Study Problems : MSE 170 Final

1. Polyethylene contains equal numbers of molecules with 100 mers, 200 mers, 300 mers, 400 mers, and 500 mers, respectively. What is the 'number-average' molecular weight ? and the 'mass-average' molecular weight ? (Ans. : $\overline{M}_w$ 10,300 g/mole)

2. Calculate the 'number-average' molecular weight of a copolymer consisting of random mix of isobutylene and isoprene *repeat units*. Assume that the isoprene-fraction is 0.75 and the degree of polymerization (DP) is 1500. (Ans.: $\overline{M}_n$ 97,675 g/mole)

3. The relaxation time (τ) for a polymer is given as 45 days and the modulus elasticity (E) is 70 MPa, under isothermal conditions at 100°C. The polymer is compressed 5% (ε_o = 0.05) and held at the specified temperature. Determine the initial stress (σ_o). Assuming that the polymer undergoes viscoelastic relaxation at 100°C, calculate the stress $\sigma(t)$ after a period of (a) 1 day (b) 30 days (c) 365 days ? (Ans.: 3.5 MPa ; a. 3.4 MPa ; c. 1000 Pa)

4. List the *mer* structure for the following : (a) Butadiene (b) *cis*-Isoprene (c) Chloroprene.

5. The vulcanization of polyisoprene is accomplished with sulfur atoms which provide the cross-linking between molecules. If the vulcanized polyisoprene showed 32 wt% of S, how many sulfur cross-links exist per isoprene *mer* ? (Ans.: 1 S per *mer*)

6. Ten kg of polychloroprene is vulcanized with 0.72 kg of sulfur. Assuming one sulfur-atom participates in each bond, determine the fraction of the sulfur-cross-linked bonds at the specified sulfur concentration. (Ans.: 0.20)

7. A structural member 250 mm long must be able to support a load of 44,400 N without experiencing any plastic deformation. Using the following data for aluminum, brass, and steel determine the alloy that will meet the requirements at the lowest weight:

Alloy	Yield strength, MPa	Density, g/cm^3
Aluminum	275	2.7
Brass	415	8.5
Steel	860	7.9

8. Suppose that a steel of eutectoid composition is cooled from 760°C to 550°C in less than 0.5 sec and held at this temperature (Fig. 10.14). How much time is required for the austenite-to-pearlite reaction to reach 50% completion ? to reach 100% completion ?

9. The kinetics of phase-transformation in a system obey the Avrami equation: fraction transformed, $y = 1 - \exp(-kt^{1.7})$. It was noted that in 100 sec duration, 'y' reached 0.5; calculate the length of time required to obtain a transformation of $y = 0.99$.

10. What is the driving force for the formation of spheroidite in iron-carbon alloys ?

11(a). Recrystallization is a thermally-activated process with the rate $\mathbf{r} = A.\exp(-Q/RT)$ where **r** is expressed as reciprocal of time t_R; the latter is the time required to obtain fully-recrystallized microstructure. It was found that a 75% cold-worked aluminum alloy needs for complete recrystallization (i) $t_R = 100$ hours at 256°C and (ii) $t_R = 10$ hours at 283°C. Find the activation energy Q in kJ/mole and use the result to determine the temperature at which the recrystallization would be completed in a duration (t_R) of 2.5 hours.
11(b). During an investigation of age-hardening in aluminum-based alloys, it was found that maximum hardness could be achieved by aging for 10 hr at 600°K or 280 hr at 500°K. How long would it take to reach maximum hardness for the same alloy at 530°K ?

12. The fracture-toughness is given by : $K_{IC} = Y.\sigma_f [\pi a]^{1/2}$ with $Y \approx 1$. The yield strength of a special steel is 1400 MPa and its fracture-toughness is $K_{IC} = 150$ MPa.(m)$^{1/2}$. Find the size (length) of the inner-crack that will propagate and produce failure at an applied stress (σ_f) of 600 MPa. What would be the critical crack-length if it occurs on surface ?

13. Calculate the breaking strength (σ_f) for MgO(s) when a surface-crack 1 mm long is present. Use $K_{IC} = 3$ MPa.(m)$^{1/2}$ and the equation given in the previous problem.

14. A 1-mm rod drawn from plate glass ($\alpha_L = 9\text{x}10^{-6}$ °K^{-1}) is heated to 200°C to remove any residual stresses. Now the rod is cooled to 20°C at fixed-length. Calculate the stress (σ) that develops in the rod. The modulus of elasticity E = 70 GPa for the plate glass.

15. A fiberglass contains 50 vol% E-glass (54 w/o SiO_2, 17 w/o CaO, 5 w/o MgO, 15 w/o $Al_2O_3 + Fe_2O_3$, 8 w/o B_2O_3 and < 1 w/o each of K_2O and Na_2O) in an epoxy matrix. Find (a) the w/o of E-glass fibers in the composite and (b) the density. For the two components of this composite, it is given that $\rho_E = 2.54$ g/cm^3 and $\rho_{epy} = 1.1$ g/cm^3, respectively.

16. Calculate the elastic modulus, $E_{com} = v_{epy}E_{epy} + v_C E_C$ for a carbon-fiber reinforced epoxy matrix composite and compare the result with the experimental value of 221 GPa. Assume that the volume-fractions are 0.33 for epoxy and 0.67 for carbon; furthermore, the corresponding elastic moduli are: $E_{epy} = 6.9$ GPa and $E_C = 360$ GPa. This equation for E_{com} predicts the so-called *isostrain modulus* of the composite.

17. An intrinsic semiconductor (probably Ge) has a conductivity of 390 ohm^{-1}.m^{-1} at 5°C and 1010 ohm^{-1}.m^{-1} at 25°C, respectively. (a) How large is the band-gap energy (E_g) ? (b) What is the conductivity at 15°C ? The Boltzmann constant $k = 8.617\text{x}10^{-5}$ eV/°K. It is well to note that, to a good approximation, $\sigma = \sigma_o.\exp[-E_g/(2kT)]$, ohm^{-1}.m^{-1}.

18. Silicon has a density of 2.33 g/cm^3 (2330 kg/m^3). (a) What is the concentration of silicon atoms per m^3 ? (b) By adding phosphorus, silicon can be made into an n-type semiconductor. If the measured conductivity is 100 ohm^{-1}.m^{-1} and the mobility μ_n of the electrons is 0.19 m^2/V.s, what would be the concentration of donor electrons per m^3 ?

19. A 1-mm cylindrical rod with the composition of borosilicate glass (α_B : $2.7\text{x}10^{-6}$ K^{-1}) is coated with 0.1 mm plate glass (α_P : $9\text{x}10^{-6}$ K^{-1}), so that the diameter of the rod is now 1.2 mm. Assuming no initial stresses at 200°C, compute the longitudinal stress that would develop upon cooling the composite-rod to 20°C. Assume E = 70 GPa.