UNIVERSITY OF TORONTO

FACULTY OF APPLIED SCIENCE AND ENGINEERING

October 24, 2023 — **Duration: 90 minutes**

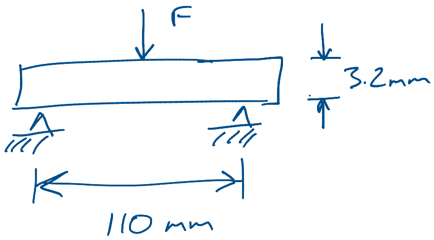
First Year, APS110 ENGINEERING CHEMISTRY AND MATERIALS SCIENCE

Exam Type: B - Closed Book, Provided equation sheet permitted. Calculator from Faculty approved list permitted.

Examiners: F Gu, CQ Jia, SD Ramsay

Key

1. (5 points) A sample of sapphire (Al_2O_3) having a strength in bending of 865 MPa and having height, width and length of 3.2 mm × 25 mm × 130 mm, respectively, is used to support a load across a span of 110 mm and is loaded in the middle of this span. At what force would you expect this sample to fracture?



1

$$\sigma = \frac{3FL}{2bd^2}$$ 1

1

$$F = \frac{2\sigma b d^2}{3L} \quad \Bigg| \quad \sigma = 865(10^6) \quad L = 110(10^{-3}), \quad b = 25(10^{-3}), \quad d = 3.2(10^{-3})$$

$$F = \frac{2 \cdot 865(10^6)\, 25(10^{-3})\left[3.2(10^{-3})\right]^2}{3 \cdot 110(10^{-3})}$$

$$[=] \quad \frac{N}{m^2} \cdot \frac{m \cdot m^2}{m} = N$$

$$F = 1.34(10^3)\,N = \underline{1.3\ kN}$$

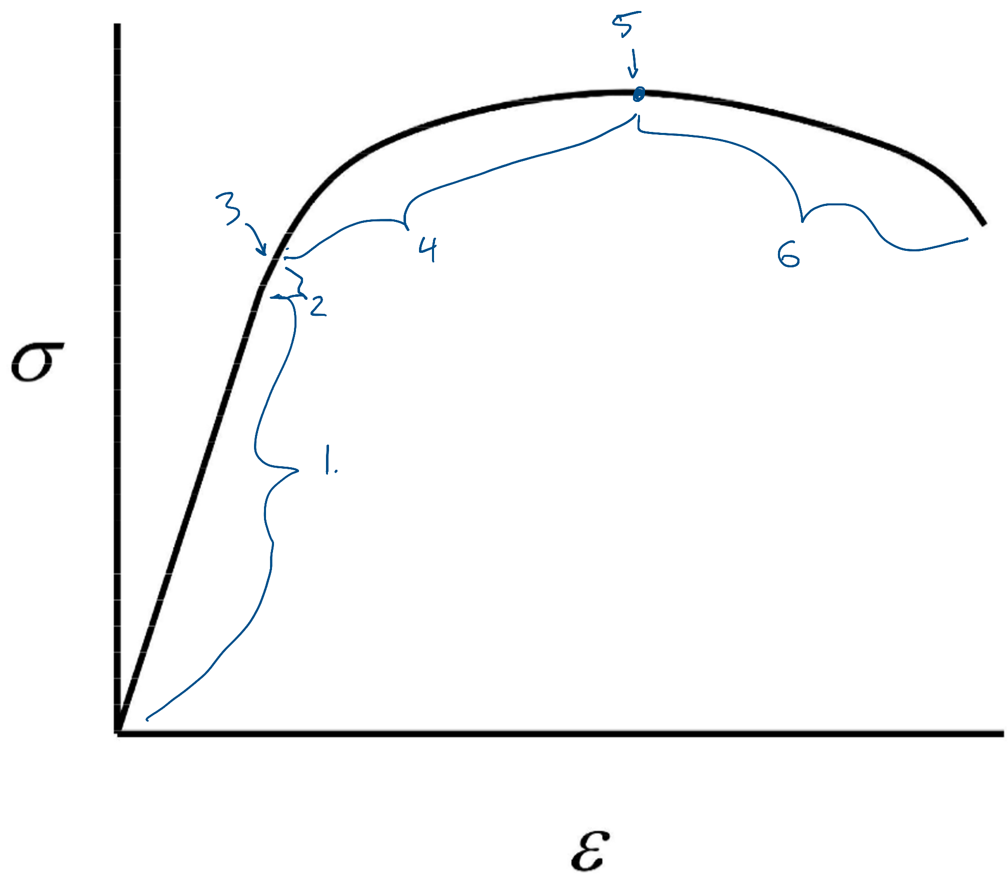
units 1

value 1

2. (6 points) On the figure below, carefully identify each of the following points or regions.

1. linear elastic deformation
2. non-linear elastic deformation
3. Beginning of plastic deformation
4. Uniform plastic deformation
5. Onset of localized plastic deformation
6. Region of localized plastic deformation

1 each



3. Match the most appropriate word(s) to each concept described below by writing the number corresponding to the correct word(s) on the line beside each concept. 1 each.

