Electricity and Magnetism

$\vec{F}_{21} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r_{21}^2}\hat{r}_{21}$

$U(r) = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r}$

$\Phi_E = \int \vec{E}\cdot d\vec{A} = \frac{q}{\varepsilon_0}$

$\Phi_B = \oint \vec{B}\cdot d\vec{A} = 0$

$\mathcal{E} = -\frac{d\Phi_B}{dt} = \oint \vec{E}\cdot d\vec{s}$

$\oint \vec{B}\cdot d\vec{s} = \mu_0\left(i + \varepsilon_0 \frac{d\Phi_E}{dt}\right)$

$p = qd$

$\vec{\tau} = \vec{p}\times\vec{E}$

$U = -\vec{p}\cdot\vec{E}$

$E \to \frac{1}{4\pi\varepsilon_0}\frac{p}{x^3}$

$\vec{\mu} = iA\hat{n}$

$\vec{\tau} = \vec{\mu}\times\vec{B}$

$U = -\vec{\mu}\cdot\vec{B}$

$\vec{B} = \frac{\mu_0\vec{\mu}}{2\pi z^3}$

$\vec{M} = \frac{\vec{\mu}}{V}$

$\vec{E} = \vec{E}_0 + \vec{E}_P = \vec{E}_0 / \kappa_e$

$\varepsilon = \kappa_e \varepsilon_0$

$\mu_0 \vec{M} = (\kappa_M - 1)\vec{B}_0$

$\vec{B} = \vec{B}_0 + \vec{B}_M = \kappa_M \vec{B}_0$

$\Delta V = \frac{\Delta U}{q_0}$

$V_p = -\int_\infty^P \vec{E}\cdot d\vec{s}$

Loop: $B = \frac{\mu_0 i}{2R}$

Solenoid:
$B = \mu_0 n i$ where
$n = N/L$

$\vec{F} = q\vec{E} + q\vec{v}\times\vec{B}$

$\omega = \frac{|q|B}{m}$

$d\vec{F}_B = i d\vec{L}\times\vec{B}$

$\vec{\tau} = NiA\hat{n}\times\vec{B}$

$d\vec{B} = \frac{\mu_0}{4\pi}\frac{i d\vec{s}\times\vec{r}}{r^3}$

$u = \frac{\varepsilon_0}{2}E^2 + \frac{B^2}{2\mu_0}$

$\vec{S} = \frac{1}{\mu_0}\vec{E}\times\vec{B}$

$\frac{F_{av}}{A} = \frac{I}{c}$ or $\frac{2I}{c}$

$(1 \pm x)^n = 1 \pm \frac{nx}{1!} + \frac{n(n-1)x^2}{2!} \pm \ldots$

$(1 \pm x)^{-n} = 1 \mp \frac{nx}{1!} + \frac{n(n+1)x^2}{2!} \mp \ldots$

$\int \frac{dz}{(z^2+d^2)^{3/2}} = \frac{z}{d^2(z^2+d^2)^{1/2}}$

Circuits and Elements of Circuits

$i = \frac{dq}{dt}$

$i = \int \vec{j}\cdot d\vec{A}$

$\rho = \frac{m}{ne^2\tau} = \frac{1}{\sigma}$

$j = \frac{i}{A}$

$\vec{j} = -ne\vec{v}_d$

$\vec{j} = \sigma\vec{E}$

$R = \rho\frac{L}{A}$

$C' = \frac{\kappa_e \varepsilon_0 A}{d}$

$L = N\Phi_B / i$

$L = \kappa_M L_0$

$V = iR$

$P_R = iV = i^2 R$

$V = \frac{q}{C}$

$U = \frac{1}{2}C(\Delta V)^2$

$V = L\frac{di}{dt}$

$U_B = \frac{1}{2}Li^2$

$Q = CV\left(1 - e^{-t/RC}\right)$

$i = \frac{V}{R}\left(1 - e^{-tR/L}\right)$

$q = q_m e^{-Rt/2L}\cos(\omega' t + \phi)$

$\omega' = \sqrt{\omega_0^2 - \left(\frac{R}{2L}\right)^2}$; $\omega_0 = \sqrt{\frac{1}{LC}}$

$X_C = (\omega C)^{-1}$; $X_L = \omega L$

$Z = \sqrt{R^2 + (X_L - X_C)^2}$

$\tan\phi = \frac{X_L - X_C}{R}$

Driver: $V = V_M \sin\omega t$

Response:
$i = i_M \sin(\omega t - \phi)$
$i_M = V_M / Z$

Parallel:
$C = C_1 + C_2$
$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$

Series:
$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$
$R = R_1 + R_2$

Light and Optics: 430 nm (violet) to 690 nm (red)

