

PHY 251, Fall 2009: Equations for Final Exam

This is the August 19, 2009 version.

$p = h/\lambda$, $E = hc/\lambda = h\nu$ with $hc = 1240 \times 10^{-9} \text{ eV}\cdot\text{m}$. $1 \text{ eV} = 1.602 \times 10^{-19} \text{ J}$.

$h = 4.14 \times 10^{-15} \text{ eV}\cdot\text{sec}$, $h = 6.63 \times 10^{-34} \text{ J}\cdot\text{sec}$ and $c = 3.00 \times 10^8 \text{ m/sec}$.

Masses: $m_e = 510.998 \text{ keV}/c^2$, $m_p = 938.272 \text{ MeV}/c^2$, $m_n = 939.565 \text{ MeV}/c^2$, $1 \text{ u} = 931.494 \text{ MeV}/c^2$. $\Delta E \Delta t \geq \hbar$, $\Delta x \Delta p \geq \hbar$.

Bohr model: $r_n = \frac{n^2}{Z} a_0$ with $a_0 = \frac{\epsilon_0 h^2}{m \pi e^2} = 0.053 \text{ nm}$, and $E_n = -\frac{Z^2}{n^2} E_0$ with $E_0 = \frac{m e^4}{8 \epsilon_0^2 h^2} = 13.60 \text{ eV}$.

$m_r = \frac{m_1 m_2}{m_1 + m_2}$. $\frac{1}{4\pi\epsilon_0} \frac{Z e^2}{r^2} = m \frac{v^2}{r}$. $-\frac{\hbar^2}{2m} \nabla^2 \psi + V\psi = i\hbar \frac{\partial \psi}{\partial t} = E\psi$ if time independent.

3D Schrödinger equation with Coulomb potential: $\psi(r, \theta, \varphi) = R_{n,l}(r) \Theta_{l,m_l}(\theta) \Phi_{m_l}(\varphi)$.

Volume element: $r^2 dr \sin \theta d\theta d\varphi$.

Infinite box: $\psi_n = \sqrt{2/L} \sin(n\pi x/L)$, with $E_n = n^2 h^2 / (8mL^2)$.

For V constant:

$E > V$: $A \sin kx + B \cos kx$, $k = \sqrt{2m(E - V)}/\hbar$, and

$E < V$: $C \exp[-kx]$, $k = \sqrt{2m(V - E)}/\hbar$.

Harmonic oscillator: $E_n = (n + \frac{1}{2})\hbar\omega$, $\psi_0 = A \exp[-\omega m x^2 / (2\hbar)]$.

Rotational states: $E = \frac{\hbar^2 \ell(\ell + 1)}{2m_r r_0^2}$.

Energy order of shells: $1s < 2s < 2p < 3s < 3p < 4s \lesssim 3d < 4p < 5s < 4d < 5p < 6s < 4f \lesssim 5d < 6p < 7s < 6d \lesssim 5f \dots$

$|L| = \sqrt{\ell(\ell + 1)}\hbar$, $L_z = m_\ell \hbar$, $\vec{\mu}_L = -(e/2m)\vec{L}$.

$|S| = \sqrt{s(s + 1)}\hbar$, $S_z = m_s \hbar$, $\vec{\mu}_s = -(e/m)\vec{S}$.

$U = m_\ell \mu_B B = 2m_s \mu_B B$ with $\mu_B = e\hbar/(2m) = 9.274 \times 10^{-24} \text{ J/T}$.

$n(E) dE = f(E) g(E) dE$. Boltzmann factor: $\exp[-E/(k_B T)]$. Gibbs factor: $\exp[(N\mu - E)/(k_B T)]$.

$f_{FD}(E) = \frac{1}{\exp[(E - E_F)/(k_B T)] + 1}$. Electron gas: $E_{F0} = \frac{\hbar^2}{8m} \left(\frac{3N}{\pi V}\right)^{2/3}$, $C_V = \frac{9Nk_B^2}{2E_{F0}} T$

$f_{BE}(E) = \frac{1}{\exp[E/(k_B T)] - 1}$.

$\frac{A_{21}}{B_{21}} = 8\pi h \nu^3 / c^3$. $B_{12} = B_{21}$. $k_B = 8.617 \times 10^{-5} \text{ eV/K}$.

$R = r_0 A^{1/3}$ with $r_0 = 1.2 \times 10^{-15} \text{ m}$.

$$BE = -a_1 A + a_2 A^{2/3} + a_3 \frac{Z^2}{A^{1/3}} + a_4 \frac{(N - Z)^2}{A}$$

with $a_1 = 15.5 \text{ MeV}$, $a_2 = 16.8 \text{ MeV}$, $a_3 = 0.72 \text{ MeV}$, and $a_4 = 19 \text{ MeV}$.

$N = N_0 \exp[-\lambda t]$, activity $R = \lambda N$. $1 \text{ Gray} = 1 \text{ J/kg} = 100 \text{ rad}$. Sievert = Gray · RBE = 100 rem. $1 \text{ Curie} = 3.7 \times 10^{10} \text{ decay/sec}$. $N_A = 6.02 \times 10^{23} \text{ atoms/mol}$.

$\nu = \frac{\nu_0}{\gamma[1 + (v/c) \cos \theta]}$ with $\theta = 0$ for emitter moving directly away.

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

$$p = \gamma m_0 v, F_{\perp} = \gamma m_0 a, F_{\parallel} = \gamma^3 m_0 a.$$

$$x_2 = \gamma(x_1 - vt_1)$$

$$y_2 = y_1$$

$$z_2 = z_1$$

$$t_2 = \gamma\left(t_1 - \frac{v}{c}x_1\right)$$

and

$$v_{2,x} = \frac{v_{1,x} - v}{1 - \frac{v v_{1,x}}{c^2}}$$

$$v_{2,y} = \frac{v_{1,y}}{\gamma\left[1 - \frac{v v_{1,x}}{c^2}\right]}$$

$$v_{2,z} = \frac{v_{1,z}}{\gamma\left[1 - \frac{v v_{1,x}}{c^2}\right]}$$

$$E = E_0 + E_k = m_0 c^2 + (\gamma - 1)m_0 c^2, E^2 = E_0^2 + p^2 c^2.$$

$$p_{x,2} = \gamma\left(p_{x,1} - v(E/c^2)\right)$$

$$p_{y,2} = p_{y,1}$$

$$p_{z,2} = p_{z,1}$$

$$E_2 = \gamma(E - vp_x).$$