Cheat Sheets

Constants:

$$
\begin{aligned}
N_A &= 6.022 \times 10^{23} \text{ things/mol} \\
k_e &= 8.98755 \times 10^{9}\,\text{N} \cdot \text{m}^2 \cdot \text{C}^{-2} \\
\mu_0 &\equiv 4\pi \times 10^{-7}\,\text{T} \cdot \text{m/A} \\
\epsilon_0 &= 8.85 \times 10^{12}\,\text{C}^2/\text{N} \cdot \text{m}^2 \\
e &= 1.60218 \times 10^{-19}\,\text{C} \\
h &= 6.6261 \times 10^{-34}\,\text{J} \cdot \text{s} = 4.1357 \times 10^{-15}\,\text{eV} \cdot \text{s} \\
\hbar &= \frac{h}{2\pi} \\
c &= \frac{1}{\sqrt{\mu_0 \epsilon_0}} = 2.99792 \times 10^{8}\,\text{m/s} \\
m_{e^-} &= 9.10938 \times 10^{-31}\,\text{kg} = 0.510998\,\text{MeV}/c^2 \\
m_{p^+} &= 1.67262 \times 10^{-27}\,\text{kg} = 938.272\,\text{MeV}/c^2 \\
m_{n^0} &= 1.67493 \times 10^{-27}\,\text{kg} = 939.565\,\text{MeV}/c^2 \\
1\,\text{u} &= 931.494\,\text{MeV}/c^2 \\
hc &= 1239.84\,\text{eV} \cdot \text{nm}
\end{aligned}
$$

Quadratic formula:

$$0 = ax^2 + bx^2 + c \Longrightarrow x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Basic Equations:

$$
\begin{aligned}
\vec{\mathbf{F}}_{\text{net}} &= m\vec{\mathbf{a}} \text{ Newton's Second Law} \\
\vec{\mathbf{F}}_{\text{centr}} &= -\frac{mv^2}{r}\hat{\mathbf{r}} \text{ Centripetal}
\end{aligned}
$$

Magnetism

$$
\begin{aligned}
|\vec{\mathbf{F}}_B| &= q|\vec{\mathbf{v}}||\vec{\mathbf{B}}| \sin\theta_{vB} \\
|\vec{\mathbf{F}}_B| &= BIl\sin\theta \text{ wire} \\
|\vec{\boldsymbol{\tau}}| &= BIAN\sin\theta \text{ torque current loop} \\
\vec{\mathbf{B}} &= \frac{\mu_0 I}{2\pi r}\hat{\boldsymbol{\theta}} \text{ wire} \\
\vec{\mathbf{B}} &= \frac{\mu_0 I}{2r}\hat{\boldsymbol{\theta}} \text{ loop} \\
\vec{\mathbf{B}} &= \mu_0 \frac{N}{L} I\,\hat{\mathbf{z}} \equiv \mu_0 n I\,\hat{\mathbf{z}} \text{ solenoid} \\
\frac{|\vec{\mathbf{F}}_{12}|}{l} &= \frac{\mu_0 I_1 I_2}{2\pi d} \text{ 2 wires, force per length}
\end{aligned}
$$

Current:

$$
\begin{aligned}
I &= \frac{\Delta Q}{\Delta t} = nqAv_d \\
J &= \frac{I}{A} = nqv_d \\
v_d &= \frac{-e\tau}{m}E \quad \tau = \text{scattering time} \\
\varrho &= \frac{m}{ne^2\tau} \\
\Delta V &= \frac{\varrho l}{A} I = RI \\
R &= \frac{\Delta V}{I} = \frac{\varrho l}{A} \\
\mathscr{P} &= E \cdot \Delta t = I\Delta V = I^2 R = \frac{[\Delta V]^2}{R} \text{ power}
\end{aligned}
$$

Ohm:

$$
\begin{aligned}
\Delta V &= IR \\
\mathscr{P} &= E \cdot \Delta t = I\Delta V = I^2 R = \frac{[\Delta V]^2}{R} \quad \text{power}
\end{aligned}
$$

