SE104 Structural Materials
Sample Midterm Exam

The Avogadro's number = 6.02×10^{23}
1 lb = 4.45 N
1 nm = 10 Å = 10^{-9} m

Multiple choice problems (2.5 points each)
For each problem, choose <u>one and only one</u> most relevant answer.

1. Glass is hard. This statement means that
   (a) the Young's modulus of glass is high
   (b) the strength of glass is high
   (c) the fracture toughness of glass is high
   (d) the Poisson's ratio of glass is high
   (e) glass is amorphous

2. Which one of the following is NOT a mechanical property of material:
   (a) Stiffness
   (b) Strength
   (c) Toughness
   (d) Hardness
   (e) None of the above

3. When a material has a large Young's modulus, it has a high
   (a) Stiffness
   (b) Strength
   (c) Toughness
   (d) Density
   (e) Probability of deflection

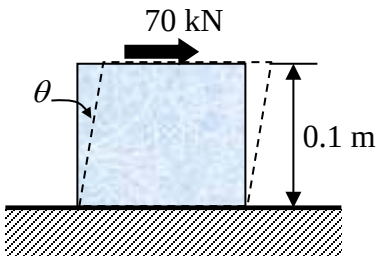
4. Boron carbide is an engineering ceramic. It has a high stiffness; that is
   (a) Its Young's modulus is low
   (b) When it is subjected to a load, it will not be damaged
   (c) When it is subjected to a load, its deformation tends to be small
   (d) When it is hammered, it may not break into pieces
   (e) When it is compressed, indentation is small

5. A round rod is subjected to an axial force of 10 kN. The diameter of the rod is 1 inch. The engineering stress is
   (a) 12.74 MPa
   (b) 3.18 MPa
   (c) 19.7 MPa
   (d) 4.94 MPa
   (e) 49.4 MPa

6. In the above problem, if the engineering strain is 1.5% and the Poisson's ratio is 0.4, what is the diameter after deformation?
   (a) 0.006"
   (b) 0.994"
   (c) 1.006"
   (d) 0.4"
   (e) 1.6"

7. In the above problem, the Young's modulus of the material is
   (a) 849 MPa
   (b) 212 MPa
   (c) 2.12 GPa
   (d) 1.3 GPa
   (e) 13 MPa

8. As shown in the figure on the right, a 0.1-m-large cubic block is subjected to a 70-kN horizontal frictional force along its top surface. There is no relative motion between the block and the floor. The shear modulus of the material is 0.70 GPa; the Young's modulus is 1.86 GPa. The shear stress applied on the top surface is
   (a) 70 GPa
   (b) 0.7 GPa
   (c) 70 MPa
   (d) 7 MPa
   (e) 0.7 MPa



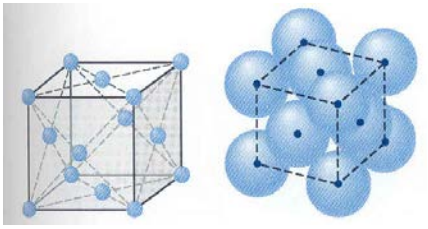
9. In the above problem, the shear strain, γ, is
   (a) 1%
   (b) 0.1%
   (c) 0.1
   (d) 0.4
   (e) 0.38%

10. In the above problem, the Poisson's ratio of the material is
   (a) 0.15
   (b) 0.30
   (c) 0.28
   (d) -0.3
   (e) 0.33

11. The yield strength of a material is determined in the stress-strain curve as
   (a) The maximum stress
   (b) The stress at the maximum strain
   (c) The stress at the onset of nonlinearity
   (d) The stress at the end of nonlinearity
   (e) The strain at the necking point

12. In which of the following crystalline structure the atoms are *least* close-packed?
    (a) BCC
    (b) FCC
    (c) HCP
    (d) The atoms are always equally close-packed
    (e) BCC and FCC

13. The figure on the right shows an unit cell of a
    (a) BCC crystal
    (b) FCC crystal
    (c) HCP crystal
    (d) Glass structure
    (e) None of the above

