Modern Physics: Comprehensive Cheat Sheet

Core Equations, Constants, and Principles for Advanced Physics Evaluations

1. Dual Nature of Radiation Matter

Planck's Quantum Theory:

$$E = h\nu = \frac{hc}{\lambda}$$

where $h \approx 6.626 \times 10^{-34}$ J s.

Einstein's Photoelectric Equation:

$$K_{\max} = eV_s = h\nu - \phi = \frac{hc}{\lambda} - \lambda_0$$

where ϕ is the work function and V_s is the stopping potential.

De Broglie Wavelength:

$$\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{h}{\sqrt{2mE_k}} = \frac{h}{\sqrt{2meV}}$$

Heisenberg's Uncertainty Principle:

$$\Delta x \cdot \Delta p \geq \frac{\hbar}{2}, \quad \Delta E \cdot \Delta t \geq \frac{\hbar}{2}$$

where $\hbar = \frac{h}{2\pi}$.

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2. Atomic Structure Bohr Model

Coulomb Force Centripetal Balance:

$$\frac{1}{4\pi\epsilon_0}\frac{e^2}{r^2} = \frac{mv^2}{r}$$

Quantization of Angular Momentum:

$$mvr = n\hbar = \frac{nh}{2\pi}, \quad n = 1, 2, 3, \ldots$$

Radius of n-th Orbit:

$$r_n = \frac{\epsilon_0 n^2 h^2}{\pi m e^2} \approx 0.529\frac{n^2}{Z} \text{ Å}$$

Velocity of Electron:

$$v_n = \frac{e^2}{2\epsilon_0 nh} \approx 2.18 \times 10^6 \frac{Z}{n} \text{ m/s}$$

Total Energy in n-th Orbit:

$$E_n = -\frac{me^4}{8\epsilon_0^2 h^2}\frac{Z^2}{n^2} = -13.6\frac{Z^2}{n^2} \text{ eV}$$

Rydberg Formula for Spectral Lines:

$$\frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

where $R \approx 1.097 \times 10^7$ m^{-1} (Rydberg constant).

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3. X-Rays

Continuous X-Ray (Duane-Hunt Law):

$$\lambda_{\min} = \frac{hc}{eV} = \frac{12400}{V \text{ (in volts)}} \text{ Å}$$

Characteristic X-Ray (Moseley's Law):

$$\sqrt{\nu} = a(Z - b)$$

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4. Nuclear Physics Radioactivity

Nuclear Radius Formula:

$$R = R_0 A^{1/3}$$

where $R_0 \approx 1.2 \times 10^{-15}$ m $= 1.2$ fm, and A is the mass number.

Mass-Energy Equivalence:

$$\Delta E = \Delta m \cdot c^2$$

1 amu$(u) \approx 931.5$ MeV.

Mass Defect (Δm):

$$\Delta m = [Zm_p + (A - Z)m_n] - M_{\text{nucleus}}$$

Binding Energy per Nucleon (BE/A):

$$\text{BE} = \Delta m \cdot c^2$$

Radioactive Decay Law:

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

where λ is the decay constant.

Half-Life ($T_{1/2}$) Mean Life (τ):

$$T_{1/2} = \frac{\ln 2}{\lambda} \approx \frac{0.693}{\lambda}, \quad \tau = \frac{1}{\lambda} = 1.443T_{1/2}$$

Activity of a Sample:

$$A = \frac{dN}{dt} = \lambda N = A_0 e^{-\lambda t}$$

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5. Special Relativity Highlights

Lorentz Factor:

$$\gamma = \frac{1}{\sqrt{1 - v^2/c^2}}$$

Time Dilation Length Contraction:

$$t = \gamma t_0, \quad L = \frac{L_0}{\gamma}$$

Relativistic Momentum Energy:

$$p = \gamma m v, \quad E^2 = p^2 c^2 + (mc^2)^2$$