MSE160: Equation Sheet

Stress & Strain:

$$\sigma = \frac{F}{A_0} \mid \varepsilon = \frac{\Delta l}{l_0}$$

Stress & Strain Relationship:

$$\sigma = E\varepsilon$$

Young's Modulus Proportionality:

$$E \, \alpha \frac{dF/}{dr}\Big|_{r=r_0}$$

Poisson's Ratio:

$$v = -\frac{\varepsilon_R}{\varepsilon_Z} = -\frac{\varepsilon_x}{\varepsilon_Z} = -\frac{\varepsilon_y}{\varepsilon_Z}\mathrm{W}$$

Shear Stress:

$$\tau = \frac{F}{A_0}$$

Shear Strain:

$$\gamma = \frac{\Delta l}{l_0}$$

Young's Modulus & Shear's Modulus Relationship:

$$E = 2G(1 + v)$$

Shear Stress & Strain Relationship:

$$\tau = G\gamma$$

3-Point Stress for Ceramics:

$$\sigma_{3-pt} = \frac{3FL}{2wh^2}$$

The Mass of All the Atoms in the Unit Cell:

$$m = n \cdot \frac{A}{N_A}$$

Theoretical Density of a Crystalline Solid:

$$\rho = \frac{n \cdot A}{V_c \cdot N_A}$$

Where A is the molar mass, n is the # of atoms in a unit cell, V_C is the volume of a unit cell, and N_A is the Avagadro's Number.

Density:

$$\rho = \frac{m}{V}$$

Atomic Packing Factor:

$$APF_{FCC} = \frac{Volume_{Spheres}}{Volume_{Unit\ Cell}}$$

Bragg's Law:

$$n\lambda = 2d_{hkl} sin(\theta)$$

$$d_{hkl} = \frac{a}{\sqrt{h^2+k^2+l^2}}$$

- n is the order of reflection
- λ is the wavelength.
- d_{hkl} is the interplanar spacing between the planes, where h,k, and l refer to the Miller indices in the x,y, and z positions.

Theoretical Density of Ceramics:

$$\rho = \frac{n_C A_C + n_A A_A}{V_c N_A}$$

- $n_A = 4$ and $n_C = 4$
- A_c *and* A_A are molar masses of the cation and anion.
- V_c is the volume of the unit cell.

Vacancy Population:

$$\frac{N_V}{N} = exp(\frac{-Q_v}{kT})$$

- N_V is the number of vacancies
- Q_v is the energy to form vacancy
- k is Boltzmann's Constant
- T is the temperature in Kelvin
- N is the number of lattice sites.

True Stress/Strain

Type	Equation	Meaning
True Stress	$\sigma_T = \frac{F}{A_i}$	• A_i is the instantaneous cross-sectional area. • Works for all points.
	$\sigma_T = \sigma(1 + \epsilon)$	• Works prior to necking.
True Strain	$\epsilon_T = ln\frac{l_i}{l_0}$	• l_i is the instantaneous length. • l_0 is the original length. • Works for all points
	$\epsilon_T = ln(1 + \epsilon)$	• Works prior to necking.

Strain Hardening Equation	$\sigma_T = K\varepsilon_T^n$	• K is strain hardening coefficient (MPa). • N is a strain hardening exponent (Dimensionless).

Polymer Average:

Type	Equation	Meaning
Number Average Molecular Weight	$\overline{M}_{number} = \sum_{n=1}^{i} M_n x_n$	• i is the number of groups • M_n is the molecular weight of the n^{th} group. • x_n is the number fraction of the n^{th} group (number of molecules in that group, divided by the total number of molecules).
Weight Average Molecular Weight	$\overline{M}_{weight} = \sum_{n=1}^{i} M_n w_n$	• i is the number of groups • M_n is the molecular weight of the n^{th} group. • W_n is the weight fraction of the n^{th} group (combined mass of molecules in that group, divided by the total mass of all molecules).
Dispersity	$Đ = \frac{M_{weight}}{M_{number}}$	

Relaxation Modulus:

$$E_R = \frac{\sigma(t)}{\varepsilon_0}$$

- $\sigma(t)$ is the stress relaxing with time. ↑ temp. = more rapid stress relaxation
- E_R always decreases with time.

