MIDTERM – 2006 **Student Name:** ________________________________

MECH 321 Properties and Failure of Materials **Student Number:** ________________

Answer all questions. Put your answers to the true and false and multiple choice questions on this exam paper as illustrated and the answers to the remaining questions in the space provided. Use the blank sides for rough work. An equation sheet is attached at the end of the exam paper.

Marking Scheme: Questions 1-10, one mark each, Questions 11-30, two marks each, other questions marks as indicated.

For these True/False questions, circle the response that you think is correct. E.g. Circle **T** if you think the statement is TRUE or **F** if you think the statement is False.

T F **(1)** In solid solution strengthening, solute atoms of a different size from the solvent atoms hinder dislocation motion through interaction with the tension and compression zones of the edge dislocation.

T F **(2)** In solid solution strengthening, the strengthening is greater when the size difference between solute and solvent ions is smaller.

T F **(3)** In ordinary carbon steels, strengthening results from the presence of partite which consists of tungsten carbide platelets between iron platelets.

T F **(4)** If the properties of a material depend on the crystallographic direction along which the property is measured, then the material is anisotropic.

T F **(5)** A brittle material typically exhibits substantial plastic deformation with high energy absorption before fracture.

T F **(6)** Increased hindering of dislocation motion makes a metallic material harder.

T F **(7)** During the *recovery* of a cold-worked material, there is a significant reduction in the number of dislocations.

T F **(8)** The recrystallization temperature is normally higher for a pure metal than for its alloys.

T F **(9)** An alloy that has been precipitation hardened may be used at elevated temperatures without compromising its hardness and strength.

T F **(10)** For a particular crystal structure, the favoured slip direction is that direction in the slip plane having the highest linear density.

For the multiple choice questions below, fill in the letter (with a pencil) which you believe corresponds to the best answer. Eg. (a)

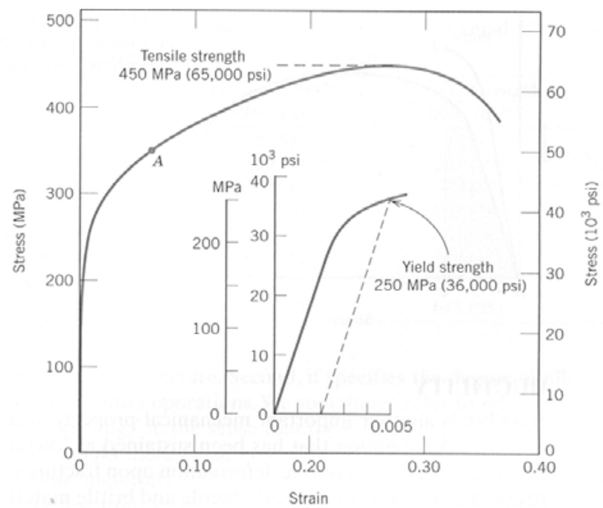
11. Grain boundaries:

(a) are virtually impossible to observe in an optical microscope.
(b) interfere with dislocation motion.
(c) are point defects.
(d) do not exist in polycrystalline materials.
(e) are always undesirable.

12. Addition of Zn to Cu to form a solid solution alloy would be expected to:

(a) decrease the tensile strength and increase the yield strength
(b) decrease the tensile strength and decrease the yield strength
(c) increase the tensile strength and decrease the yield strength
(d) increase the tensile strength and increase the yield strength
(e) have no effect.

13. Consider a brass alloy the stress-strain behavior of which is shown below.



A cylindrical specimen of this alloy, 20 mm in diameter and 188 mm long, is to be pulled in tension. Calculate the stress (in MPa) necessary to cause a 0.0136 mm reduction in diameter. Assume a value of 0.34 for Poisson's ratio.

(a) 150
(b) 250
(c) 350
(d) 450
(e) Not enough information

14. Hot working takes place at a temperature that is above a metal's

(a) melting temperature.
(b) recrystallization temperature.
(c) eutectoid temperature.
(d) glass transition temperature.
(e) Curie temperature.