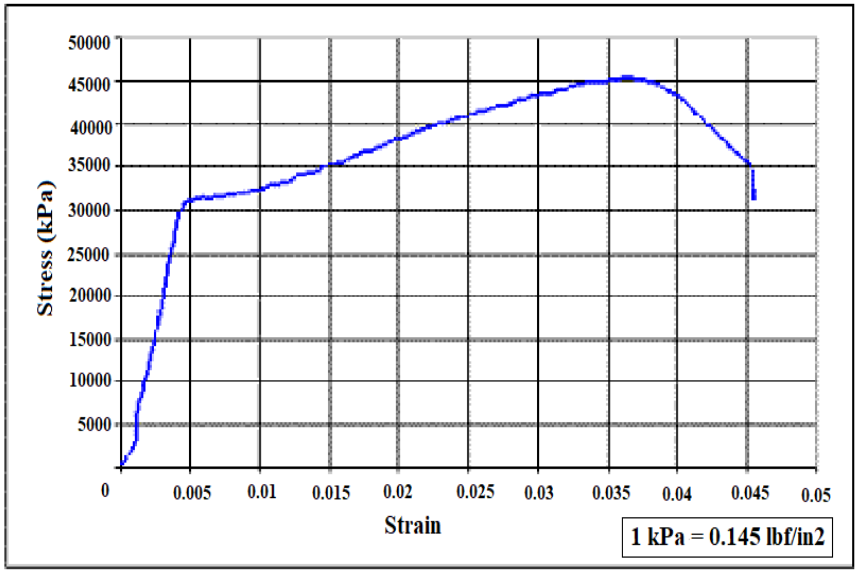


14. A beam is simply supported at both ends and is excited by an external cyclic loading. If it is made of _____, its natural frequency of vibration would be the lowest:
    (a) Silicon carbide (SiC)
    (b) Tungsten (W) alloy
    (c) Teflon (PTFE)
    (d) Lead alloy
    (e) Titanium (Ti) alloy

15. In the above problem, the performance index of material selection is
    (a) $E^{1/2}/\rho$
    (b) $E\cdot\rho$
    (c) E/ρ
    (d) $E^{1/2}\cdot\rho$
    (e) $E/\rho^{1/2}$

16. For a material selection, the performance index is derived as $E\cdot C_V^2$, where E is the Young's modulus and C_V is the cost per volume. The performance index needs to be minimized. Among the following candidates, the best one is
    (a) Ionomer
    (b) Wood ($\perp$ grain)
    (c) Stone
    (d) Glass finer reinforced polymer (GFRP)
    (e) PEEK

17. According to the stress-strain curve shown below (on the next page), the stiffness of the material is about
    (a) 75 GPa
    (b) 7.5 GPa
    (c) 750 MPa
    (d) 75 MPa
    (e) 7.5 MPa



18. According to the above stress-strain curve, by using the 0.2% offset approach, the yield strength of the material can be assessed as
    (a) 28 MPa
    (b) 38 MPa
    (c) 42 MPa
    (d) 32 MPa
    (e) 45 MPa

19. According to the above stress-strain curve, the ultimate tensile strength is nearly
    (a) 28 MPa
    (b) 38 MPa
    (c) 42 MPa
    (d) 32 MPa
    (e) 45 MPa

20. The tensile strength of a steel is 300 MPa. That is, if a 300 MPa tensile stress is applied, all the atomic bonds among the iron atoms in the steel would be broken apart.
    (a) True; (b) False

21. Plastic yielding of a large copper sample is likely caused by
    (a) Migration of grain boundaries
    (b) Collapse of atomic vacancies
    (c) Motion of dislocations
    (d) Diffusion of solute impurities
    (e) Rupture of atomic bonds in tension

22. As long as the external load is sufficiently high, a dislocation can slide along any crystalline plane, but only along some specific crystallographic directions.
    (a) True; (b) False

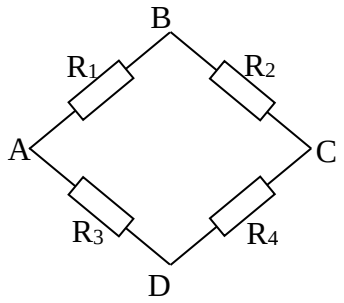
23. Through a single-crystal experiment, it is measured that the critical resolved shear stress of a material is 30 MPa. For a polycrystalline sample of the same material, the tensile yield strength is about (assume the grain orientation is random)
    (a) 9.7 MPa
    (b) 93 MPa
    (c) 30 MPa
    (d) 15 MPa
    (e) None of the above