Chapter 9 Equations:

Type	Equation	Meaning

Energy in a Quanta of Radiation	$E = \frac{hc}{\lambda} = \frac{h}{\nu}$	• h is Planck's constant ($6.626 \times 10^{-34} J \cdot s$) • c is the speed of light in a vacuum ($3 \times 10^{8} \frac{m}{s}$) • λ is the wavelength of the light in $\frac{m}{s}$ • ν is the frequency of light, in Hertz ($\nu = \frac{c}{\lambda} [\frac{1}{s}]$)
eV⇔J:	$E[eV] = \frac{E[J]}{1.602\times10^{-19}[\frac{J}{eV}]}$	
Conductivity of Intrinsic Semiconductor	$\sigma = nq(\mu_n + \mu_p)$	• σ is the conductivity $[\Omega^{-1} m^{-1}]$ • n is the number of electrons $[\frac{\#}{m^3}]$ • q is the fundamental charge $[C]$ • μ_n is the electron mobility $[\frac{m^2}{V \cdot s}]$ • μ_p is the hole mobility $[\frac{m^2}{V \cdot s}]$
Conductivity of n-Type Semiconductor	$\sigma_{n-type} = nq\mu_n$	• σ is the conductivity $[\Omega^{-1} m^{-1}]$ • n is the number of electrons $[\frac{\#}{m^3}]$ • q is the fundamental charge $[C]$ • μ_n is the electron mobility $[\frac{m^2}{V \cdot s}]$
Conductivity of p-Type Semiconductor	$\sigma_{p-type} = nq\mu_p$	• σ is the conductivity $[\Omega^{-1} m^{-1}]$ • n is the number of electrons $[\frac{\#}{m^3}]$ • q is the fundamental charge $[C]$ • μ_p is the electron mobility $[\frac{m^2}{V \cdot s}]$

Relationship Between Conductivity and Temperature	$\sigma = \sigma_0 e^{\frac{-E_g}{2K_bT}}$	• K_b is Boltzmann's constant • E_g is band gap energy. • T is temperature in Kelvin.

Chapter 10 Equations:

Magnetic Field	$H = \frac{NI}{L}$	• H is the magnetic field • N is the number of turns of the wire • I is the current • L is the length of solenoid
Flux Density in a Vacuum	$B_0 = \mu_0 H$	• μ_0 is the permeability of vacuum $= 4\pi \times 10^{-7}[\frac{N}{A^2}]$
Magnetization	$M = \chi_m H$	• M is magnetization $[\frac{A}{m}]$ • H is magnetic field $[\frac{A}{m}]$ • χ_m is the magnetic susceptibility
Total Flux Density in the Material	$B = \mu_0 H + \mu_0 M$ $= (1 + \chi_m)\mu_0 H$	• χ_m is the magnetic susceptibility (measure of the materials response to the applied magnetic field, H).
Bohr Magneton (Unit of Atomic Magnetic Dipole Moment)	$\mu_B = \frac{eh}{2m_e} = \beta$ $\mu_B = 1\beta = 9.27 \times 10^{-24} Am^2$	
Magnetic Saturation	$M_{sat} = M \times N$	• M is the magnetization • N is the number of atoms/volume

Chapter 11 Equations:

Entropy	$\Delta S = \frac{q_{reversible}}{T}$	• ΔS is entropy. • q_{rev} is the heat transferred. • T is the thermodynamic temperature (K)
2nd Law of Thermodynamics	$\Delta S_{universe} = \Delta S_{system} + \Delta S_{surroundings} > 0$	
1st Law of Thermodynamics	**Isolated System:** $\Delta U = 0$ **Closed System:** $\Delta U = q + w$	• q is heat transferring into the system (+ve) • w is work done on the system (+ve)
Enthalpy	$H = U + PV$	
Change in Enthalpy	$\Delta H = \Delta U + P\Delta V$	• Constant pressure
Internal Energy	$\Delta U = \Delta H - P\Delta V$	
Gibb's Energy	$G = H - TS$	
Change in Gibbs Energy (Restatement of 2nd Law)	$\Delta G = \Delta H_{sys} - T\Delta S_{sys} < 0,\ spontaneous$ $\Delta G = - T\Delta S_{universe}$	• Constant T
Molar Heat	$q = nC_p\Delta T$	• n is # of moles • C_p is molar heat capacity $[\frac{J}{mol\cdot K}]$ • ΔT is change in temperature

Specific Heat	$q = mc\Delta T$	• m is mass • c is specific heat $[\frac{J}{g\cdot K}]$

Chapter 12 Equations:

Lever Rule	$Weight\ fraction\ of\ a\ phase = \frac{Opposite\ side\ of\ lever}{Total\ length\ of\ lever}$ $W_L = \frac{C_s - C_0}{C_s - C_l}$ for a liquid
Concentration	$C_i = \frac{m_x}{m_x + m_y}$