UNIVERSITY OF CALIFORNIA
College of Engineering
Department of Materials Science & Engineering
Professor R. Gronsky Fall Semester, 2005

Engineering 45 Midterm 01

SOLUTIONS

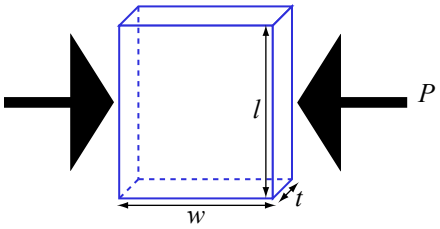
INSTRUCTIONS

LATTICE seating..... Please be seated with *occupied* seats to your front and back, *vacant* seats to your left and right.
CLOSED BOOK format..... All you need are writing instruments and a straightedge. Please store all books, reference materials, calculators, PDAs, cell phones (OFF), and iPods.
NO DISRUPTION rule..... Questions cause too much of a disturbance to others in the room. Instead of asking questions, write any concerns or alternative interpretations in your answers.
PROFESSIONAL protocol... Engineers do not cheat on the job and they certainly don't cheat on exams.

Do not open until "START" is announced.

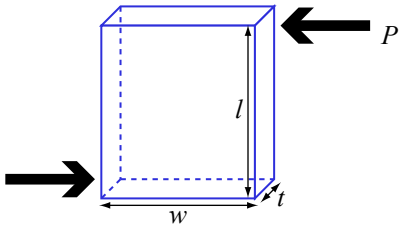
1. Mechanical Properties (20 points)
Mark ☒ the ballot box corresponding to the best answer.
Two (**+2**) points for correct answers, **-1** if wrong, **0** if blank.

(**a**) The compressive stress induced in the volume element shown below is defined by which expression?



☐ $\sigma = P / (w \times t)$
☐ $\sigma = P / (l \times w)$
☒ $\sigma = P / (l \times t)$

(**b**) The shear stress induced in the volume element shown below is defined by which expression?



☐ $\sigma = P / (w \times t)$
☒ $\sigma = P / (l \times w)$
☐ $\sigma = P / (l \times t)$

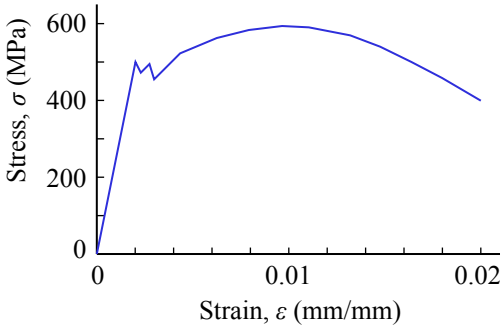
(**c**) In order to convert the data from a load *vs* elongation plot to a stress *vs* strain plot, the following information is essential.
☐ the cross-sectional area of the sample
☐ the yield strength of the sample
☒ the geometry of the sample

(**d**) Elastic deformation is_____?
☐ linear
☒ recoverable
☐ time-dependent

(**e**) The gage length of a metallic alloy sample used in the standard uniaxial tensile test
☒ has the smallest cross-sectional area
☐ establishes the initial length of the sample
☐ calibrates the sample's elongation to failure

(**f**) "True" stress differs from "engineering" stress
☐ in the way tensile test data is collected
☒ in the way tensile test data is reported
☐ in the way tensile test data represents the actual sample

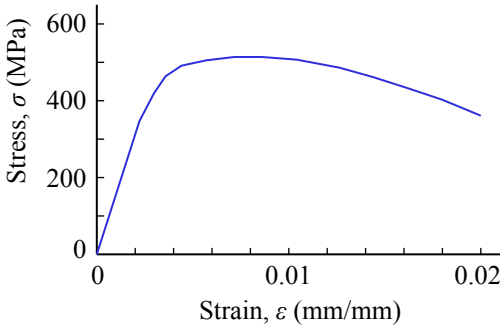
(**g**) The following data from a uniaxial tensile test of a low carbon steel sample indicates that



☒ it has a lower yield point of 450 MPa
☐ it has an 0.2% offset yield point of 450 MPA
☐ it fractured at precisely 0.02% offset