$f = \frac{1}{T}$, $\omega = \frac{2\pi}{T}$

$k = \frac{2\pi}{\lambda}$,

$v = \lambda f = \frac{\omega}{k} = \frac{2\pi f}{k}$

$c_{vac} = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$

$c_{matter} = \frac{c_{vac}}{\sqrt{\kappa_m \kappa_e}}$

$n_1 \sin\theta_1 = n_2 \sin\theta_2$

$n = c_{vac} / c_{matter}$

$\theta_c = \sin^{-1}\frac{n_2}{n_1}$

Doppler for light

$f = f_0\sqrt{\frac{1-u/c}{1+u/c}}$

$f \cong f_0(1 - u/c)$

$f = f_0 \frac{\sqrt{1 - u^2/c^2}}{1 + u/c\cos\theta}$

Mirrors:

$f = \frac{r}{2}$; $\frac{1}{o} + \frac{1}{i} = \frac{1}{f}$

$m = -\frac{i}{o}$; $m_t = mm'$

Spherical Surface:

$\frac{n_2}{i} + \frac{n_1}{o} = \frac{n_2 - n_1}{r}$

Lens Maker's eq.

$\frac{1}{f} = (n-1)\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$

Double Slit:

Maxima $d\sin\theta = m\lambda$

$I_\theta = 4I_0\cos^2\left(\frac{\pi d\sin\theta}{\lambda}\right)$

Diffraction and Interference

Minima: $a\sin\theta = m\lambda$

$I_\theta = I_m(\cos\beta)^2\left(\frac{\sin\alpha}{\alpha}\right)^2$ where

$\alpha = \frac{\pi a\sin\theta}{\lambda}$, $\beta = \frac{\pi d\sin\theta}{\lambda}$

Multi-Slit

Maxima: $d\sin\theta = m\lambda$

$\delta\theta = \frac{\lambda}{Nd\cos\theta}$; $D = \frac{\Delta\theta}{\Delta\lambda} = \frac{m}{d\cos\theta}$; $R = \frac{\lambda}{\Delta\lambda} = Nm$

Bragg (x rays): $2d\sin\theta = m\lambda$

Circular: Minima at

$\sin\theta = 1.22\frac{\lambda}{d}$

$pathdiff = 2d + \left(\frac{1}{2}\frac{\lambda}{n} front?\right) + \left(\frac{1}{2}\frac{\lambda}{n} back?\right)$

Thin films: Does the next medium have a higher index of refraction?

Polarization

$I = I_m\cos^2\theta$; $n_e \neq n_o$; $\theta_p + \theta_r = 90^\circ$; $\tan\theta_p = \frac{n_2}{n_1}$

Modern Physics and Relativity

$c = 3.00\times10^{8} m/\sec$

$G = 6.67\times10^{-11} N\cdot m^2/kg^2$

$N_A = 6.02\times10^{23} mol^{-1}$

$R = 8.31 J/mol\cdot K$

$c^2 = 8.99\times10^{16} J/kg$

$c^2 = 931.5 MeV/u$

$\varepsilon_0 = 8.85\times10^{-12} F/m$

$\mu_0 = 1.26\times10^{-6} H/m$

$h = 6.63\times10^{-34} J\cdot s$

$h = 4.14\times10^{-15} eV\cdot s$

$k = 1.38\times10^{-23} J/K$

$e = 1.60\times10^{-19} C$

$\mu_B = 9.27\times10^{-24} J/T$

$\mu_B = 5.79\times10^{-5} eV/T$

$m_e = 9.11\times10^{-31} kg$

$m_e c^2 = 0.511 MeV$

$m_p = 1.67\times10^{-27} kg$

$m_p c^2 = 938.3 MeV$

$1eV = 1.60\times10^{-19} J$

$\gamma = \left(1-\frac{v^2}{c^2}\right)^{-1/2}$; $\vec{p} = \gamma m\vec{v}$

$K = mc^2(\gamma-1) = E - E_0$

$E = K + E_0 = \sqrt{(pc)^2 + (mc^2)^2}$

$E = \gamma mc^2, \quad E_0 = mc^2$

$T = 16\frac{E}{U_0}\left(1-\frac{E}{U_0}\right)e^{-2k'L}$; $\frac{(hk')^2}{8\pi^2 m} = (U_0 - E)$

$L = \sqrt{l(l+1)}\, h/2\pi$; $L_z = m_l\, h/2\pi$; $\Delta L_z \Delta\phi \ge h/2\pi$

$S = \sqrt{s(s+1)}\, h/2\pi$; $S_z = m_s\, h/2\pi$; $m_s = \pm\frac{1}{2}$

Infinite potential well:

$\lambda_n = \frac{2L}{n}$; $E_n = \frac{p_n^2}{2m} = \frac{n^2h^2}{8mL^2}$

$n(E) = \frac{8\sqrt{2}\pi m^{3/2}}{h^3}E^{1/2}$ density of states

$n_o(E) = n(E)p(E)$; $E_F = \frac{h^2}{8m}\left(\frac{3n}{\pi}\right)^{2/3}$

$p(E) = \frac{1}{e^{(E-E_F)/kT}+1}$

Bohr: $E_n = -\frac{mZ^2e^4}{8\varepsilon_0^2h^2}\frac{1}{n^2}$; 13.6eV

$r_n = a_0 n^2$; $a_0 = \frac{\varepsilon_0 h^2}{\pi m Z e^2}$; $5.29\times10^{-11} m$

$P(r) = \frac{4}{a_0^3}r^2 e^{-2r/a_0}$; $\sqrt{f} = C(Z-1)$ Mosley

Bremsstrahlung: $K = eV = hf_{\max} = \frac{hc}{\lambda_{\min}}$

l = 0, 1, 2, 3, … corresponds to s, p, d, f, …

Selection Rule: $\Delta l = \pm1$

$E = hf$; $p = \frac{h}{\lambda}$;

$\hbar = \frac{h}{2\pi}$; $k = \frac{2\pi}{\lambda} = \frac{2\pi p}{h}$

$\Delta k\Delta x \cong 1$; $\Delta\omega\Delta t \cong 1$

$\Delta x\Delta p \ge h/2\pi$; $\Delta E\Delta t \ge h/2\pi$

Photoelectric:

$hf = \phi + K_{\max}$; $K_{\max} = eV_0$

Compton Scattering:

$\lambda' - \lambda = \frac{h}{mc}(1-\cos\phi)$

Black Body

$R(\lambda,T) = \frac{2\pi c^2 h}{\lambda^5}\frac{1}{e^{hc/\lambda kt}-1}$

$I = \sigma T^4$ where

$\sigma = \frac{2\pi^5 k^4}{15c^2h^3} = 5.670\times10^{-8} W/m^2\cdot K^4$

$\lambda_{\max}T = const = 2898\mu m\cdot K$

$\vec{\mu}_l = -\frac{e}{2m}\vec{L}$; $\mu_{lz} = -m_l\mu_B$;

$U = -\vec{\mu}_l\cdot\vec{B} = m_l\mu_B B_z$; $\mu_{sz} = -g_s m_s \mu_B$;

$g_s \cong 2$; $\mu_N = \frac{eh}{4\pi m_p} = 3.15\times10^{-8} eV/T$

$\frac{n(E_2)}{n(E_1)} = e^{-(E_2-E_1)/kT}$

$1u = 1.66054\times10^{-27} kg$; $(1u)c^2 = 931.5 MeV$

$m_p = 1.007825u$

$m_n = 1.008665u$; $m_e = 0.0005486u$

$A = Z + N$; $R = R_0 A^{1/3}$;

$R_0 \cong 1.2 fm$

$N = N_0 e^{-\lambda t}$;

$N = N_0\left(\frac{1}{2}\right)^{t/t_{1/2}}$; $R = N\lambda$;

Decays: alpha (2p, 2n); beta

$n \to p + e^- + \bar{v}$ or

$p \to n + e^+ + v$

Magic: 2, 8, 20, 28, 50, 82, 126

Leptons (spin $\frac{1}{2}$): $e^-, e^+, \mu^-, \mu^+, \tau^-, \tau^+$

Also: $\nu_e, \bar{\nu}_e, \nu_\mu, \bar{\nu}_\mu, \nu_\tau, \bar{\nu}_\tau$

Mesons (spin 1):

$\pi^+, \pi^-, K^+, K^-, K^0, \bar{K}_0, \eta, \ldots$

Baryons (half integer spin):

$p, \bar{p}, n, \bar{n}, \Lambda^0, \bar{\Lambda}^0, \Sigma^{+0-}, \bar{\Sigma}^{+0-}, \ldots$

Field: graviton, W^+, W^-, Z^0, γ, g

Conservation laws:

Charge conservation.

Lepton number constant for e, μ, τ .

Baryon number constant.

EM processes, strangeness constant.

Weak processes, total strangeness constant or changes by 1.

1st generation: $\begin{pmatrix} e \\ \nu_e \end{pmatrix}$ and $\begin{pmatrix} u \\ d \end{pmatrix}$

2nd generation: $\begin{pmatrix} \mu \\ \nu_\mu \end{pmatrix}$ and $\begin{pmatrix} c \\ s \end{pmatrix}$

3rd generation: $\begin{pmatrix} \tau \\ \upsilon_\tau \end{pmatrix}$ and $\begin{pmatrix} t \\ b \end{pmatrix}$

$v = Hd$;

$H = 72 km/s\cdot MPs$; $1Mps = 3.084\times10^{19} km$

$T = \frac{1.5\times10^{10} s^{1/2}\cdot K}{t^{1/2}}$