1. Polymers
2. The grain boundary
3. Only highest state occupied
4. Wood
5. Metals
6. Second phase particles
7. Ceramics
8. Eight
9. The ultimate tensile strength
10. Iron
11. Only uniform plastic deformation
12. Gold
13. Aluminum
14. The yield strength
15. Salt
16. All states equally occupied
17. FCC
18. Only lowest state occupied
19. Four
20. Six
21. Twelve
22. A decrease in force required to continue elongation
23. The vacancy
24. An increase in the cross-sectional area
25. The Young's modulus
26. The fracture strength
27. Absent of plastic deformation
28. Only non-uniform plastic deformation
29. BCC
30. Simple cubic
31. The dislocation

(a) (1 point) 7 ceramics The material class generally having the highest value of Young's modulus.

(b) (1 point) 4 wood An example of a material that does not fit well into our three material categories.

(c) (1 point) 16. all equally occupied The best description for the theoretical distribution of particles over possible energy states for a substance at infinite temperature.

(d) (1 point) 20 six The coordination number for cations in the rock salt crystal structure.

(e) (1 point) 22 decrease in force The reason that the engineering stress decreases beyond the onset of necking.

(f) (1 point) 14 yield strength The material property that would be used to determine the load at which deformation became permanent.

(g) (1 point) 25 Young's Modulus The material property that would be used to determine the change in length of a sample loaded below the 0.2% offset yield strength.

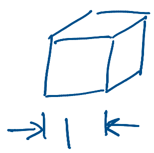
(h) (1 point) 27 Absent of plastic The best description for the mechanical behaviour of a ceramic at room temperature.

(i) (1 point) 21 twelve The coordination number of the only other crystal structure apart from HCP that is a close-packed structure.

(j) (1 point) 31 Dislocation The crystalline imperfection directly responsible for plastic deformation.

4. (5 points) A steel bar that is initially 370 mm in length transforms from BCC to FCC. Assuming no temperature change, approximate the final length of this bar. State any necessary assumptions.

take cube $L = 1$, $V = 1$



BCC

$APF = 0.68$

$n = 2$

$V_{Atoms} = APF \cdot V_{cube}$

$= 0.68$

$V_{cube} = 1$

1

FCC

$APF = 0.74$

$n = 4$

$V_{atoms} = \frac{4}{2} \cdot 0.68$

$APF = \frac{V_{atoms}}{V_{cube}}$

$V_{cube} = \frac{V_{atoms}}{APF} = \frac{2 \cdot 0.68}{0.74}$

$= 1.8378$

$V_{cube,\,2\,atoms} = \frac{1.8378}{2}$

$= 0.9189$

1

assuming change in length same in all directions, approximate as:

1

since $V_{FCC} = L_{FCC}^3$

$L_{FCC} = V_{FCC}^{1/3} = 0.9189^{1/3} = 0.9722$ 1

so if $L_0 = 370$ mm $\quad L_f = 0.9722 \cdot 370$

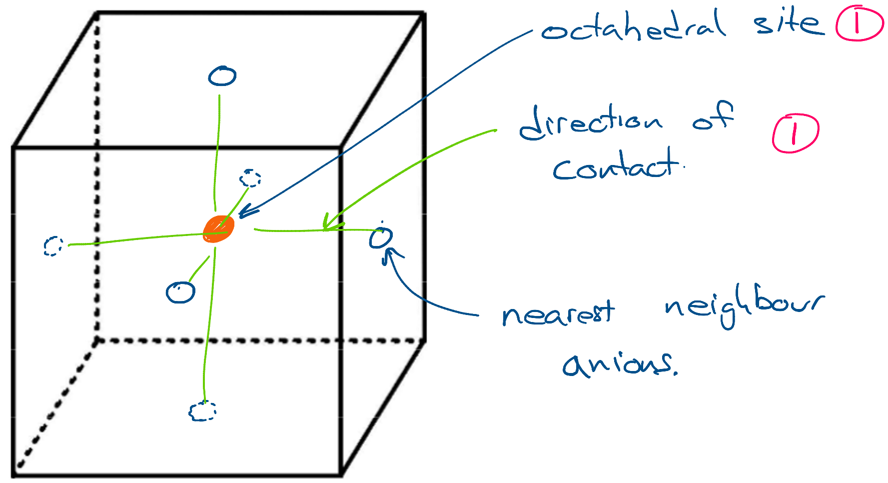
$= 359$ mm

1

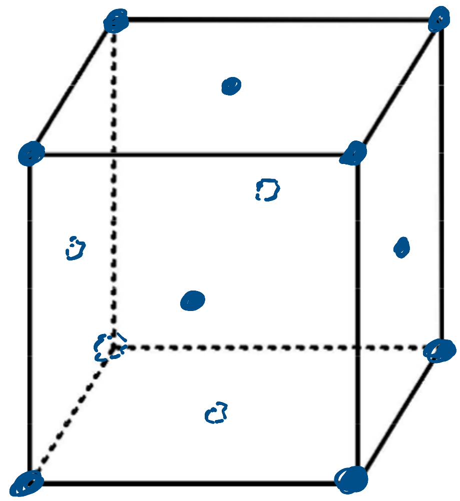
note: in reality, change will be less than this

5. This question pertains to crystal structures. For each of the sketches, please use a reduced sphere depiction, rather than a full hard sphere model.

