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MSE 2001
Fall 2011
Midterm Exam #2
October 10, 2011

I have neither received nor given help in taking this exam.

Signature: _____

Multiple choice - Fill in the blanks with the appropriate letters. Two points each.

D 1. A two dimensional defect consisting of incorrect (out of order) placement of one or more close packed planes of atoms.
A. Twin; B. Grain boundary; C. Surface; D. Stacking fault;

D 2. An equation describing strength v. grain size.
A. Fick's first law; B. Fick's second law; C. Schmid's law;
D. Petch-Hall equation

C 3. The type of solution formed when C is added to Fe.
A. Substitutional; B. Ideal; C. Interstitial; D. Heterogeneous

A 4 A polymer that can be melted and molded.
A. Thermoplastic; B. Thermoset; C. Epoxy; D. Crosslinked

B 5. A defect which has a Burgers vector neither parallel nor perpendicular to the unit tangent vector.
A. Screw dislocation; B. Mixed dislocation; C. Edge dislocation;
D. Stacking fault

A 6. A pure twist boundary can be accommodated by an array of:
A. Screw dislocations; B. Edge dislocations; C. Twins; D. Stacking faults

B 7. Spherulites form in:
A. Amorphous metals; B. Semicrystalline polymers; C. Amorphous polymers; D. Ionic ceramics

A 8. A noncrystalline solid that is above its glass transition temperature.
A. Rubber; B. Elastomer; C. Vinyl; D. Atactic polymer

C 9. A measure of an amorphous material's resistance to flow.
A. Fluidity; B. Critical shear stress; C. Viscosity; D. Modulus

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B 10. Polydispersity is a measure of:
A. A polymer's molecular weight; B. A polymer's heterogeneity;
C. Spread of a polymer's T_g values; D. A polymer's tacticity

Circle the correct underlined word or words in each statement. Three points per question.

11. A rubber's viscosity increases / decreases as its temperature decreases.

12. Vacancies are required / not required for interstitial diffusion.

13. Random atomic motions of an impurity typically result in diffusion in the direction of increasing / decreasing impurity concentration.

14. The [111] direction is a valid / invalid slip direction for the (110) plane in body centered cubic iron.

15. The Burgers vector of a specific dislocation changes / does not change with the character of the dislocation (e.g., screw, edge or mixed).

16. Many metallic alloys can be strengthened by increasing / decreasing the material's grain size.

17. Phenomena that interfere with dislocation motion strengthen / weaken an alloy.

18. Semi-crystalline materials exhibit / do not exhibit a glass transition temperature.

19. Atactic polymers will crystallize more easily / less easily than otherwise similar isotactic polymers.

20. Amorphous materials between their melting and glass transition temperature display time dependent / time independent mechanical behavior.

Short answer - Provide answers to the questions posed. Five points per question.

21. SiO_2 can be either a crystalline solid or an amorphous solid (glass). In which would you expect diffusion be faster? Why?

Amorphous silica - because it is more open (less dense) than crystalline silica (quartz)

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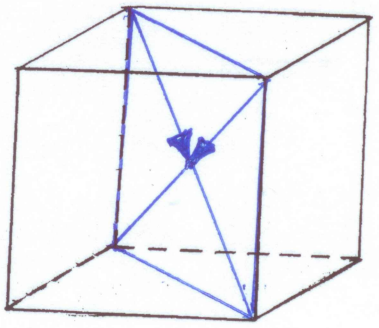
22. A steel part is case hardened by carburizing in a carbonaceous atmosphere at 1,200 K for 4 hours. A case depth of 0.4 mm is produced. How much time is required under identical conditions to produce a case depth of 0.2 mm?

$x_{eff} = 0.4 \propto \sqrt{t}$

$x'_{eff} = \frac{x_{eff}}{2} \propto \frac{\sqrt{t}}{2} = \sqrt{\frac{t}{4}} = \sqrt{t'}$

$t' = \frac{t}{4} = \frac{4}{4} = 1 \text{ hr.}$

23. A BCC unit cell is shown below. Sketch in a single slip plane and two possible Burgers vectors, neither of which is parallel nor antiparallel to the other.