(**h**) For the same steel sample as above, an observer in the room would have observed necking in the sample
☐ just before the sample fractured at 400 MPa
☐ just when the sample yielded at 500 MPa
☒ just as the stress exceeded 600 MPa

(**i**) An aluminum alloy produced the following stress-strain plot during a uniaxial tensile test. Its yield strength is



☐ 400 MPa
☐ 450 MPa
☒ 500 MPa

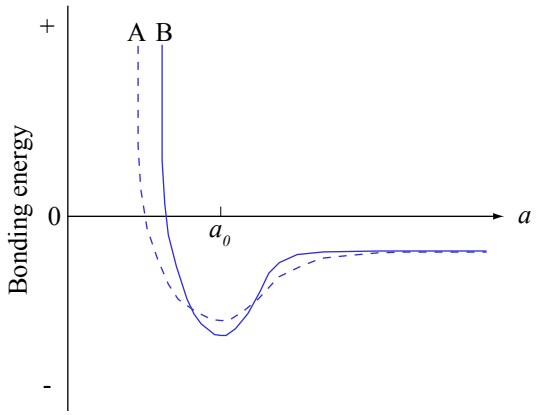
(**j**) Comparing the above plots from a steel sample and an Al alloy sample, it can be concluded that
☒ the Al alloy has greater elastic recovery after fracture
☐ the Al alloy has a larger elastic modulus
☐ the Al alloy deforms more before it fails

2. Bonding (20 points)
Mark ☒ the ballot box corresponding to the best answer.
Two (+**2**) points for correct answers, **-1** if wrong, **0** if blank.

(**a**) "Primary" bonds are formed
☐ by the transfer of primary electrons
☒ primarily between individual atoms or ions
☐ during primary chemical reactions

(**b**) "Secondary" bonds are so-named because
☐ they require secondary electrons to complete the charge transfer necessary for bonding
☒ they occur between groups of atoms after primary bonding has occurred
☐ they result in secondary reactions with reduced efficiency relative to primary bonds

(**c**) Consider the following bonding energy curves for two alloys, A and B.



☐ A has a higher tensile strength than B
☒ A has a lower elastic modulus than B
☐ A has a smaller lattice constant than B

(**d**) The "octet rule" predicts that Group IV elements
☒ form bonds with four near neighbors
☐ have eight bonding electrons
☐ reside in octahedral sites

(**e**) When compared with materials that form ionic bonds, metallic alloys
☐ melt at higher temperatures
☐ exhibit greater bond directionality
☒ have higher coordination numbers

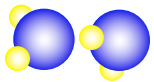
(**f**) During the formation of covalent bonds, a bonding model called "hybridization" explains why
☐ some bonds show both covalent and metallic character
☐ carbon has more than one isotope
☒ silicon atoms are tetrahedrally coordinated

(**g**) The metallic bonding model explains ductility on the basis of
☐ lack of bonding electrons, yielding weaker bonds
☐ excess of mobile electrons, causing fluid bonds
☒ lack of bond directionality

(**h**) The basis for the van der Waals interaction that causes molecular bonding is
☐ mutual charge symmetry
☒ induced electric dipoles
☐ distortion in electron orbitals

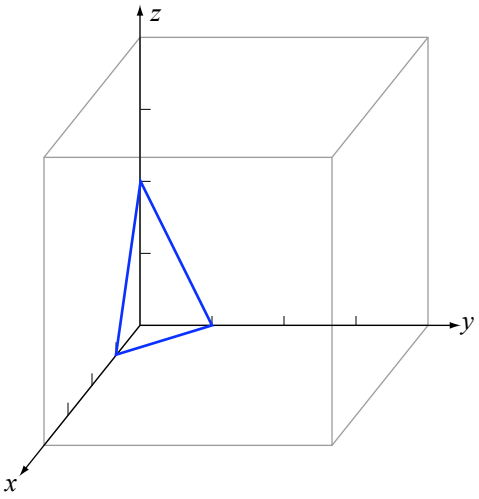
(**i**) One explanation for why graphite powder acts so well as a "solid lubricant" is
☒ carbon atoms in graphite are covalently bonded within planar layers but have weaker secondary bonds between layers
☐ finely-powdered carbon has many unsatisfied bonds at the particle surfaces, which act as a "sea of electrons" to cause lubrication
☐ when crushed into a fine powder, graphite establishes a "polar" distribution of charge, leading to Coulombic repulsion between powder particles