EM Waves:

$$
\begin{aligned}
c &= \lambda f = \frac{|\vec{\mathbf{E}}|}{|\vec{\mathbf{B}}|} \\
\mathcal{I} &= \left[\frac{\text{photons}}{\text{time}}\right]\left[\frac{\text{energy}}{\text{photon}}\right]\left[\frac{1}{\text{Area}}\right] \\
\mathcal{I} &= \frac{\text{energy}}{\text{time} \cdot \text{area}} = \frac{E_{\max}B_{\max}}{2\mu_0} = \frac{\text{power } (\mathscr{P})}{\text{area}} = \frac{E_{\max}^2}{2\mu_0 c}
\end{aligned}
$$

Electric Potential:

$$
\begin{aligned}
\Delta V &= V_B - V_A = \frac{\Delta \text{PE}}{q} \\
\Delta PE &= q\Delta V = -q|\vec{\mathbf{E}}||\Delta\vec{\mathbf{x}}|\cos\theta = -qE_x\Delta x \\
&\quad \uparrow \text{ constant E field} \\
V_{\text{point charge}} &= k_e\frac{q}{r} \\
PE_{\text{pair of point charges}} &= k_e\frac{q_1 q_2}{r_{12}} \\
PE_{\text{system}} &= \text{sum over unique pairs of charges} = \sum_{\text{pairs } ij} \frac{k_e q_i q_j}{r_{ij}} \\
-W &= \Delta\text{PE} = q(V_B - V_A)
\end{aligned}
$$

Optics:

$$
\begin{aligned}
\mathscr{E} &= hf = \frac{hc}{\lambda} \\
n &= \frac{\text{speed of light in vacuum}}{\text{speed of light in a medium}} = \frac{c}{v} \\
\frac{\lambda_1}{\lambda_2} &= \frac{v_1}{v_2} = \frac{c/n_1}{c/n_2} = \frac{n_2}{n_1} \quad \text{refraction} \\
n_1 \sin\theta_1 &= n_2 \sin\theta_2 \quad \text{Snell's refraction} \\
\lambda f &= c \\
M &= \frac{h'}{h} = -\frac{q}{p} \\
\frac{1}{f} &= \frac{1}{p} + \frac{1}{q} = \frac{2}{R} \quad \text{mirror \& lens} \\
\frac{n_1}{p} + \frac{n_2}{q} &= \frac{n_2 - n_1}{R} \quad \text{spherical refracting} \\
q &= -\frac{n_2}{n_1}p \quad \text{flat refracting} \\
\frac{1}{f} &= \left(\frac{n_2 - n_1}{n_1}\right)\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \quad \text{lensmaker's}
\end{aligned}
$$

Electric Force & Field

$$
\begin{aligned}
\vec{\mathbf{F}}_{e,12} &= q\vec{\mathbf{E}}_{12} = \frac{k_e q_1 q_2}{r_{12}^2}\hat{\mathbf{r}}_{12} \\
\vec{\mathbf{E}} &= k_e\frac{|q|}{r^2} \\
\Phi_E &= |\vec{\mathbf{E}}|A\cos\theta_{EA} = \frac{Q_{\text{inside}}}{\epsilon_0} \\
\Delta PE &= -W = -q|\vec{\mathbf{E}}||\Delta\vec{\mathbf{x}}|\cos\theta = -qE_x\Delta x \\
&\quad \uparrow \text{ constant E field}
\end{aligned}
$$

Capacitors:

$$
\begin{aligned}
Q_{\text{capacitor}} &= C\Delta V \\
C_{\text{parallel plate}} &= \frac{\epsilon_0 A}{d} \\
E_{\text{capacitor}} &= \frac{1}{2}Q\Delta V = \frac{Q^2}{2C} \\
C_{\text{eq, par}} &= C_1 + C_2 \\
C_{\text{eq, series}} &= \frac{C_1 C_2}{C_1 + C_2} \\
C_{\text{with dielectric}} &= \kappa C_{\text{without}}
\end{aligned}
$$

Cheat Sheets

Resistors:

$$I_{\text{V source}} = \frac{\Delta V}{R+r}$$
$$\Delta V_{\text{V source}} = \Delta V_{\text{rated}}\frac{R}{r+R}$$
$$I_{\text{I source}} = I_{\text{rated}}\frac{r}{r+R}$$
$$R_{\text{eq, series}} = R_1 + R_2$$
$$\frac{1}{R_{\text{eq, par}}} = \frac{1}{R_1} + \frac{1}{R_2}$$
$$R_{\text{eq, par}} = \frac{R_1 R_2}{R_1 + R_2}$$