24. Among the following approaches, ___ may NOT increase the strength of a metallic material:
    (a) Adding solute impurities
    (b) Tailoring the precipitation particle configuration
    (c) Increasing the grain size
    (d) Inducing a certain plastic deformation
    (e) Increasing the dislocation density

25. In engineering practice, strain cannot be directly measured. We usually first measure stress, and then calculate the strain.
    (a) True (b) False

26. In the Wheatstone bridge shown on the right, the bridge output (δE_0) is measured between
    (a) B and D
    (b) A and B
    (c) A and C
    (d) D and A
    (e) C and B

27. In the above problem, a strain gauge is used as R_1. A similar strain gauge is employed to mitigate the thermal mismatch during the measurement. The second strain gauge should be
    (a) R_2
    (b) R_3
    (c) R_4
    (d) R_2 or R_3
    (e) added at position "B"



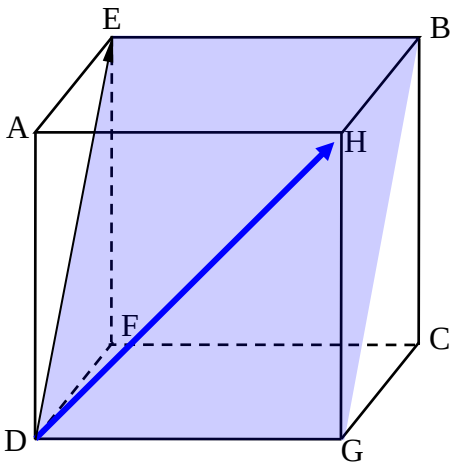
28. In the above problem, the temperature-compensating strain gauge (the second strain gauge) should be mounted
    (a) on the same specimen right next to R_1, along the same direction
    (b) on the same specimen right next to R_1, along the transverse direction
    (c) on the same specimen but at the surface opposite to R_1, along the same direction
    (d) at the position of "D"
    (e) on an unloaded separate specimen

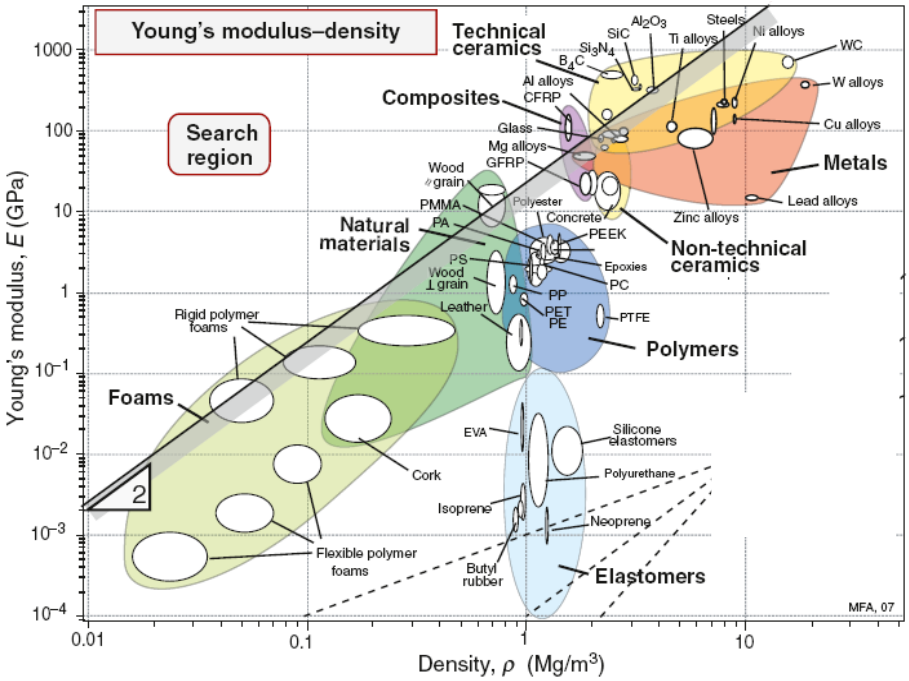
29. We need to select material for a connection rod that transmits a torque from one end to the other end. The shape and size of the cross section are given. With a certain torque, T_0, the twist angle across the rod must be smaller than θ_0. The rod should be as lightweight as possible. (a) List the constraint(s), objective(s), and free variable(s). (b) Derive the material performance index, as a function of shear modulus (G) and density (ρ). (c) Which one among the following candidates is the best: tungsten carbide (WC), lead alloy, glass fiber reinforced polymer (GFRP). (10 points)