(**j**) The following schematic shows two water molecules in a "bonded" configuration due to

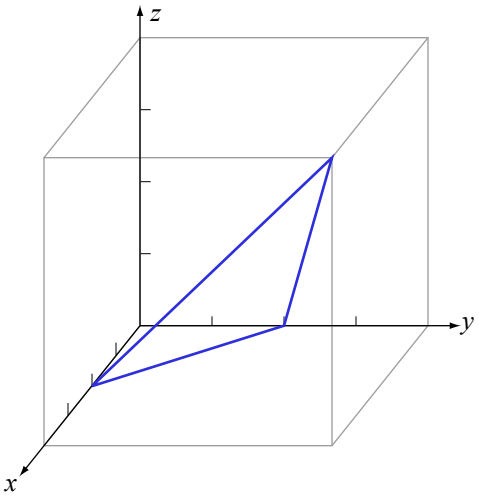


☐ 109.5° covalent bond angles
☒ a functional hydrogen bridge
☐ the ideal radius ratio, $0 < r/R < 0.155$

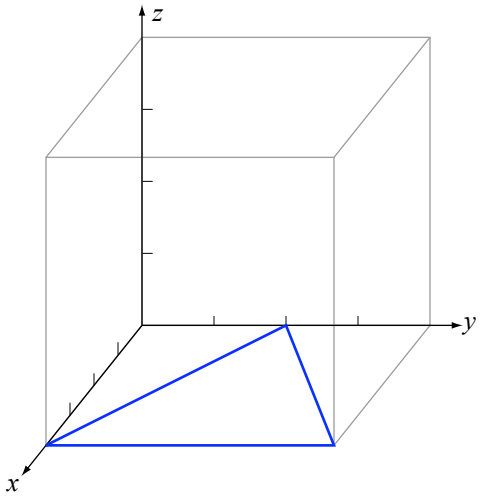
3. **Lattice Planes (20 points)**
The triangles drawn here are sections of planes through cubic and hexagonal lattices. Identify the relevant planes by their Miller indices or Miller-Bravais indices.
Four (**4**) points for *correct answers in the boxes* provided.



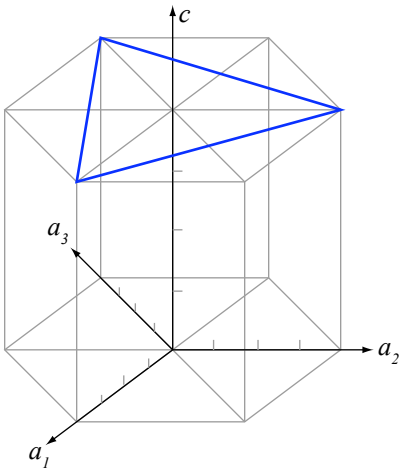
(a) (442)



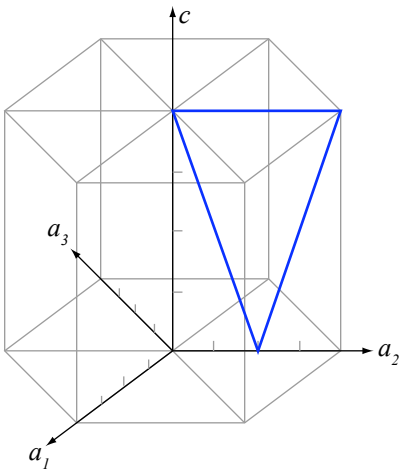
(b) $(22\bar{3})$



(c) (001)