RC circuits

$$Q_C(t) = Q_0\left[1 - e^{-t/\tau}\right] \quad \text{charging}$$
$$Q_C(t) = Q_0 e^{-t/\tau} \quad \text{discharging}$$
$$Q(t) = C\Delta V(t)$$
$$\tau = RC$$

Vectors:

$$|\vec{\mathbf{F}}| = \sqrt{F_x^2 + F_y^2} \ \text{magnitude}$$
$$\theta = \tan^{-1}\left[\frac{F_y}{F_x}\right] \ \text{direction}$$

Units

$$1\,\text{T}\cdot\text{m/A} = 1\,\text{N/A}^2$$
$$1\,\text{T}\cdot\text{m}^2 = 1\,\text{V}\cdot\text{s}$$
$$1\,\text{T} = 1\,\text{kg/A}\cdot\text{s}^2$$
$$1\,\text{eV} = 1.6\times10^{-19}\,\text{J}$$
$$1\,\text{J} = 1\,\text{N}\cdot\text{m} = 1\,\text{kg}\cdot\text{m}^2/\text{s}^2$$
$$1\,\text{N} = 1\,\text{kg}\cdot\text{m/s}^2$$
$$1\,\text{W} = 1\,\text{J/s} = 1\,\text{kg}\cdot\text{m}^2/\text{s}^3$$
$$1\,\text{F} = 1\,\text{C/V} \qquad 1\,\text{C} = 1\,\text{A/s}$$
$$1\,\text{N/C} = 1\,\text{V/m}$$

Induction:

$$\Phi_B = B_\perp A = BA\cos\theta_{BA}$$
$$\Delta V = -N\frac{\Delta\Phi_B}{\Delta t}$$
$$L = N\frac{\Delta\Phi_B}{\Delta I} = \frac{N\Phi_B}{I}$$
$$\Delta V = |\vec{\mathbf{v}}||\vec{\mathbf{B}}|l = |\vec{\mathbf{E}}|l \ \text{motional voltage}$$

ac Circuits

$$\tau = L/R \ \text{RL circuit}$$
$$\tau = RC \ \text{RC circuit}$$
$$X_C = \frac{1}{2\pi f C} \ \text{“resistance” of a capacitor for ac}$$
$$X_L = 2\pi f L \ \text{“resistance” of an inductor for ac}$$
$$\omega_{\text{cutoff}} = \frac{1}{\tau} = 2\pi f$$

Nuclear

$$E^2 = p^2c^2 + m^2c^4$$
$$\text{alpha particle} = {}^4_2\alpha = {}^4_2\text{He} \qquad \text{beta particle} = {}^{\ 0}_{-1}\beta = e^-$$
$$\text{Binding Energy} = \left[\sum_{p^+ \& n^0} mc^2\right] - m_{\text{atom}}c^2$$

Relativity

$$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$$
$$\Delta t'_{\text{moving}} = \gamma\Delta t_{\text{stationary}} = \gamma\Delta t_p$$
$$L'_{\text{moving}} = \frac{L_{\text{stationary}}}{\gamma} = \frac{L_p}{\gamma}x' = \gamma(x - vt)$$
$$\Delta t' = t'_1 - t'_2 = \gamma\left(\Delta t - \frac{v\Delta x}{c^2}\right)$$
$$p = \gamma mv$$
$$v_{\text{obj}} = \frac{v + v'_{\text{obj}}}{1 + \frac{vv'_{\text{obj}}}{c^2}} \qquad v'_{\text{obj}} = \frac{v_{\text{obj}} - v}{1 - \frac{vv_{\text{obj}}}{c^2}}$$
$$\text{KE} = (\gamma - 1)mc^2$$
$$E_{\text{rest}} = mc^2$$
$$E^2 = p^2c^2 + m^2c^4$$