15. Which of the following statements regarding dislocations and their movement is true:

(a) Dislocations are easier to move in metals with fewer slip systems
(b) The concentration of dislocations decreases with increased strain hardening.
(c) For dislocations to move, resulting in slip, the applied shear stress must be greater than the critical resolved shear stress.
(d) Dislocations are easier to move as the grain size decreases.
(e) Precipitate size in precipitation hardening does not affect the mobility of dislocations.

16. An alloy has a yield strength of 805 MPa and an elastic modulus of 107 GPa. What is the modulus of resilience for this alloy [in MJ/m^3 (which is equivalent to MPa)] given that it exhibits linear elastic stress-strain behavior.

(a) 7.11
(b) 7.50×10^{-3}
(c) 3.03
(d) 3028
(e) 132

17. Which of the following may occur during an annealing heat treatment?

(a) Stresses may be relieved.
(b) Ductility may increase.
(c) Toughness may increase.
(d) A specific microstructure may be produced
(e) All of the above.

18. A cylindrical specimen of a metal alloy 48.5 mm long and 9.72 mm in diameter is stressed in tension. A true stress of 369 MPa causes the specimen to plastically elongate to a length of 54.7 mm. If it is known that the strain-hardening exponent for this alloy is 0.20, calculate the true stress (in MPa) necessary to plastically elongate a specimen of this same material from a length of 48.5 mm to a length of 57.2 mm.

(a) 563
(b) 393
(c) 333
(d) 453
(e) The material will fracture before reaching 57.2 mm

19. The atoms surrounding a screw dislocation experience what kinds of strains?

(a) Tensile strains
(b) Compressive strains
(c) Shear strains
(d) All of the above
(e) Both b and c

20. The mechanical properties of a metal may be improved by incorporating fine particles of its oxide. Given that the moduli of elasticity of the metal and oxide are, respectively, 60 GPa and 380 GPa, what are the upper-bound and lower-bound modulus of elasticity values (in GPa) for a composite that has a composition of 33 vol% of oxide particles.

(a) 60 and 380
(b) 137.7 and 274.4
(c) 83 and 274.4
(d) 137.7 and 165.6
(e) 83 and 165.6

21. Ductile failure at room temperature is:

(a) when there is a cup-cone type fracture which starts by the opening of cracks around impurity particles inside the neck.
(b) when necking to zero radius occurs as long as brittle fracture does not occur.
(c) when the grains separate from each other along the grain boundaries.
(d) the kind of failure that usually occurs in as-quenched martensite.
(e) promoted by increasing the rate of loading.

22. Your company tells you to increase the factor of safety for a component that has a working load of 20 kN. The component must not deform permanently under load. Which of the following changes would increase the factor of safety?

(a) increase the tensile load on the component
(b) select a material with smaller work hardening
(c) decrease the cross sectional area of the component
(d) change to a material with a higher yield strength
(e) the safety factor is a constant that can not be changed.

23. A single crystal of FCC metal is oriented so that the [001] direction is parallel to an applied stress. If the critical resolved shear stress required for slip is 1.5 MPa, what is the magnitude of the applied stress required to cause slip to begin on the (111) plane in the $[0\bar{1}1]$ direction?

(a) 3.00 MPa
(b) 2.12 MPa
(c) 2.45 MPa
(d) 2.60 MPa
(e) 3.67 MPa

24. Increasing the amount of cementite in a steel will:

(a) result in a less brittle steel
(b) decrease the eutectoid temperature
(c) increase the eutectoid composition
(d) result in a harder steel
(e) none of the above.

25. The strength of titanium is found to be 450 MN/m² when the grain size is 17 x 10^{-3} mm and 565 MPA when the grain size is 0.8 x 10^{-6} m. What is the strength of the titanium when the grain size is reduced to 0.4 x 10^{-3} mm?

(a) 712 MPa
(b) 141 MN/m²
(c) 625 MPa
(d) 875 MN/m²
(e) 561 MPa

26. At 135°C, 50% of a cold worked Cu sample has recrystallized in 10 sec. Which of the following statements is true:

(a) the rate will increase as the temperature increases
(b) the rate will increase as the amount of cold working increases
(c) the recrystallization temperature increases as the amount of cold working increases
(d) a and b
(e) a, b and c.