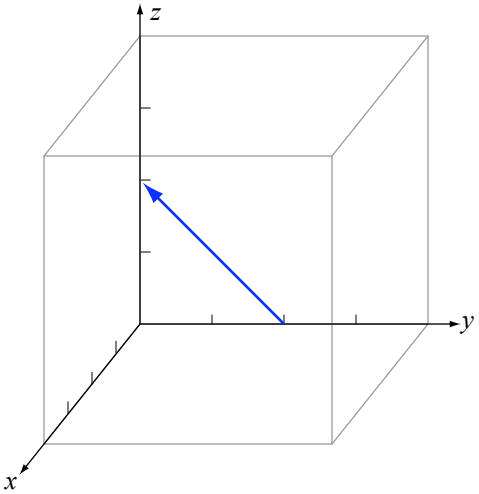


(d) (0001)

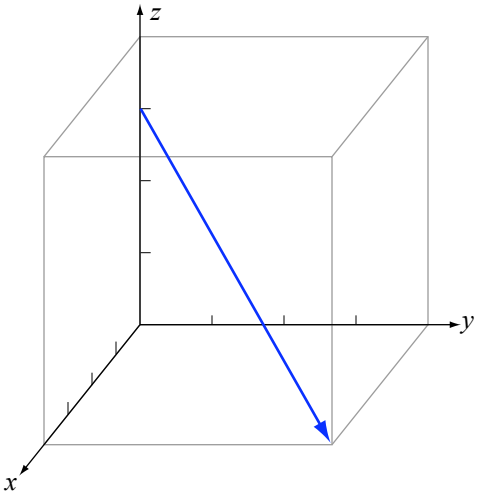


(e) $(10\bar{1}0)$

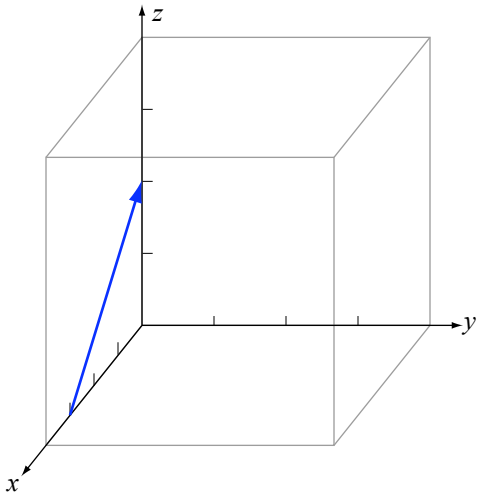
4. **Lattice Directions (20 points)**
Identify the following directions through both cubic and hexagonal lattices using the appropriate Miller index or Miller-Bravais index notation.
Four (**4**) points for *correct answers in the boxes* provided.



