Name:

Constants:

$h = 6.63\times10^{-34}$ Js $= 4.13\times10^{-15}$ eVs

$\hbar = h/2\pi = 1.05\times10^{-34}$ Js $= 6.58\times10^{-16}$ eVs

$k = 1.38\times10^{-23}$ J/K $= 8.62\times10^{-5}$ eV/K, $c = 3\times10^{10}$ cm/s, $\varepsilon_0 = 8.85\times10^{-14}$ F/cm

$m_0 = 9.11\times10^{-31}$ kg, $q = 1.60\times10^{-19}$ C $\mu_0 = 4\pi\times10^{-7}$ H/m

$kT/q = 0.0259$ V at 300 K Visible light: 400 nm to 750 nm

Equations:

Schrödinger wave equation:

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

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

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

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

Kinetic energy: $K.E. = \frac{m^*v^2}{2} = \frac{\hbar^2k^2}{2m^*}$, operator: $-\frac{\hbar^2}{2m}\frac{\partial^2}{\partial x^2}$; Effective mass: $m^* = \frac{\hbar^2}{\partial^2E/\partial k^2}$

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

$n = \int_{E_C}^{\infty} f(E)g(E)dE = N_C e^{(E_F-E_C)/kT}$, $p = \int_0^{E_V}[1-f(E)]g(E)dE = N_V e^{(E_V-E_F)/kT}$

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

$E_{Fn} - E_i = kT\ln\frac{n}{n_i}$, $E_{Fn} - E_C = kT\ln\frac{n}{N_C}$, $E_i - E_{Fp} = kT\ln\frac{p}{n_i}$, $E_V - E_{Fp} = kT\ln\frac{p}{N_V}$

Equilibrium: $n_0p_0 = n_i^2$, Charge neutrality: $n_0 + N_A = p_0 + N_D$

Conductivity: $\sigma = q\mu_n n + q\mu_p p$, Drift velocity: $\vec{v}_d = \mu\vec{E}$

Current density: $\vec{J} = \vec{J}_n + \vec{J}_p$, $\vec{J}_n = q\mu_n n\vec{E} + qD_n\vec{\nabla}n$, $\vec{J}_p = q\mu_p p\vec{E} - qD_p\vec{\nabla}p$

Einstein's relation: $\frac{D}{\mu} = \frac{kT}{q}$, Diffusion length: $L_n = \sqrt{D_n\tau_n}$, $L_p = \sqrt{D_p\tau_p}$

Continuity: $\frac{\partial\hat{n}}{\partial t} = \frac{1}{q}\frac{\partial J_n}{\partial x} - \frac{\hat{n}}{\tau_n}$, $\frac{\partial\hat{p}}{\partial t} = -\frac{1}{q}\frac{\partial J_p}{\partial x} - \frac{\hat{p}}{\tau_p}$

Name:

PN junction: $V_0 = \frac{kT}{q}\ln\frac{N_A N_D}{n_i^2} = \frac{q}{2\varepsilon}\frac{N_A N_D}{N_A + N_D}W^2, \mathsf{E}_0 = -\frac{2V_0}{W},\ x_{n0} = \frac{N_A}{N_A + N_D}W$

$x_{p0} = \frac{N_D}{N_A + N_D}W,\ \ I = I_0\left(e^{qV/kT} - 1\right) = qA\left(\frac{D_p}{L_p}p_n + \frac{D_n}{L_n}n_p\right)\left(e^{qV/kT} - 1\right)$

$\hat{p}_n(x_n) = p_n e^{-x_n/L_p}\left(e^{qV/kT} - 1\right)$

Small signal: Reverse: $C_j = \left|\frac{dQ_j}{dV}\right| = \frac{\varepsilon A}{W}$, Forward: $C_s = \frac{q}{kT}I\left(\tau_p + \tau_n\right),\ G = \left|\frac{dI}{dV}\right| = \frac{q}{kT}I$

Solar Cell: $I_{cell} = I_0\left(e^{qV/kT} - 1\right) - I_L,\ V_{oc} = \frac{kT}{q}\ln\frac{I_L}{I_0},\ \ FF = \frac{P_{\max}}{I_{sc}V_{oc}}$

$\vec{\boldsymbol{D}} = \varepsilon_0\varepsilon_r\vec{\boldsymbol{\mathcal{E}}},\ \vec{\boldsymbol{P}} = \varepsilon_0(\varepsilon_r - 1)\vec{\boldsymbol{\mathcal{E}}} = \varepsilon_0\chi\vec{\boldsymbol{\mathcal{E}}},\ n = \sqrt{\varepsilon_r}$

Polarizability: $\vec{\boldsymbol{p}} = \alpha\vec{\boldsymbol{\mathcal{E}}}_{loc},\ \vec{\boldsymbol{p}}_{av} = (\alpha_e + \alpha_i + \alpha_d)\vec{\boldsymbol{\mathcal{E}}}_{loc}$

Clausius-Mossotti equation: $\vec{\boldsymbol{\mathcal{E}}}_{loc} = \vec{\boldsymbol{\mathcal{E}}}_{ext} + \frac{\vec{\boldsymbol{P}}}{3\varepsilon_0},\ \frac{\varepsilon_r - 1}{\varepsilon_r + 2} = \frac{N}{3\varepsilon_0}(\alpha_e + \alpha_i + \alpha_d)$

Debye equation: $\alpha_d(\omega) = \frac{\alpha_d(0)}{1 + j\omega\tau_d}$

Complex dielectric constant: $\varepsilon = \varepsilon_0\left(\varepsilon_r' - j\varepsilon_r''\right),\ \varepsilon_r'' = \frac{\sigma}{\varepsilon_0\omega},\ \tan\delta = \frac{\varepsilon_r''}{\varepsilon_r'}$

$C = \varepsilon_0\varepsilon_r'(\omega)\frac{A}{d},\ G = \omega\varepsilon_0\varepsilon_r''(\omega)\frac{A}{d},\ E_{vol} = \tfrac{1}{2}\varepsilon_0\varepsilon_r'(\omega)\left(\frac{V}{d}\right)^2,\ W_{vol} = \varepsilon_0\omega\varepsilon_r''(\omega)\left(\frac{V}{d}\right)^2$

Piezoelectric: $P_i = d_{ij}T_j,\ S_i = d_{ij}\mathsf{E}_j$

Mechanical strain: $S_i = \Delta l_i / l_i$, stress: $T_i = F_i / A$

Magnetic field: $B = \mu_0(nI + I_m) = \mu_0(H + M)$, magnetic susceptibility: $\chi_m = \mu_r - 1,\ \mu_r = \frac{B}{\mu_0 H}$

1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 Ac	104 Rf	105 Ha	106 Sg	107 Ns	108 Hs	109 Mt	110	111	112	(113)	(114)	(115)	(116)	(117)	(118)
(119)	(120)	(121)	(154)	(155)	(156)	(157)	(158)	(159)	(160)	(161)	(162)	(163)	(164)	(165)	(166)	(167)	(168)

LANTHANIDES	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
ACTINIDES	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr
SUPER-ACTINIDES	(122)	(123)	(124)	(125)	(126)									(153)