



Name \_\_\_\_\_

4. The shear modulus (G) of aluminum is about 27 GPa. If a T4 hardening is performed followed by an H16 temper in a 6061 alloy, estimate the shear modulus of the material.
  
5. Discuss the process that aluminum undergoes to create a precipitate in hardening (such as the T6 alloy). Suggest at least two reasons an engineer who is not a material specialist should know about precipitation hardened alloys.
  
  
  
  
  
  
  
  
  
  
6. In an 1060-H14 aluminum alloy the 1060 designation indicates (choose one)
  - 99.6% minimum Aluminum
  - One half of the total amount of possible cold work
  - Solution heat treatment plus artificial aging
  
7. In an 1060-H14 aluminum alloy the H14 designation indicates (choose one)
  - 99.6% minimum Aluminum
  - One half of the total amount of possible cold work
  - Solution heat treatment plus artificial aging
  
8. Define fracture toughness. Why should fracture toughness be considered when designing a travel mug?



Name \_\_\_\_\_

13. At 800°C an alloy of 0.45% C in Fe is at equilibrium. The  $\alpha$  phase has (choose one)
- 0.0123% C in Fe
  - 0.53% C in Fe
  - 0.45% C in Fe

14. At 800°C an alloy of 0.45% C in Fe is at equilibrium. For a 100 gram sample the  $\alpha$  phase is (choose one)
- 84.5 grams
  - 15.5 grams
  - 53.0 grams
  - 45.0 grams

15. An airplane propeller must sustain constant loading as it rotates. However, fracture toughness cannot be neglected because of the possibility of impact with a bird or other

object while in flight. If the propeller is assumed to act like a brittle plate --  $\frac{K_{IC}^{1/2}}{\rho} = C$

Select several possible candidate materials for building an airplane propeller from the given chart for light fracture resistant materials.

16. Aluminum as a pure material has very high formability. Explain why this is different for some of the precipitation hardened alloys? What changes in the material?

17. A 1060-H14 aluminum alloy has a higher \_\_\_\_\_ than the 1060 alloy in the annealed condition. a) ductility b) yield c) modulus d) none of the above

18. On the Fe-C phase diagram  $\gamma$  is a FCC crystal that is stable at high temperatures. When  $\gamma$  is quenched (cooled quickly) a different structure is obtained at room temperature that is called Martensite. Is this structure shown on the attached Fe-C phase diagram? Indicate the Greek letter that represents Martensite or explain why it is not on the phase diagram.

Name \_\_\_\_\_

19. At 1450°F an alloy of 0.20% C in Fe is at equilibrium. The  $\alpha$  phase has (choose one)
- 0.02% C in Fe
  - 0.52% C in Fe
  - 0.20% C in Fe
20. At 1450°F an alloy of 0.45% C in Fe is at equilibrium. For a 100 gram sample the  $\alpha$  phase is (choose one)
- 64.0 grams
  - 36.0 grams
  - 53.0 grams
  - 47.0 grams
21. In the Al-Si phase diagram describe the composition of the material when 10% by wt of silicon is added to Al and it is at equilibrium at 300 °C.
22. From the Al-Si phase diagram find the Greek letter that represents the precipitate that forms in a precipitation hardened alloy. Write that Greek letter here
- ⇒ \_\_\_\_\_
23. At 577°C an alloy of 0.10% Si in Al is at equilibrium. The  $\alpha$  phase has \_\_\_\_\_% Si.
24. At 577°C an alloy of 0.10% Si in Al is at equilibrium. For a 100 gram sample the  $\alpha$  phase is \_\_\_\_\_ grams.
25. When corrosion of a chrome-plated part begins – like the bumper on an old car – the plating often appears to be peeling off the metal. Explain this process in terms of a loss of material at the anode. Describe the differences in the process that would occur if you galvanize the bumper versus chrome plating the bumper.

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26. As wood becomes scarcer and old growth wood becomes unavailable, the modulus of wood used in many applications decreases. Suggest a modification of the standard wood floor joist using composite materials to stiffen the beam.

