1. Mechanical Properties (20 points)

Instructions: Mark ☒ the ballot box corresponding to the best answer.
Scoring: +2 points for correct answers, -1 for incorrect answers, 0 for blanks

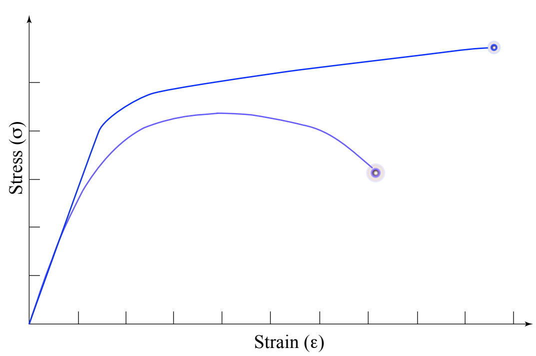
(a) Elastic deformation is
- ☐ linear
- ☐ constant
- ☒ temporary

(b) Hardness is
- ☐ resistance to fracture
- ☒ resistance to penetration
- ☐ resistance to elastic deformation

(c) The slope of the linear portion of a stress-strain curve defines
- ☐ elasticity
- ☒ Young's modulus
- ☐ the proportionality limit

(d) Engineering stress is
- ☒ always lower than true stress
- ☐ equal to true stress at high strain
- ☐ sometimes higher than true stress

(e) On stress-strain plots below, yield stress
- ☒ is found by 0.2% offset
- ☐ is where the curves bifurcate
- ☐ is higher for higher values of strain



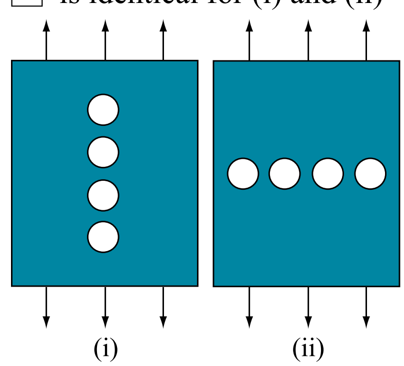
(f) Poisson's ratio describes
- ☐ tension-induced contraction
- ☐ compression-induced expansion
- ☒ both of the above behaviors

(g) Cyclic loading at low stress can
- ☒ cause failure by fatigue
- ☐ increase resistance to fatigue
- ☐ be a combination of both effects

(h) A transition from ductile to brittle failure can occur in plain carbon steels
- ☐ at low strain rates
- ☒ at low temperatures
- ☐ at low carbon concentrations

(i) Creep deformation
- ☐ results in surprise failure
- ☐ occurs at all temperatures
- ☒ depends upon melting point

(j) Stress concentration in the samples below with through holes
- ☐ is higher for (i)
- ☒ is higher for (ii)
- ☐ is identical for (i) and (ii)



2. Bonding (20 points)

Instructions: Mark ☒ the ballot box corresponding to the best answer.
Scoring: +2 points for correct answers, -1 for incorrect answers, 0 for blanks

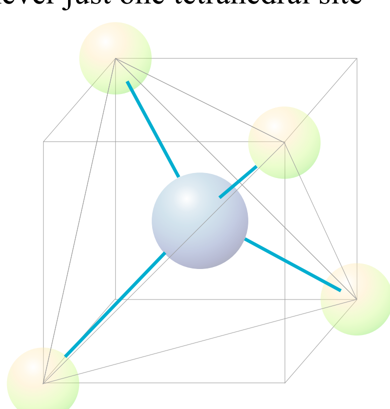
(a) Primary bonds are chemical bonds
- ☐ when they involve different ions
- ☐ if they cause a chemical change
- ☒ for all atoms and ions

(b) Secondary bonds are
- ☐ less likely than primary bonds
- ☒ more likely to be physical bonds
- ☐ equally likely to be chemical bonds

(c) During covalent bonding, the electrons that form bonds are known as
- ☐ core electrons
- ☒ valence electrons
- ☐ a "sea" of electrons

(d) Bonds lengths in ionic solids are
- ☐ determined by coulombic forces
- ☐ modeled by a zero energy state
- ☒ established by a zero force condition

(e) The bonding configuration below is
- ☒ common to Group IV elements
- ☐ also called body centered cubic
- ☐ never just one tetrahedral site



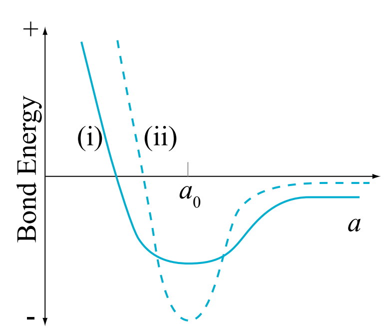
(f) Long chain polymers are bonded by
- ☐ covalent bonds within chains
- ☐ secondary bonds among chains
- ☒ a combination of both bond types

(g) Metallic bonds are
- ☐ localized
- ☒ non-directional
- ☐ formed between ion cores

(h) A dipole bond differs from an ionic bond in that it
- ☒ is directional
- ☐ fluctuates over time
- ☐ does not require electron transfer