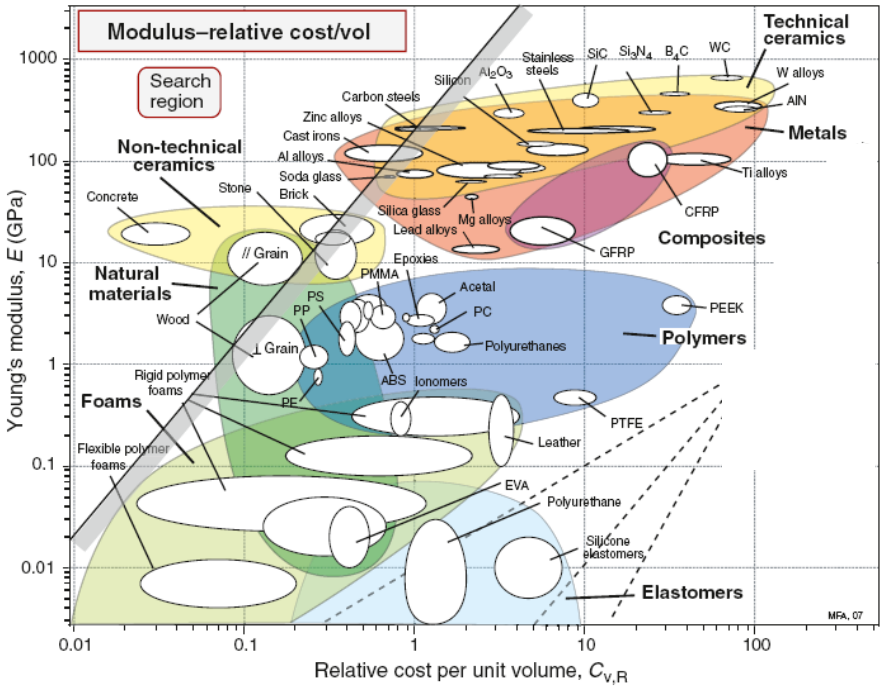
30. A round rod is subjected to an axial compressive load. Under the maximum working load, F_{max}, it should not buckle. Its length should be around 1±0.05 m. The material cost must be as low as possible. (a) List the constraint(s), objective(s), and free variable(s). (b) derive the performance index. (c) Which one of the following candidates is the best choice: stone, alumina (Al_2O_3), silicon carbide (SiC), glass fiber reinforced polymer (GFRP), teflon (PTFE)? (10 points)

31. At room temperature chromium (Cr) is a BCC crystal. Its atomic radius is 0.128 nm and its standard atomic weight is 52 g per mole. (a) What is the unit cell size of Cr? (b) What is the mass of a unit cell of Cr? (c) What is the mass density of Cr? (10 points)

Bonus Question (8 points). The figure on the right shows a unit cell of a BCC crystal. An external tensile stress of 50 MPa is applied along the direction of DH. The slip plane is EBGD, and the slip direction is DE. (a) Calculate the angle between the loading direction and the normal of slip plane. (b) What is the resolved shear stress along the slip direction? (c) If the critical resolved shear stress is 40 MPa, will plastic deformation happen? Why?




Young's modulus–density
Search region
Technical ceramics
Composites
Metals
Natural materials
Non-technical ceramics
Polymers
Foams
Elastomers
Young's modulus, E (GPa)
Density, ρ (Mg/m³)
MFA, 07


Modulus–relative cost/vol
Search region
Technical ceramics
Metals
Non-technical ceramics
Composites
Natural materials
Polymers
Foams
Elastomers
Young's modulus, E (GPa)
Relative cost per unit volume, C_V,R
MFA, 07