# **Cheat Sheet**

#### **Constants**

$$N_A = 6.02 \times 10^{23} \; \mathrm{molecules/mole}$$
  $k = 1.38 \times 10^{-23} \; \mathrm{J/K}$   $= 8.62 \times 10^{-5} \; \mathrm{ev/K}$   $q = 1.60 \times 10^{-19} \; \mathrm{C}$   $m_0 = 9.11 \times 10^{-31} \; \mathrm{kg}$   $\epsilon_0 = 8.85 \times 10^{-14} \; \mathrm{F/cm}$   $h = 6.63 \times 10^{-34} \; \mathrm{Js}$   $= 4.14 \times 10^{-15} \; \mathrm{eVs}$   $kT = 0.0259 \; \mathrm{eV}$   $c = 2.998 \times 10^{10} \; \mathrm{cm/s}$   $\mathring{\mathrm{A}} = 10^{-8} \; \mathrm{cm}$   $1 \; \mathrm{eV} = 1.6 \times 10^{-19} \; \mathrm{J}$ 

### **Formulas**

$$egin{aligned} p &= mv = \hbar ec{k} = rac{h}{\lambda} \ E &= hv = \hbar \omega \ E &= rac{1}{2} m v^2 = rac{1}{2} rac{p^2}{m} = rac{\hbar}{2m^*} ec{k}^2 \ m^* &= rac{\hbar^2}{d ec{k}^2} \ E_N &= KE + PE = E_c + E(k) = -rac{mq^4}{K^2 n^2 \hbar^2} \end{aligned}$$

	Classical Mechanics	<b>Quantum Mechanics</b>
Position	x	x
Momentum	p=mv	$\frac{\hbar}{j} \frac{\partial}{\partial x}$
Energy	$E=KE+PE=rac{1}{2}mv^2+PE$	$-rac{\hbar}{j}rac{\partial}{\partial t}$

$$egin{align} \langle Q 
angle &= \int\limits_{-\infty}^{\infty} \psi^* Q_{op} \psi \ dec{x} \ Eg(x) &= \int\limits_{-\infty}^{\infty} g(x) P(x) dx \ f(E) &= rac{1}{e^{(E-E_F)/kT} + 1} pprox e^{(E_F-E)/kT} & L = \sqrt{D au} \ n_0 &= N_c f(E_C) & 
ho &= rac{1}{\sigma} \ N_c &= 2(rac{2\pi m_n^* kT}{h^2})^{3/2} & R &= rac{
ho L}{wt} \ N_v &= 2(rac{2\pi m_p^* kT}{h^2})^{3/2} & J &= rac{I}{A} \ p_0 &= N_v f(E_v) & J &= J_n + J_p + C rac{dV}{dt} &= \sigma arepsilon \ \end{array}$$

$$egin{aligned} n_i &= N_c e^{-(E_C - E_i)/kT} = \sqrt{N_c N_v} e^{-E_g/2kT} \ p_i &= N_v e^{-(E_i - E_C)/kT} \ E &= rac{mq^4}{2K^2\hbar^2} \end{aligned}$$

$$J_n(x) = q \mu_n n(x) arepsilon(x) + q D_n rac{dn(x)}{dx} \ J_p(x) = q \mu_p p(x) arepsilon(x) - q D_p rac{dp(x)}{dx} \ rac{kT}{q} = rac{D}{\mu}$$

### **Equilibrium**

$$egin{aligned} n_0 &= n_i e^{(E_F-E_i)/kT} \ p_0 &= n_i e^{(E_i-E_F)/kT} \ n_0 p_0 &= n_i^2 \end{aligned}$$

# **Steady State**

$$egin{aligned} n &= N_c e^{-(E_C - F_n)/kT} = n_i e^{(F_n - E_i)/kT} \ p &= N_v e^{-(F_p - E_v)/kT} = n_i e^{(E_i - F_p)/kT} \ np &= n_i^2 e^{(F_n - F_p)/kT} \end{aligned}$$

### **Potential Well**

$$egin{aligned} \psi &= A \sin K x \ K &= rac{\sqrt{2mE}}{\hbar} \ \ \psi_H &= \sqrt{rac{2}{L}} \sin rac{nm}{L} x \ \psi_K(X) &= U(k_x,x) e^{jKxX} \end{aligned}$$

### p-n

$$egin{aligned} V_0 &= rac{kT}{q} \mathrm{ln} \left(rac{N_a N_d}{n_i^2}
ight) \ rac{p_p}{p_n} &= rac{n_n}{n_p} = e^{qV_0/kT} \ W &= \sqrt{rac{2\epsilon(V_0 - V)}{q} \left(rac{N_a + N_d}{N_a N_d}
ight)} \ n &= n_0 + \delta_n \ p &= p_0 + \delta_p \ \delta_p(x_n) &= \Delta p_n e^{-x_n/L_p} \ \delta_n(x_n) &= \Delta n_n e^{-x_p/L_n} \end{aligned}$$

$$egin{aligned} Q_{+} &= qAx_{n0}N_{d} = qAx_{p0}N_{a} \ arepsilon_{0} &= -rac{q}{arepsilon}x_{n0}N_{d} = -rac{q}{arepsilon}x_{p0}N_{a} \ I_{p} &= qArac{D_{p}}{L_{p}}p_{n}(e^{qV/kT}-1) \ I_{n} &= qArac{D_{n}}{L_{n}}n_{p}(e^{qV/kT}-1) \ I_{op} &= qAg_{op}(L_{p}+L_{n}+W) \ \Delta\sigma &= qg_{op}( au_{n}\mu_{n}+ au_{p}\mu_{p}) \end{aligned}$$

### One sided

$$x_{p0} = W rac{N_d}{N_a + N_d} \ x_{n0} = W rac{N_a}{N_a + N_d}$$