Midterm Formula Sheet

Constants:

$h = 6.63 \times 10^{-34}$ J-s $= 4.13 \times 10^{-15}$ eV-s

$\hbar = h/2\pi = 1.05 \times 10^{-34}$ J-s $= 6.58 \times 10^{-16}$ eV-s $\qquad kT/q = 0.0259$ V at 300 K

$k = 1.38 \times 10^{-23}$ J/K $= 8.62 \times 10^{-5}$ eV/K, $\qquad c = 3 \times 10^{10}$ cm/s

$m_0 = 9.11 \times 10^{-31}$ kg, $\qquad q = 1.60 \times 10^{-19}$ C

Equations:

$$J = \frac{I}{A} = \sigma E = (q\mu_n n + q\mu_p p)E, \quad R = \rho\frac{L}{S}, \quad \sigma = \frac{1}{\rho}, \quad \sigma = q\mu_n n + q\mu_p p$$

Photoelectric experiment: $K.E._{max} = h\nu - \Phi$

Time-dependent: $-\dfrac{\hbar^2}{2m}\nabla^2\psi(\vec{r},t) + U(\vec{r},t)\psi(\vec{r},t) = j\hbar\dfrac{\partial\psi(\vec{r},t)}{\partial t}$

Time-independent: $-\dfrac{\hbar^2}{2m}\nabla^2\psi(\vec{r}) + U(\vec{r})\psi(\vec{r}) = E\psi(\vec{r})$

Wave number: $k = \dfrac{\sqrt{2m(E-U_0)}}{\hbar}$ for $E > U_0$ and $k = \dfrac{\sqrt{2m(U_0-E)}}{\hbar}$ for $E < U_0$

Momentum: $p = m^* v = \hbar k = \dfrac{h}{\lambda}$, operator: $\dfrac{\hbar}{j}\dfrac{\partial}{\partial x}$; Energy: $E = h\nu = \hbar\omega$, operator: $-\dfrac{\hbar}{j}\dfrac{\partial}{\partial t}$

Kinetic energy: $K.E. = \dfrac{m^* v^2}{2} = \dfrac{\hbar^2 k^2}{2m^*}$, operator: $-\dfrac{\hbar^2}{2m}\dfrac{\partial^2}{\partial x^2}$

$k = \dfrac{2\pi}{\lambda}, \quad \omega = 2\pi\nu, \qquad\qquad$ Hydrogen atom: $E(n) = \dfrac{-13.6}{n^2}$ eV

Mobility: $\mu_d = \dfrac{q\tau}{m}$, $v_d = \mu_d E$

Fermi-Dirac distribution: $f(E) = \dfrac{1}{1 + e^{(E-E_F)/kT}} \cong e^{(E-E_F)/kT}$ for $E - E_F \gg kT$

$$n = N_C\exp\left(\frac{E_F - E_C}{kT}\right) = n_i\exp\left(\frac{E_F - E_{Fi}}{kT}\right), \qquad p = N_V\exp\left(\frac{E_V - E_F}{kT}\right) = n_i\exp\left(\frac{E_{Fi} - E_F}{kT}\right)$$

$$N_C = 2\left(\frac{2\pi m_n^* kT}{h^2}\right)^{3/2}, \quad N_V = 2\left(\frac{2\pi m_p^* kT}{h^2}\right)^{3/2}, \quad n_i = B\exp\left(\frac{-E_g}{2kT}\right) = \sqrt{N_C N_V}\exp\left(\frac{-E_g}{2kT}\right)$$

Equilibrium: $n_0 p_0 = n_i^2$

Charge neutrality: $n_0 + N_A = p_0 + N_D$

Recombination: $r(T) = \alpha_r np = \alpha_r n_o p_o + \alpha_r n_o \hat{p} + \alpha_r \hat{n} p_o$

$\hat{n}(t) = \hat{n}(0)\exp(-t/\tau_n), \qquad\qquad \hat{p}(t) = \hat{p}(0)\exp(-t/\tau_p)$