27. In a simply supported beam (such as the carbon-epoxy specimens passed around in class) compare the stiffness of a  $[0,90]_s$  and a  $[90, 0]_s$  lay-up. Use diagrams to show your coordinate axes and the sequence of layers.

28. A bar with a circular cross-section is subject to a tensile load of  $P$  and a torsional load of  $P/2$ . Propose two designs for a composite lay-up for this configuration. Please give numbers for the fiber orientation angles relative to the central axis of the cylinder.

Name \_\_\_\_\_

29. It is possible to make a canoe paddle handle out of either aluminum or wood. If strength is the design parameter, write out the type of equation that would show how you include shape into your material selection. The exponent for a bar in bending is  $2/3$  in the numerator and 1 in the denominator.
30. Why can you make a canoe paddle out of aluminum as well as wood if the density of aluminum is 10 times greater and the strength may be similar? Assume that the design of a paddle is a weight and strength optimization problem.
31. How do dislocations allow a metal to plastically deform?
32. What happens to the dislocation density as the material deforms and what is the process for reversing this process during annealing.
33. Aluminum as a pure material has very high formability. Explain why this is different for some of the precipitation hardened alloys? What changes in the material?

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34. On the Fe-C phase diagram  $\gamma$  is a FCC crystal that is stable at high temperatures. When  $\gamma$  is quenched (cooled quickly) a different structure is obtained at room temperature that is called Martensite. Is this structure shown on the attached Fe-C phase diagram? Indicate the Greek letter that represents Martensite or explain why it is not on the phase diagram.

35. At 800°C an alloy of 0.45% C in Fe is at equilibrium. The  $\alpha$  phase has(choose one)  
 0.0123% C in Fe  
 0.53% C in Fe  
 0.45% C in Fe

36. At 800°C an alloy of 0.45% C in Fe is at equilibrium. For a 100 gram sample the  $\alpha$  phase is (choose one)  
 84.5 grams  
 15.5 grams  
 53.0 grams  
 45.0 grams

37. In the Al-Si phase diagram describe the composition of the material when 0.2% by wt of silicon is added to Al and it is at equilibrium at 467 °C (point 6 on the diagram).

Name \_\_\_\_\_

38. From the Al-Si phase diagram find the Greek letter that represents the precipitate that forms in a precipitation hardened alloy. Write that Greek letter here

⇒ \_\_\_\_\_

39. When referring to the Fe-C phase diagram tell what change in austenite makes the solubility of carbon in that phase higher.

40. At 570°C an alloy of 1.20% Si in Al is at equilibrium. The  $\alpha$  phase has \_\_\_\_\_% Si.

41. At 570°C an alloy of 1.20% Si in Al is at equilibrium. For a 100 gram sample the  $\alpha$  phase is \_\_\_\_\_ grams.

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42. When corrosion of a chrome-plated part begins – like the bumper on an old car – the plating often appears to be peeling off the metal. Explain this process in terms of a loss of material at the anode. Describe the differences in the process that would occur if you galvanize the bumper versus chrome plating the bumper.

43. What is the meaning of the 2.0 value on the Fe-C phase diagram at 1130°C? What happens to the carbon above this value? The point at 1130°C is generally the same as at temperatures slightly above and below 1130°C.

44. For a spoke on a bicycle wheel it is necessary to select a material with high strength to weight ratio. What is the slope of the line that should be used for selecting equivalent materials on the density versus modulus diagram?

Name \_\_\_\_\_

45. Name three strengthening mechanisms and write a one or two sentence description of each
46. What are the three primary and 2 secondary bonds we discussed in class. Give one example of each.
47. For a covalent bond, draw a qualitatively accurate graph of  $U$ , the interatomic potential, and  $r$  the interatomic spacing.
48. From the graph of  $U(r)$  show the equilibrium position, and the relationship of the elastic modulus to the interatomic potential.

