Spring 2021: Mechanical Properties Materials Science

Take Home Exam I: (Elasticity)
Given out on Mon 03/01/2021, due (by email) on Mon 03/15/2021
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Each question carries equal points.

This exam is not very long. May I therefore ask you to think very carefully about your answers. Here are some suggestions on how to prepare your answers:

- Work in at least two phases, which are about one week apart. In the first phase prepare your answers. Later read them over, edit your English to make sure that your answers are clear and read well.
- Some of the questions require "descriptive" answers.
- Where analytical solutions are required, please clearly state the steps and the assumptions.
- When you have significant derivation then please describe the implications of the equation in words.

Since in some instances the answers will be found in the notes, the grading will especially pay heed to the clarity of your answers, both in content and in the writing.

Question 1.

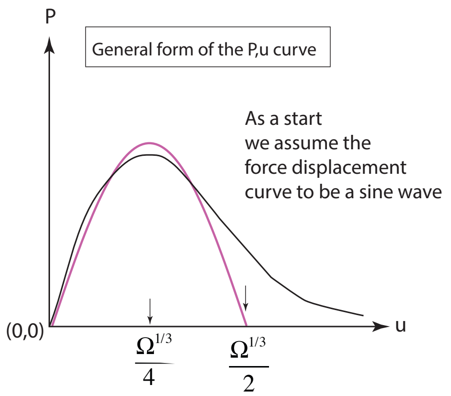
Give <u>three</u> examples of iconic figures, or equations that pertain to the understanding of elastic deformation in solids.

Question 2.

Assuming a sinusoidal force displacement curve between atoms separated by a distance $\Omega^{1/3}$, where Omega is the volume per atom (or the molar volume V_{molar}), <u>derive the following equation</u> that relates the elastic modulus to the heat of "disassociation" (which may be the heat of melting or the heat of evaporation):

$$E = 4\pi^2 \frac{\Delta H}{V_{molar}} Z \tag{1}$$

Here Z is the coordination number, that is the number of nearest neighbors of the atom.



Question 3.

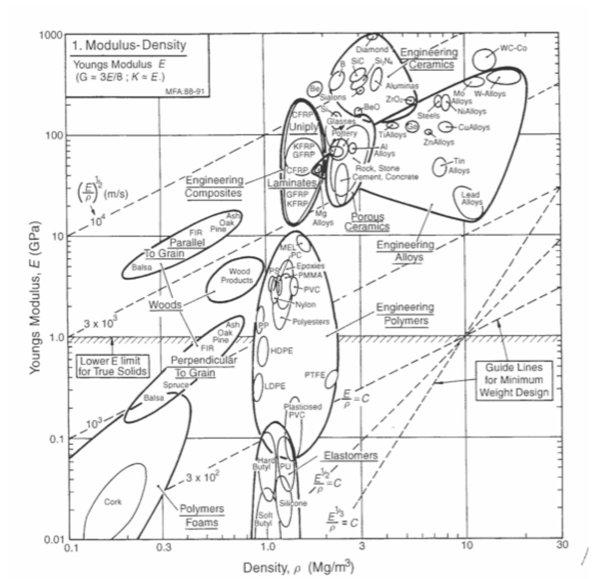
Ice is a crystal of H_2O units placed in a crystalline array. The structure of the crystal is complex. <u>Assume</u> that ice has a simple cubic structure with H_2O molecules placed at the corners of the cube.

•Knowing the molecular weight and the density of ice, calculate the spacing between the water molecules in this assumed structure.

•The Youngs Modulus of ice is 9 GPa. The latent heat of melting and evaporation can be found on the Web.

•Check the applicability of Eq. (1) to ice with the above assumption. Which comes closer to the result: heat of melting or the heat of evaporation?

Question 4.



•Comment on why the Youngs modulus has a relationship with the density as shown in the map.

•Comment on why the materials (as a class) move upwards.

Comment on the extent to which Eq. (1) provides some guidance to the above questions.

Question 5.

The following equations give relationships between the Youngs Modulus, the Bulk Modulus, the Shear Modulus and the Poisson's Ratio.

$$G = \frac{E}{2(1+\nu)}$$

$$B = \frac{2G(1+\nu)}{3(1-2\nu)}$$

$$B = \frac{E}{3(1-2\nu)}$$

Show that only two of the four constants in these equations are independent quantities.

Question 6.

Write short answers to the following statements:

(i) Covalent bonds are usually stronger than metallic bonds.

(ii) Compounds made of constituents with larger differences between their electronegativity values, are more likely to be ionically bonded.

(iii) Solids made from elements in the middle of the periodic table have the highest modulus (graphite and diamond are examples).

(iv) Related to above, (iii), why does diamond have a higher modulus than silicon (both reside in the same vertical column in the periodic table).

Question 7.

A uniaxial tension (or compression) test has one principal stress but three principal strains.

•Reduce the above quantities to hydrostatic stress, shear stress, hydrostatic strain and shear strain.

•Assume that the deformation is elastic. The measured quantities are the tensile stress and the tensile strain which are linearly related to one another.

•Derive the equation for the Bulk Modulus and the Shear Modulus in terms of the stresses and strains measured in a simple uniaxial test.

Question 8.

Explain the Hashin-Bounds for the Youngs Modulus of composites made from two materials A and B, in different microstructural configurations.