27. The principal reason why a dispersed phase is added to a ceramic matrix to produce a ceramic matrix composite is to:

(a) increase fracture toughness
(b) increase yield strength
(c) lower the operating temperature
(d) increase the melting temperature
(e) none of the above.

28. A 1000 m length of 2 mm diameter wire was made from a low carbon steel with a modulus of elasticity of 200 GPa, a yield strength of 295 MPa, a tensile strength of 340 MPa and a density of 8000 kg/m^3. The wire is used to suspend a 25 kg block inside a mine shaft. The mine shaft is 1002 m deep. If the block was fully lowered down the shaft on the wire, which of the following would occur:

(a) The wire and block would be unaffected
(b) The wire would be permanently deformed but would not break and the block would not hit the base of the shaft.
(c) The wire would break.
(d) The block would hit the base of the shaft.
(e) None of the above.

29. For a given applied stress, the maximum stress near a crack will increase as:

(a) the crack length decreases
(b) the radius of curvature at the crack tip decreases
(c) the fracture toughness increases
(d) the thermal conductivity increases
(e) none of the above

30. Which of the following is not a characteristic of ductile failure in metals:

(a) final shear at 45° angle relative to the tensile direction
(b) cup and cone fracture surface
(c) necking
(d) dimpled surface in an SEM micrograph
(e) grainy or faceted fracture surface

(8 marks) **31** i) What is the structure of martensite (with regard to steels)?

ii) How is it formed?

iii) What is tempered martensite?

iv) If tempering results in the decomposition of martensite, why should we form martensite to start with?

(4 marks) **32.** Suppose that a wing component on an aircraft is fabricated from an aluminum alloy that has a plane-strain fracture toughness of 26 $MPa.m^{1/2}$. It has been determined that fracture results at a stress of 112 MPa when the maximum (or critical) internal crack length is 8.6 mm. For this same component and alloy, will fracture occur at a stress level of 125 MPa when the critical internal crack length is 6.0 mm? Show your working and put your answer in this box.

Fracture: *(Yes or No)* Why?

MECH 321 **Equation Sheet**

$$U_r = \frac{\sigma_y^2}{2E} \qquad \varepsilon_T = \ln\left(\frac{l_i}{l_o}\right) \qquad \varepsilon_{eng} = \left(\frac{l_i - l_o}{l_o}\right) = \frac{\Delta l}{l_o} \qquad \sigma_T = k\varepsilon_T^n \text{ (uniform plastic)}$$

$$\tau = \frac{M_T r}{J} \qquad \gamma = \frac{r\theta}{L} \qquad \sigma_r = \sigma_o + kd^{-1/2} \qquad \tau_r = \sigma \cos\lambda \cos\phi$$

$$\rho_c = V_f \rho_f + (1-V_f)\rho_m \qquad L_c = \frac{\sigma_f d}{2\tau_c} \qquad E_{c1} = E_f v_f + E_m v_m$$

$$E_{c2} = \frac{E_f E_m}{E_f(1-v_f) + E_m v_f} \qquad \sigma_{c2} \approx \frac{\sigma_m}{2} \qquad \sigma_{cl}^* = \sigma_m'(1-V_f) + \sigma_f^* V_f$$

$$\sigma_{cd}^* = \sigma_f^* V_f \left(1 - \frac{\ell_c}{2\ell}\right) + \sigma_m'(1-V_f) \qquad \sigma_{cd'}^* = \frac{\ell \tau_c}{d} V_f + \sigma_m'(1-V_f)$$

$$\sigma_{max} = 2\sigma_o \left(\frac{a}{\rho}\right)^{1/2} \qquad k_t = \frac{\sigma_{max}}{\sigma_o} \qquad \sigma_c = \sqrt{\frac{2E\gamma_s}{\pi a}} \text{ (brittle)} \qquad B \geq 2.5\left[\frac{K_{1c}}{\sigma_y}\right]^2$$

$$\sigma_c = \sqrt{\frac{2E(\gamma_s + \gamma_p)}{\pi a}} \text{ (plastic)} \qquad G_c = \frac{K_{1c}^2}{E} \qquad K_{1c} = Y\sigma\sqrt{\pi a}$$