   (a) (2 points) Using the unit cell below as a guide, sketch an octahedral interstitial site centred at the centre of the cube. Clearly identify the direction of contact between atoms.

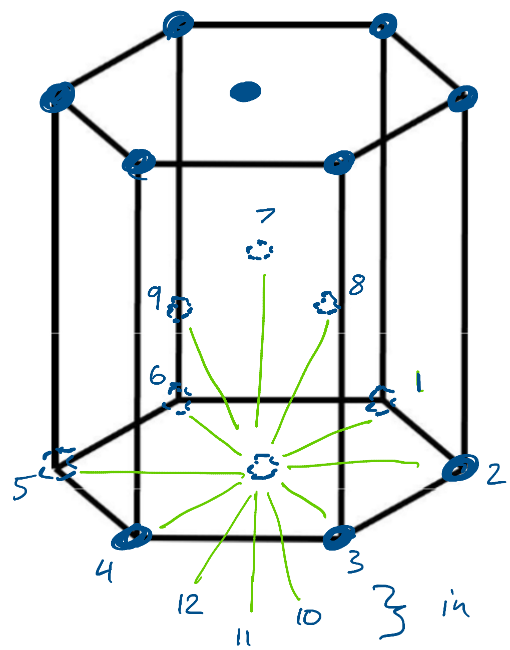


(b) (2 points) In the unit cell below, sketch the atom positions within the face-centred cubic crystal structure.



② all correct

(c) (2 points) Using the unit cell below as an aid, indicate the atom positions within the hexagonal close packed crystal structure and show the coordination number for these atoms.



① all atoms

① coordination

VERSION: 1-1

1. Ceramics typically have poor mechanical properties when loaded in which of the following manners?

   (a) In compression.
   (b) In tension.

   Correct answers: (b)

2. On a conventional tensile specimen which of the following statements is/are true?

   1. The gauge length is less than the reduced section length.
   2. The stress is the same within the reduced section as within the grip regions.
   3. All of the elongation occurs within the reduced section.
   4. Plastic deformation will initially occur homogeneously within the reduced section and the grip regions.

   (a) 3, 4
   (b) 1
   (c) 1, 2
   (d) 2, 3

   Correct answers: (b)

3. Which of the following would not be expected to increase the temperature at which a polymer could be used mechanically?

   (a) A decrease in molecular weight
   (b) An increase in the crystallinity of the polymer
   (c) An increase in cross-linking
   (d) A decrease in the extent of branching within the polymer molecule

   Correct answers: (a)

4. Which of the following statements is/are correct?

    1. It is possible for a polymer to continue supporting a load beyond necking.
    2. Plastic deformation of a polymer occurs largely by the breaking of strong intramolecular bonds.
    3. Cross-linking of a polymer would be expected to lower the Young's modulus.
    4. All else being equal, an increase in molecular weight of a polymer would be expected to increase the strength of a polymer.

    (a) 2, 4
    (b) 2, 3
    (c) 1, 3
    (d) 1, 4

    Correct answers: (d)

5. The dislocation is an example of which of the following types of crystalline imperfection?

    (a) One dimensional
    (b) Two dimensional
    (c) Three dimensional
    (d) Zero dimensional

    Correct answers: (a)

6. Which of the following statements is/are correct regarding elastic deformation?

    1. Atoms move temporarily away from their equilibrium positions.
    2. Elastic deformation normally involves a change in crystal structure.
    3. Atoms do not move past one-another to new equilibrium positions.
    4. An increase to the yield strength of a material will also result in an increase in the Young's modulus.

    (a) 2, 3
    (b) 1, 3
    (c) 3, 4
    (d) 1, 2

    Correct answers: (b)

7. Generally speaking, which of the following material classes has the lowest Young's modulus?

    (a) Polymers
    (b) Ceramics
    (c) Metals

    Correct answers: (a)

8. Which of the following is/are NOT an example of a two-dimensional imperfection?

    1. A grain boundary.
    2. A dislocation.
    3. The surface of a material.
    4. A substitutional imperfection.

    (a) 2, 4.
    (b) 3, 4.
    (c) 1, 2.
    (d) 1, 3.

    Correct answers: (a)

9. A lattice of anions in face-centred cubic positions with cations occupying all of the available octahedral interstitial sites describes which of the following crystal structures?

    (a) Body centred cubic
    (b) Not yet covered.
    (c) Hexagonal close-packed
    (d) Rock salt

    Correct answers: (d)

10. A cation that was only slightly too small to fit within the simple cubic interstitial site would be expected to occupy an interstitial site having which of the following coordination numbers?

    (a) Eight
    (b) Six
    (c) Four
    (d) Twelve

    Correct answers: (b)