Formula Sheet for Physics 251

Constants

$R = 8.3145 \ \frac{\text{J}}{\text{m}\cdot\text{K}}$

$N_A = 6.02\times10^{23}$

$k_B = \frac{R}{N_A} = 1.38\times10^{-23} \ \frac{\text{J}}{\text{m}\cdot\text{K}}$

$e = 1.602\times10^{-19}\ \text{C}$

$k = \frac{1}{4\pi\varepsilon_0} = 9\times10^{9} \ \frac{\text{N}\cdot\text{m}^2}{\text{C}^2}$

$\mu_0 = 4\pi\times10^{-7} \ \frac{\text{T}\cdot\text{m}}{\text{A}}$

$c = 3\times10^{8} \ \frac{\text{m}}{\text{s}}$

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

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

Force, Field, Energy and Potential

$\vec{F} = q\vec{E}$

$\Delta U = q\Delta V$

$V_{ab} = \int_a^b \vec{E}\cdot d\vec{l}$

$\vec{E} = -\nabla V$

1 Point Charge

$\vec{E} = k\frac{q}{r^2}\hat{r}$

$V = k\frac{q}{r}$

Distributed Charge

$\vec{E} = \int k\frac{dq}{r^2}\hat{r}$

$V = \int k\frac{dq}{r}$

Many Sources

$\vec{E}_T = \sum_i \vec{E}_i$

$U_T = \sum_{pairs} U_{ij}$

Flux and Gauss's Law

$\varphi = \iint \vec{E}\cdot d\vec{a}$

$\varphi_{\text{closed}} = \frac{Q_{\text{enclosed}}}{\varepsilon_0}$

Capacitors

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

$C_T = \sum_i C_i$ parallel

$\frac{1}{C_T} = \sum_i \frac{1}{C_i}$ series

$U = \frac{1}{2}CV^2 = \frac{Q^2}{2C} = \frac{1}{2}QV$

Current and Current Density

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

$I = \iint \vec{J}\cdot d\vec{a}$

$\vec{J} = nqv_d$

Ohm's Law

$\vec{E} = \rho\vec{J}$

$V = IR$

Resistivity and Resistance

$R = \int \rho\frac{dL}{A}$

$\rho = \rho_0\left[1+\alpha(T-T_0)\right]$

Electric Power

$P = IV$

Real Batteries

$V = \boldsymbol{E} - Ir$

Addition of Resistors

$R_T = R_1 + R_2 + \ldots$ series

$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$ parallel

Kirchoff's rules

$\sum_{loop} V = 0$

$\sum_{node} I = 0$

RC circuits (charging)

$I = I_i e^{-\frac{t}{\tau}}$

$Q = Q_f\left(1 - e^{-\frac{t}{\tau}}\right)$

$\tau = RC$

RC circuits (discharging)

$I = I_i e^{-\frac{t}{\tau}}$

$Q = Q_i e^{-\frac{t}{\tau}}$

$\tau = RC$

Magnetic Force and Torque

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

$d\vec{F} = Id\vec{l}\times\vec{B}$

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

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

Cyclotron Motion

$R = \frac{mv}{qB}$

$T = \frac{2\pi m}{qB}$

$\omega_c = \frac{qB}{m}$

Flux and Gauss's Law for Magnetism

$\varphi = \iint \vec{B}\cdot d\vec{a}$

$\varphi_{\text{closed}} = 0$

Sources of Magnetic Fields

$B = \frac{\mu_0}{4\pi}\frac{q\vec{v}\times\hat{r}}{r^2}$

$\vec{B} = \int \frac{\mu_0}{4\pi}\frac{Id\vec{l}\times\hat{r}}{r^2}$

$|B| = \frac{\mu_0 I}{2R}$ center of loop

Ampere's Law

$\oint \vec{B}\cdot d\vec{l} = \mu_0\left(I_{\text{enc}} + I_d\right)$

where

$I_d = \varepsilon_0\frac{d\varphi_E}{dt}$

Faraday's Law

$\boldsymbol{E} = -\frac{d\varphi_B}{dt}$

or

$\oint_C \vec{E}\cdot d\vec{l} = -\frac{d}{dt}\iint_S \vec{B}\cdot d\vec{a}$

Mutual Inducance

$M = \frac{N_1\varphi_{B1}}{I_2} = \frac{N_2\varphi_{B2}}{I_1}$

$\boldsymbol{E}_1 = -M\frac{dI_2}{dt}$

$\boldsymbol{E}_2 = -M\frac{dI_1}{dt}$

Self Inductance

$L = \frac{N\varphi_B}{I}$

$\boldsymbol{E} = -L\frac{dI}{dt}$

$U = \frac{1}{2}LI^2$

† indicates formulas that are specific to parallel-plate capacitors

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RL Circuits (charging)

$$I = I_f\left(1 - e^{-\frac{t}{\tau}}\right)$$

$$V_L = V_0 e^{-\frac{t}{\tau}}$$

$$\tau = \frac{L}{R}$$

RL Circuits (discharging)

$$I = I_i e^{-\frac{t}{\tau}}$$

$$V_L = V_i e^{-\frac{t}{\tau}}$$

$$\tau = \frac{L}{R}$$

AC Circuits (general)

$$X_L = \omega L$$

$$X_C = \frac{1}{\omega C}$$

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

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

$$V_0 = I_0 Z$$

$$V_{rms} = \frac{V_0}{\sqrt{2}}$$

$$I_{rms} = \frac{I_0}{\sqrt{2}}$$

$$V_{R,\max} = IR$$

$$V_{L,\max} = IX_L$$

$$V_{C,\max} = IX_C$$

$$P = \frac{1}{2} I_0^2 R = \frac{1}{2} I_0^2 Z \cos\varphi$$

AC Circuits (resonance)

$$\varphi = 0$$

$$Z = R$$

$$\omega = \frac{1}{\sqrt{LC}}$$

$$X_L = X_C$$

Light

$$E_{\max} = cB_{\max}$$

$$c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}}$$

$$c = \lambda f$$

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

$$I = S_{av} = \frac{E_{\max} B_{\max}}{2\mu_0}$$

$$p_{rad} = \frac{S_{av}}{c}$$

Propagation of Light

$$n = \frac{c}{v}$$

$$\lambda = \frac{\lambda_0}{n}$$

$$\theta_r = \theta_a$$

$$n_a \sin\theta_a = n_b \sin\theta_b$$

$$\theta_c = \sin^{-1}\left(\frac{n_b}{n_a}\right) \text{ (TIR)}$$

$$I = I_0 \cos^2 \varphi$$

Focal Lengths

$$f = \frac{R}{2}$$

$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Image Location

$$\frac{1}{f} = \frac{1}{s} + \frac{1}{s'}$$

Lateral and Angular Magnification

$$m = \frac{y'}{y} = -\frac{s'}{s}$$

$$m_T = m_1 m_2 \ldots$$

$$M = \frac{\theta'}{\theta}$$

$$M = \frac{25}{f(\text{cm})} \text{ Magnifier}$$

$$M = -\frac{f_{objective}}{f_{eyepiece}} \text{ Telescope}$$

Cameras

$$f\text{ - number} = \frac{f}{D}$$

Eyeglasses

$$\text{power} = \frac{1}{f} \text{ diopters}$$

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