Quantum & Atomic

$$\lambda_{\text{out}} - \lambda_{\text{in}} = \frac{h}{m_e c}(1-\cos\theta)$$
$$\lambda = \frac{h}{|\vec{\mathbf{p}}|} = \frac{h}{\gamma mv} \approx \frac{h}{mv}$$
$$\Delta x\Delta p \geq \frac{h}{4\pi}$$
$$\Delta E\Delta t \geq \frac{h}{4\pi}$$
$$E_n = -13.6\,\text{eV}/n^2$$
$$E_i - E_f = -13.6\,\text{eV}\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) = hf \ \textit{Hydrogen only}$$
$$mvr = n\hbar$$
$$v^2 = \frac{n^2\hbar^2}{m_e^2 r^2} = \frac{k_e e^2}{m_e r}$$
$$N(t) = N_0\left(\frac{1}{2}\right)^{t/T_{1/2}}$$

Right-hand rule #1

1. Point the fingers of your right hand along the direction of the velocity.
2. Point your thumb in the direction of the magnetic field $\vec{\mathbf{B}}$.
3. The magnetic force on a positive charge points out from the back of your hand.

Right-hand rule #2:
Point your thumb on your right hand along the wire in the direction of the current. Your fingers naturally curl around the direction of the magnetic field caused by the current, which circulates around the wire.

Derived unit	**Symbol**	**equivalent to**
newton	N	kg·m/s^2
joule	J	kg·m^2/s^2 = N·m
watt	W	J/s=m^2·kg/s^3
coulomb	C	A·s
V	W/A = m^2·kg/·s^3·A	
farad	F	C/V = A^2·s^4/m^2·kg
ohm	Ω	V/A = m^2·kg/s^3·A^2
tesla	T	Wb/m^2 = kg/s^2·A

Power	**Prefix**	**Abbreviation**
10^{-12}	pico	p
10^{-9}	nano	n
10^{-6}	micro	μ
10^{-3}	milli	m
10^{-2}	centi	c
10^{3}	kilo	k
10^{6}	mega	M
10^{9}	giga	G
10^{12}	tera	T

Periodic Table of the Elements

1 H 1.00794																1 H 1.00794	2 He 4.002602
3 Li 6.941	4 Be 9.012182											5 B 10.811	6 C 12.0107	7 N 14.00674	8 O 15.9994	9 F 18.9984032	10 Ne 20.1797
11 Na 22.989770	12 Mg 24.3050											13 Al 26.981538	14 Si 28.0855	15 P 30.973761	16 S 32.066	17 Cl 35.4527	18 Ar 39.948
19 K 39.0983	20 Ca 40.078	21 Sc 44.955910	22 Ti 47.867	23 V 50.9415	24 Cr 51.9961	25 Mn 54.938049	26 Fe 55.845	27 Co 58.933200	28 Ni 58.6934	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.92160	34 Se 78.96	35 Br 79.904	36 Kr 83.80
37 Rb 85.4678	38 Sr 87.62	39 Y 88.90585	40 Zr 91.224	41 Nb 92.90638	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.90550	46 Pd 106.42	47 Ag 107.8682	48 Cd 112.411	49 In 114.818	50 Sn 118.710	51 Sb 121.760	52 Te 127.60	53 I 126.90447	54 Xe 131.29
55 Cs 132.90545	56 Ba 137.327	57 La 138.9055	72 Hf 178.49	73 Ta 180.9479	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.217	78 Pt 195.078	79 Au 196.96655	80 Hg 200.59	81 Tl 204.3833	82 Pb 207.2	83 Bi 208.98038	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 (269)	111 (272)	112 (277)		114 (289) (287)		116 (289)		118 (293)

58 Ce 140.116	59 Pr 140.90765	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.964	64 Gd 157.25	65 Tb 158.92534	66 Dy 162.50	67 Ho 164.93032	68 Er 167.26	69 Tm 168.93421	70 Yb 173.04	71 Lu 174.967
90 Th 232.0381	91 Pa 231.03588	92 U 238.0289	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)

S.E. Van Bramer, 7/22/99
1995 IUPAC masses and Approved Names from http://www.chem.qmw.ac.uk/iupac/AtWt/
masses for 107-111 from C&EN, March 13, 1995, P 35
112 from http://www.gsi.de/z112e.html
114 from C&EN July 19, 1999
116 and 118 from http://www.lbl.gov/Science-Articles/Archive/elements-116-118.html