |\Psi(t)\rangle \quad (3.1)$$

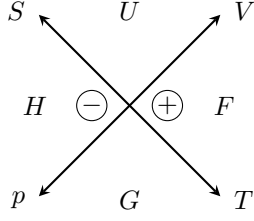
$$[x^i, p^j] = i\hbar \delta^{ij} \quad (3.2)$$

$$[L^i, L^j] = i\hbar \epsilon^{ijk} L^k \quad (3.3)$$

$$\hat{\mathbf{S}} = \frac{\hbar}{2} \boldsymbol{\sigma} \quad (3.4)$$

$$[S^i, S^j] = i\hbar \epsilon^{ijk} S^k \quad (3.5)$$

$$[\mathbf{A}\mathbf{B}, \mathbf{C}] = \mathbf{A}[\mathbf{B}, \mathbf{C}] + [\mathbf{A}, \mathbf{B}]\mathbf{C} \quad (3.6)$$



4 Thermal Physics

$$pV = K_B N T \quad (\text{Ideal gas law})$$

$$pV = nRT$$

$$E_{\text{kin}}^- = \frac{1}{2} f N K_B T \quad (\text{Equipartition thm})$$

$$\Delta U = Q + W \quad (\text{1st Law})$$

$$\frac{Q}{\Delta T} = \alpha A \frac{dT}{dx}$$

$$\ln(A!) = A \ln(A) - A \quad (\text{Stirling approx.})$$

$$S = K_B \ln \Omega \quad (\text{entropy})$$

$$S(U, V, N) = K_B N \left[\ln \left(\frac{V}{N} \left(\frac{4\pi m U}{3\hbar^2 N} \right)^{\frac{3}{2}} \right) \right] \quad (\text{Sackur-Tetrode})$$

$$\frac{1}{T} \equiv \left[\frac{\partial S}{\partial U} \right]_{N, V}$$

$$p \equiv T \left[\frac{\partial S}{\partial U} \right]_{U, N}$$

$$\eta \equiv \frac{W}{Q_H} \quad (\text{efficiency})$$

$$H \equiv U + pV$$

$$F \equiv U - TS$$

$$G \equiv H - TS$$

$$\frac{dp}{dT} \frac{L/T}{\Delta V} \quad (\text{Clausius-Clapeyron relation})$$

$$\left(p + a \frac{N^2}{V^2} \right) (V - bN) = K_B N T \quad (\text{Van der Waals eqn})$$

$$P(S) = \frac{1}{z} \exp \left(-\frac{E(s)}{T} \right)$$

$$z = \sum_s d(s) \exp \left(-\frac{E(s)}{T} \right)$$

$$\langle E \rangle = -\frac{\partial \beta}{\partial \ln z}$$

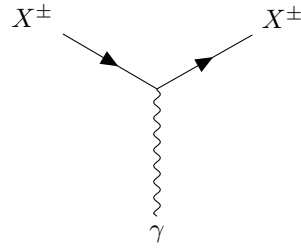
$$F = -T \ln z$$

$$p(s) = \frac{1}{Z} \sum_s \exp \left(-\frac{E(s) - \mu N(s)}{T} \right)$$

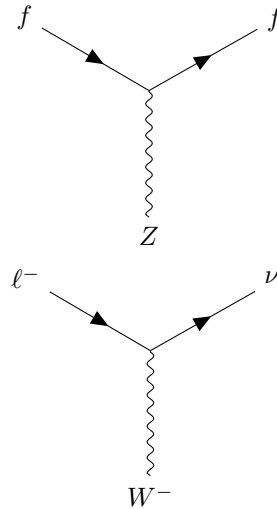
$$\mathcal{Z}(T, V, \mu) = \sum_s \exp \left(-\frac{E(s) - \mu N(s)}{T} \right)$$

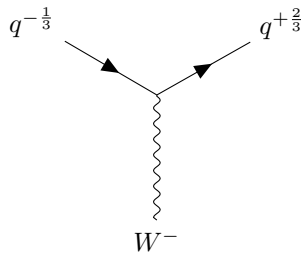
5 Particle Physics

$$s = (p_A + p_B)^2 \quad (5.1)$$

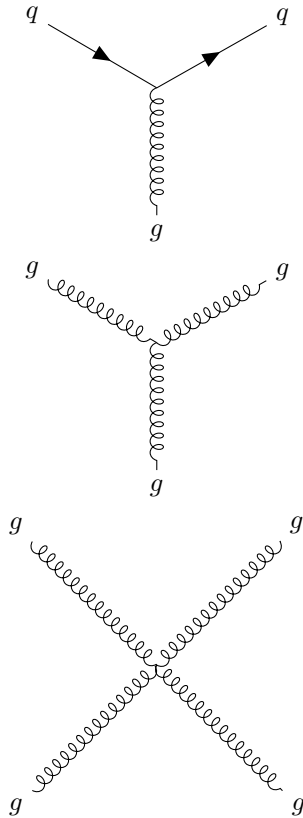


5.1 Weak Force





5.2 Strong Force



$$\frac{dN_{\text{scat}}}{dt} = \sigma \mathcal{L} \quad (5.2)$$

$$\Gamma = \frac{|\mathbf{p}|}{8\pi m_A^2} |\mathcal{M}|^2 \quad (\text{two-body decay})$$

$$\frac{d\sigma}{d\Omega} = \left(\frac{1}{8\pi} \right)^2 \frac{|\mathcal{M}|^2}{(E_A + E_B)^2} \frac{|\mathbf{p}_f|}{|\mathbf{p}_i|} \quad (2 \rightarrow 2 \text{ scatter})$$

6 Solid State Physics