PHY3004W Formula Sheet

Alex Veltman   November 2020

1 Electromagnetism

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

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

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

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

$$\begin{aligned}\boldsymbol{S} &= \frac{1}{\mu}\boldsymbol{E} \times \boldsymbol{B} \\ I &= \langle S \rangle = \frac{1}{2} v\epsilon E_0^2 \\ P &= \int \boldsymbol{S} \cdot \mathrm{d}\boldsymbol{a}\end{aligned}$$

1.1 Special Relativity

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

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

$$\Lambda^{\mu}_{\alpha} g_{\mu\nu} \Lambda^{\nu}_{\beta} = g_{\alpha\beta}$$

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

$$\mathrm{d}\tau = \frac{\mathrm{d}t}{\gamma} \qquad \text{(proper time)}$$

$$\eta^{\mu} = \frac{\mathrm{d}x^{\mu}}{\mathrm{d}\tau} = \begin{pmatrix} \gamma c \\ \gamma \boldsymbol{u} \end{pmatrix} \qquad \text{(proper velocity)}$$

$$\eta^{\mu} = m\eta^{\mu} = \begin{pmatrix} E/c \\ \boldsymbol{p} \end{pmatrix} \qquad \text{(proper velocity)}$$

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

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

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

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

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

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

$$\begin{aligned}\boldsymbol{B} &= \nabla \times A \\ \boldsymbol{E} &= -\nabla V - \frac{\partial \boldsymbol{A}}{\partial t}\end{aligned}$$

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

1.2 Radiation

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

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

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

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

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

todo Maybe do dipole stuff?

2 Nuclear Physics

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

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

$$Q = [(M_i + M_I) - (M_f + M_F)]c^2$$
$$Q = B(f) + B(F) - B(i) + B(I)$$

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

$$-\frac{\mathrm{d}N(t)}{\mathrm{d}t} = \lambda N(t)$$
$$N(t) = N(0)e^{-\lambda N(t)}$$

$$R(t) = -\frac{\mathrm{d}N(t)}{\mathrm{d}t}$$
$$R(t) = \lambda N(0)e^{-\lambda N(t)}$$

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

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

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

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

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

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

maybe include SEMF?

$$(n\ell_j)^k \qquad \text{(Labeling states } [k = 2j+1])$$
$$S, P, D, F, G, \cdots \implies \ell = 0, 1, 2, 3, 4, \ldots$$

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

3 Atomic Physics

4 Thermal Physics

5 Particle Physics

6 Solid State Physics