Formula sheet

· $m_\mathrm{e} = 9.11 \times 10^{-31}\mathrm{kg}$ $\quad m_\mathrm{p} = 1.67 \times 10^{-27}\mathrm{kg}$ $\quad e = 1.60 \times 10^{-19}\mathrm{C}$
· $K = \frac{1}{4\pi\epsilon_0} = 9.0 \times 10^9 \frac{\mathrm{Nm}^2}{\mathrm{C}^2}$ $\quad \epsilon_0 = 8.85 \times 10^{-12}\frac{\mathrm{F}}{\mathrm{m}}$ $\quad 1\,\mathrm{eV} = 1.60 \times 10^{-19}\mathrm{J}$
· $\vec{F}_\mathrm{C} = \frac{Kq_1q_2}{r^2}\hat{\mathbf{r}}$ $\quad \vec{F}_\mathrm{E} = q\vec{E}$
· $\phi_E = \oint_S \vec{E}\cdot d\vec{A} = \frac{Q_\mathrm{enclosed}}{\epsilon_0}$
· $E_\mathrm{line} = \frac{2K|\lambda|}{r} = \frac{2K|Q|}{Lr}$ $\quad E_\mathrm{plane} = \frac{|\eta|}{2\epsilon_0} = \frac{|Q|}{2A\epsilon_0}$ $\quad \vec{E}_\mathrm{cap} = \left(\frac{Q}{\epsilon_0 A}, \mathrm{pos} \to \mathrm{neg}\right)$
· $\frac{mv^2}{2} + U_\mathrm{el}(s) = \frac{mv_0^2}{2} + U_\mathrm{el}(s_0)$, $(U \equiv PE_\mathrm{el})$ $\quad U_\mathrm{el} = qEx$ for $\vec{E} = -E\ \hat{i}$
· $V_\mathrm{el} = U_\mathrm{el}/q$ $\quad E_x = -\frac{dV_\mathrm{el}}{dx}$
· $Q = C\Delta V_C$ $\quad$ farad $= \mathrm{F} = \frac{\mathrm{C}}{\mathrm{V}}$ $\quad C = \frac{\epsilon_0 A}{d}$ $\quad \epsilon_0 = 8.85 \times 10^{-12}\frac{\mathrm{C}^2}{\mathrm{Nm}^2}$
· parallel C_1, C_2: $C_\mathrm{eq} = C_1 + C_2$ $\quad$ series C_1, C_2: $C_\mathrm{eq}^{-1} = C_1^{-1} + C_2^{-1}$
· $\Delta V_\mathrm{loop} = \sum_i \Delta V_i = 0$ $\quad \sum I_\mathrm{in} = \sum I_\mathrm{out}$
· $P = \Delta V I$ $\quad$ watt $= \mathrm{W} = \mathrm{VA}$ $\quad P_R = \Delta V_R I = I^2 R$
· $\tau = RC$ $\quad Q(t) = Q_0 e^{-t/\tau}$ $\quad I(t) = -\frac{dQ}{dt} = \frac{\Delta V_0}{R}e^{-t/\tau}$
· $\oint_C \vec{B}\cdot d\vec{s} = \mu_0 I_\mathrm{enclosed}$
· $B_\mathrm{wire} = \frac{\mu_0}{2\pi}\frac{I}{d}$ (use RH rule) $\quad \mu_0 = 4\pi \cdot 10^{-7}\frac{\mathrm{Tm}}{\mathrm{A}}$ $\quad$ tesla $= \mathrm{T} = \frac{\mathrm{N}}{\mathrm{Am}}$
· short coil, $R >> L$ (N turns): $B_\mathrm{coil,centre} = \frac{\mu_0 NI}{2R}$ $\quad$ solenoid, $L >> R$: $B_\mathrm{sol,inside} = \frac{\mu_0 NI}{L}$
· $\vec{F}_\mathrm{m} = q(\vec{v} \times \vec{B})$ $\quad$ force on current $\perp$ to $\vec{B}$: $F_\mathrm{wire} = ILB$
· force betw. parallel wires: $F_\mathrm{2wires} = \frac{\mu_0 L I_1 I_2}{2\pi d}$
· $\mathcal{E} = -\frac{d\phi_B}{dt}$ where $\phi_B = \vec{B}\cdot\vec{A}$
· Harmonic oscillator: $m\ddot{x} + b\dot{x} + kx = F(t)$ [x – position/charge (the diacritical dot indicating a time derivative such that $\dot{x} = dx/dt$), m – mass/inductance, b – damping coefficient/resistance, k– spring constant/(1/capacitance), F– external drive]. The *natural frequency* is given by $\omega_o = 2\pi f_o = \sqrt{k/m}$. The energy of the system is $E = K + U = \frac{1}{2}m\dot{x}^2 + \frac{1}{2}kx^2$.
· $i = \sqrt{-1}$
· $V_{rms} = \frac{V}{\sqrt{2}}$
· $\mathrm{dB} = 20\log(x/y)$ (decibels)
· Ideal transformer equation: $\frac{\Delta V_2}{\Delta V_1} = \frac{N_2}{N_1} = \frac{I_1}{I_2}$
· RL circuit: $\tau = L/R$, $U_L = \frac{1}{2}LI^2$
· Spherically propagating wave: $I(r) = \frac{P}{4\pi r^2}$, intensity I at a radius r is related to the source power P
· Right-going wave: $f(x,t) = f(x - vt)$ where v is the wave velocity
· Left-going wave: $f(x,t) = f(x + vt)$
· (Right-going) Sinusoidal wave: $f(x,t) = A\sin(kx - \omega t)$. A – amplitude of the wave, k – wave number ($= 2\pi/\lambda$, λ being the wavelength), ω – angular frequency ($= 2\pi f = 2\pi/T$, T being the period). The *phase velocity* is given as $v = \omega/k = \lambda/T$.

· Maxwell's equations:

$$\text{Gauss' law for electricity:} \quad \oint_{\substack{\text{closed}\\\text{surface}}} \vec{E} \cdot d\vec{A} = \frac{Q_{enc}}{\epsilon_0}$$

$$\text{Gauss' law for magnetism:} \quad \oint_{\substack{\text{closed}\\\text{surface}}} \vec{B} \cdot d\vec{A} = 0$$

$$\text{Faraday's law:} \quad \oint \vec{E} \cdot d\vec{s} = -\frac{d\phi_B}{dt}$$

$$\text{Ampere-Maxwell law:} \quad \oint \vec{B} \cdot d\vec{s} = \mu_0 I_{enc} + \mu_0 \epsilon_0 \frac{d\phi_E}{dt}$$

$$\text{Lorentz force law:} \quad \vec{F} = Q(\vec{E} + \vec{v} \times \vec{B})$$

· $c = \frac{1}{\sqrt{\mu_o \epsilon_o}} = 2.998 \times 10^9$ m/s (speed of light). Also $c = \lambda f$

· For an electromagnetic wave, $E = cB$ at any point on the wave and $\vec{E} \times \vec{B}$ is in the direction of propagation

· Energy of a photon: $E = \hbar\omega = \frac{hc}{\lambda}$ where $h = 6.63 \times 10^{-34}$ J·s (Planck's constant)