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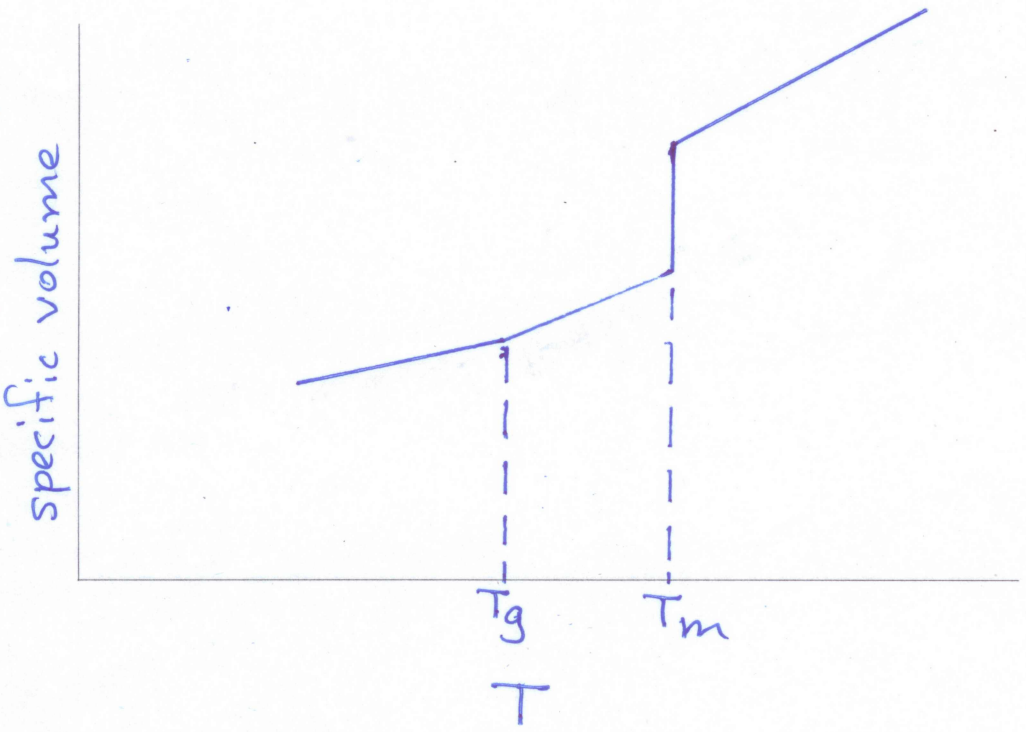
WRC

24. Using the axes below, sketch a specific volume v. temperature curve for a polymer that is partially crystalline and partially amorphous at room temperature. Indicate T_m (240°C) and T_g (110°C) on the temperature axis.



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Problems - Work the following problems in the space provided. SHOW YOUR WORK and CIRCLE YOUR ANSWER. Ten points for each problem.

25. Decarburization occurs when carbon diffuses out of the interior of a steel part and enters the atmosphere of the furnace. How long (in seconds) will it take for steel with an initial carbon content of 1.0% to obtain a carbon content of 0.832% at a distance of 0.2 cm below the surface if the atmosphere in the furnace is free of carbon and held at 1,200°C? Carbon diffusion in FCC iron is described by the following parameters: $D_o = 2 \times 10^{-5}\ m^2/s$; $Q = 142\ kJ/mole$.

Find t when $C(x=0.002m; t) = 0.832\ \%C$

$$\frac{C(x;t) - C_o}{C_s - C_o} = 1 - \text{erf}\left(\frac{x}{2\sqrt{Dt}}\right)$$

$C_s = 0\ \%C$; $C_o = 1.0\ \%C$

$$\Rightarrow \text{erf}\left(\frac{x}{2\sqrt{Dt}}\right) = 0.832$$

From erf table $\left(\frac{x}{2\sqrt{Dt}}\right) = 0.975$

$$D = D_o \exp\left(\frac{-Q}{RT}\right) = 2\times10^{-5} \exp\left(\frac{-142{,}000}{(8.314)(1473)}\right)$$

$$D = 1.84\times10^{-10}\ \frac{m^2}{s}$$

Thus $t = \frac{1}{D}\left[\frac{0.002}{2(0.975)}\right]^2 = 5.72\times10^3\ s$

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26. Calculate the magnitude of the critical stress, σ_c, applied in the [123] direction, required to cause slip in the [l l l] direction on the $(\bar{1}10)$ plane of a BCC crystal with τ_{CRSS} = 5.5 MPa.

$$\tau_{CRSS} = \sigma_c \cos\theta \cos\phi$$

$$\cos\theta = \frac{[123]\cdot[111]}{|[123]||[111]|} = \frac{6}{\sqrt{3}\sqrt{14}}$$

$$\cos\phi = \frac{[123]\cdot[\bar{1}10]}{|[123]||[\bar{1}10]|} = \frac{1}{\sqrt{2}\sqrt{14}}$$

$$\therefore \sigma_c = \frac{\sqrt{2}\sqrt{3}(14)(5.5)}{6} = 31.4 \text{ MPa}$$