Name \_\_\_\_\_

49. Draw a stress strain curve for a visco-elastic material (a material that has a loss coefficient, designated  $\eta$  in your text) and label the total strain energy and the elastic strain energy that is dissipated due to the material losses.



50. A compact tension specimen is used to measure fracture toughness. Place in order the fracture toughness of the following four materials, and describe a situation where the fracture toughness of these materials might be important: mild steel, cast iron, aluminum and silicon nitride.

Name \_\_\_\_\_

51. Draw on a figure the plastic strain in a stress strain curve.



52. Explain the difference between fracture toughness and fatigue.

53. For isolation of a machine from vibrations due to truck traffic, would you use a material with a high or a low loss coefficient and why?

Name \_\_\_\_\_

54. You are responsible for finding an appropriate material for a spring. The objective function is the maximum stored energy per unit volume. Maximize the objective function where:

$M_1 = \frac{\sigma_f^2}{E}$ . Show what materials you would consider on the chart, and if possible give actual numbers for their M function.

55. Assume that the STRENGTH of a floor joist is the dominant consideration. This is often the case since a homeowner will often be worried about a floor long before it collapses :). The material index for a low cost beam with the shape factor is:

$$M_1 = \frac{(\phi_B^f E)^{2/3}}{C_m \rho}$$

Determine whether a low density wood, glass-epoxy composite or a high carbon steel are best suited to the shape optimized beam. Note: for most floor joists LOW carbon steel or higher density wood are used. This is an example of a selection for a more weight critical design – high speed houses.

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56. At 200°C, the equilibrium constitution for a 25 Wt% Sn alloys of Pb and Sn is:  
The overall composition  
Number of phases  
Composition of each phase  
Proportion of each phase

57. At what temperature does Pb. Melt?  
Sn. Melt?  
A mixture of 62% Sn and 38% Pb?

58. At 100°C, the equilibrium constitution for a 25 Wt% Sn alloys of Pb and Sn is:  
The overall composition  
Number of phases  
Composition of each phase  
Proportion of each phase

Name \_\_\_\_\_

**Low density wood**

Density 0.24-0.49 Mg/m<sup>3</sup>  
Price 0.788-12.61 USD/kg  
Compressive strength 14.8-46.6 MPa  
Elastic Limit 16.2-45.1 MPa  
Endurance limit 8-24.6 MPa  
Fracture Toughness 0.6-3.6 MPa m<sup>0.5</sup>  
Young's Modulus 3.7-14.3 Gpa

**High Carbon Steel**

Density 7.8-7.9 Mg/m<sup>3</sup>  
Price 0.394-0.709 USD/kg  
Compressive strength 335-1155 MPa  
Elastic Limit 335-1155 MPa  
Endurance limit 281-606 MPa  
Fracture Toughness 27-92 MPa m<sup>0.5</sup>  
Young's Modulus 200-215 GPa

**Brass**

Density 7.8 – 8.8 Mg/m<sup>3</sup>  
Price 1.57-2.21 USD/kg  
Compressive strength 70-500 Mpa  
Elastic Limit 70-500 MPa  
Endurance limit 105-300 MPa  
Fracture Toughness 30-86 MPa m<sup>0.5</sup>  
Young's Modulus 90-120 GPa

**Titanium**

Density 4.36-4.84 Mg/m<sup>3</sup>  
Price 23.64-63.04 USD/kg  
Compressive strength 130-1395 Mpa  
Elastic Limit 172-1245 MPa  
Endurance limit 175-705 MPa  
Fracture Toughness 14-120 MPa m<sup>0.5</sup>  
Young's Modulus 90-137 GPa

**Epoxy-Glass Fiber Composite**

Density 1.5-2.0 Mg/m<sup>3</sup>  
Price 2.05-111.03 USD/kg  
Compressive strength 240-880 MPa  
Elastic Limit 150-1100 MPa  
Endurance limit 128-765 MPa  
Fracture Toughness 6-40 MPa m<sup>0.5</sup>  
Young's Modulus 15-45 GPa