

Formula Sheet for Physics 251

Constants

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

$$N_A = 6.02 \times 10^{23}$$

$$k_B = \frac{R}{N_A} = 1.38 \times 10^{-23} \frac{\text{J}}{\text{m} \cdot \text{K}}$$

$$e = 1.602 \times 10^{-19} \text{ C}$$

$$k = \frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \frac{\text{N} \cdot \text{m}^2}{\text{C}^2}$$

$$\mu_0 = 4\pi \times 10^{-7} \frac{\text{T} \cdot \text{m}}{\text{A}}$$

$$c = 3 \times 10^8 \frac{\text{m}}{\text{s}}$$

$$m_e = 9.11 \times 10^{-31} \text{ kg}$$

$$m_p = 1.67 \times 10^{-27} \text{ kg}$$

Force, Field, Energy and Potential

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

$$\Delta U = q\Delta V$$

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

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

Point Charges

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

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

Distributed Charges

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

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

Many Sources

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

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

Flux and Gauss's Law

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

$$\phi_{\text{closed}} = \frac{Q_{\text{enclosed}}}{\epsilon_0}$$

Capacitors

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

$$C_T = \sum_i C_i \text{ parallel}$$

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

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

Current and Current Density

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

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

$$\vec{J} = nqv_d$$

Ohm's Law

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

$$V = IR$$

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

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

Electric Power

$$P = IV$$

Real Batteries

$$\mathcal{E} = V - Ir$$

Addition of Resistors

$$R_T = R_1 + R_2 + \dots \text{ series}$$

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

Kirchoff's rules

$$\sum_{\text{loop}} V = 0$$

$$\sum_{\text{node}} I = 0$$

RC circuits (charging)

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

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

$$\tau = RC$$

RC circuits (discharging)

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

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

$$\tau = RC$$

Magnetic Force and Torque

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

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

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

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

Flux and Gauss's Law for Magnetism

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

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

Sources of Magnetic Fields

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

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

Ampere's Law

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

where

$$I_d = \epsilon_0 \frac{d\phi_E}{dt}$$

Faraday's Law

$$\mathcal{E} = -\frac{d\phi}{dt}$$

or

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

Mutual Inductance

$$M = \frac{N_1 \phi_1}{I_2} = \frac{N_2 \phi_2}{I_1}$$

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

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

Self Inductance

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

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

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

*applies to ideal gases only

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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)

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

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

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

AC Circuits (general)

$$X_L = \omega L$$

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

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

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

$$V_0 = I_0 Z$$

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

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

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

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

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

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

AC Circuits (resonance)

$$\omega_{res} = \frac{1}{\sqrt{LC}}$$

$$X_L = X_C$$

Light

$$E_{max} = c B_{max}$$

$$c = \frac{1}{\sqrt{\epsilon_0 \mu_0}}$$

$$c = \lambda f$$

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

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

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

Propagation of Light

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

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

$$\theta_r = \theta_a$$

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

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

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

Lateral and Angular Magnification

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

$$m_T = m_1 m_2 \dots$$

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

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

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

Focal Lengths

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

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

Image Location

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

Eyeglasses

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

Thermal Expansion

$$\Delta L = \alpha L_0 \Delta T$$

$$\beta = 3\alpha$$

Heat

$$Q = mc\Delta T$$

$$Q = \pm mL$$

$$Q = nC_V \Delta T$$

$$Q = nC_P \Delta T$$

Heat Current

$$H = k \frac{A}{L} (T_H - T_C)$$

$$H = Ae\sigma T^4$$

Work

$$W = \int_{V_i}^{V_f} PdV$$

Ideal gases

$$* PV = nrT$$

$$* PV = NkT$$

$$* v_{RMS} = \sqrt{\frac{3RT}{M}}$$

$$* C_V = \frac{3}{2} R \text{ (monatomic)}$$

$$* C_V = \frac{5}{2} R \text{ (diatomic)}$$

$$* C_P = C_V + R$$

$$* \Delta U = nC_V \Delta T$$

(for any process)

Isochoric Processes

$$W = 0$$

$$Q = nC_V \Delta T$$

Isobaric Processes

$$W = P\Delta V$$

$$Q = nC_P \Delta T$$

Isothermal Processes

$$* W = nRT \ln \left(\frac{V_f}{V_i} \right)$$

$$* Q = nRT \ln \left(\frac{V_f}{V_i} \right)$$

Adiabatic Processes

$$Q = 0$$

$$* W = -nC_V \Delta T$$

$$* P_1 V_1^\gamma = P_2 V_2^\gamma$$

$$* T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1}$$

$$\gamma = \frac{C_P}{C_V}$$

Heat Engines

$$W = Q_H + Q_C$$

$$e = \frac{W}{Q_H}$$

$$e_c = 1 - \frac{T_C}{T_H}$$

Refrigerators

$$W = Q_H + Q_C$$

$$K = \frac{|Q_C|}{|W|}$$

$$K_c = \frac{T_C}{T_H - T_C}$$

*applies to ideal gases only