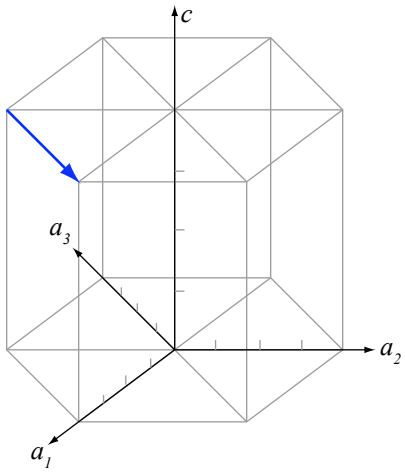
(a) $[0\bar{1}1]$



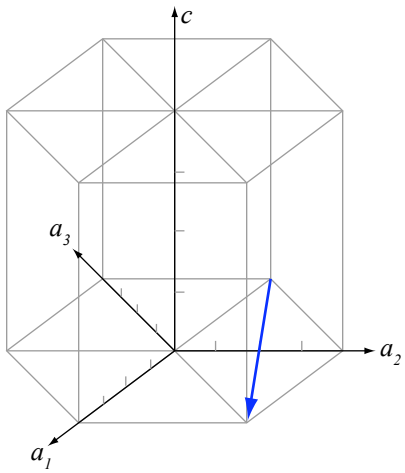
(b) $[44\bar{3}]$



(c) $[\bar{3}02]$



(d) $[11\bar{2}0]$

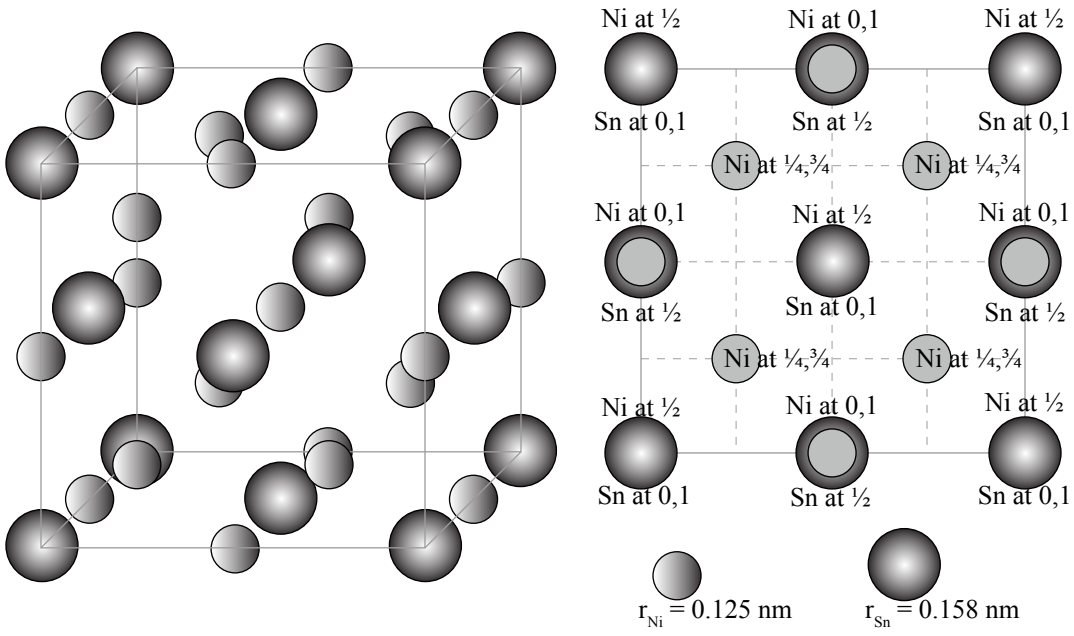


(e) $[10\bar{1}0]$

5. Crystal Structure (20 points)

An alloy of nickel and tin adopts a number of different structures, one of which is cubic, designated by the *Strukturbericht* symbol DO_3, where the first index *D* is reserved for the more "complicated" crystal structures. In this case, the larger Sn atoms are located at all face-centered-cubic lattice sites, and the smaller Ni atoms are found in all of the tetrahedral interstices and all of the octahedral interstices. A perspective sketch of the positions is shown below on the left.

(**a**) On the grid provided to the right, draw a cube-axis projection of the structure, and label the "elevation" of each atom from the bottom plane (elevation "0") to the top plane (elevation "1"). [*Hint*: On this scheme, for example, the side faces would be occupied by a single Sn atom at elevation "½."] (**5** points)



(**b**) How many Sn atoms are there in this unit cell? Ans: [4] (**2** points)
(Show how you "count" the atoms occupying the lattice points in the unit cell)

Corners: 8 x 1/8 = 1
Face Centers: 6 x 1/2 = 3
Total: 3 + 1 = 4

How many Ni atoms are there in this unit cell? Ans: [12] (**2** points)
(Show how you "count" the atoms occupying the interstitial sites in the unit cell)

Tetrahedral sites: 8 x 1 = 8
Octahedral site at body center: 1 x 1 = 1 Octahedral sites at edge centers: 12 x 1/4 = 3
Total: 8 + 1 + 3 = 12

Now write the "chemical formula" with the stoichiometry of the Ni-Sn alloy shown here. Ans: [Ni_3Sn] (**1** point)

(**c**) Using your evaluation above, specify both a Bravais lattice and motif that fully describes this $D0_3$ crystal structure.

Lattice: [fcc] (**5** points) Motif: [**1 Sn** atom at 0,0,0 and **3 Ni** atoms at: 1/2,0,0; 1/4, 1/4, 1/4; and 3/4, 1/4, 1/4] (**5** points)