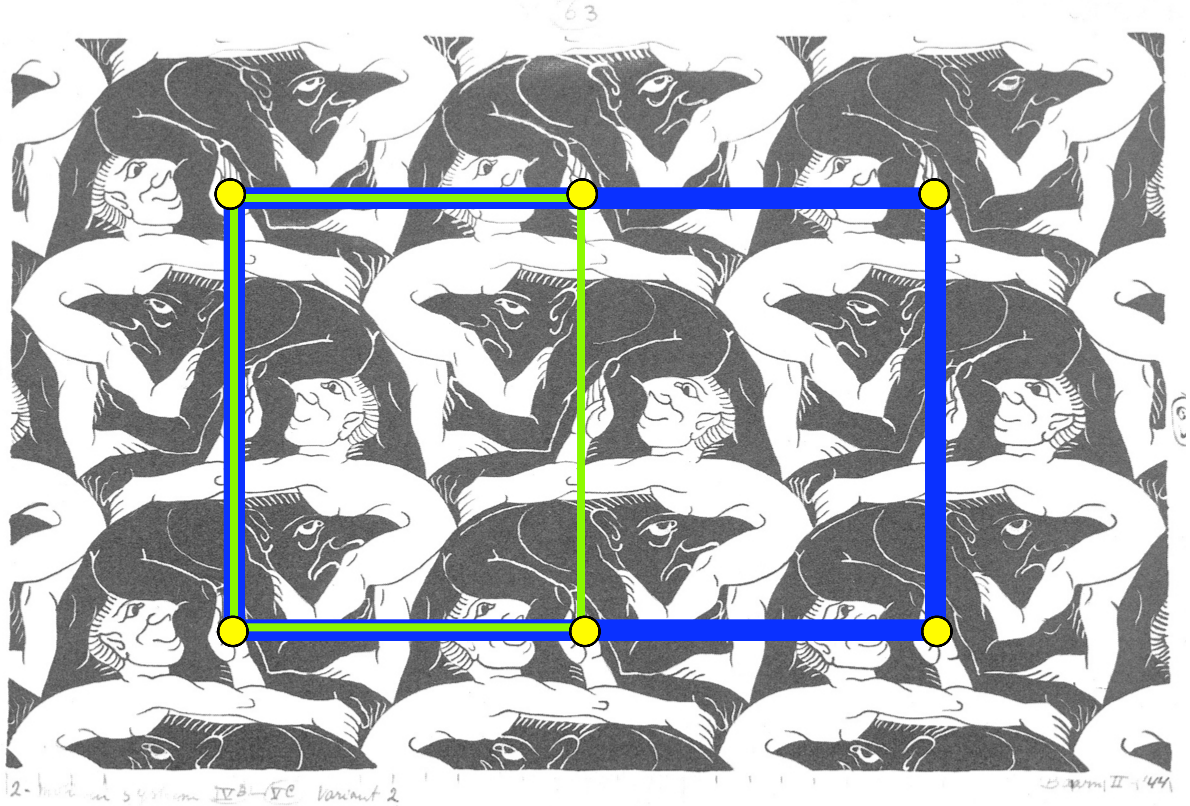
(i) A "hydrogen bridge" refers to
- ☒ the dipole bonding in liquid water
- ☐ any covalent bond with hydrogen
- ☐ electron sharing between H atoms

(j) From the plots below,
- ☐ (i) melts before (ii)
- ☒ (i) is softer than (ii)
- ☐ (i) has a larger lattice constant



3. Lattice and Motif (20 points)

(**a**) Show directly on this figure[1] by M.C. Escher using bold dots (●) the points of a lattice suitable to define its regular structure (allowing for small variations in hand drawings).



(**b**) Outline on the same figure a primitive unit cell appropriate to your choice of lattice.
(A primitive cell contains a single lattice point. One choice is the thin (green) rectangle at left.)

(**c**) Outline on the same figure a non-primitive unit cell containing two (2) lattice points.
(One choice is the thick (blue) rectangle outlined above.)

(**d**) Outline on the same figure a motif appropriate to your choice of lattice that suitably defines the regular structure of this figure. How many "human figures" comprise your motif? Number of figures = __**4** __.

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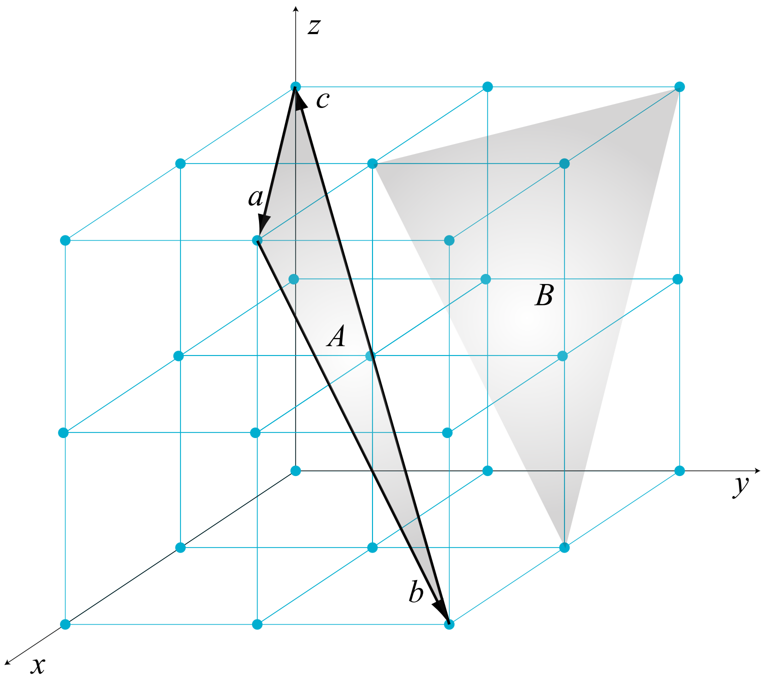
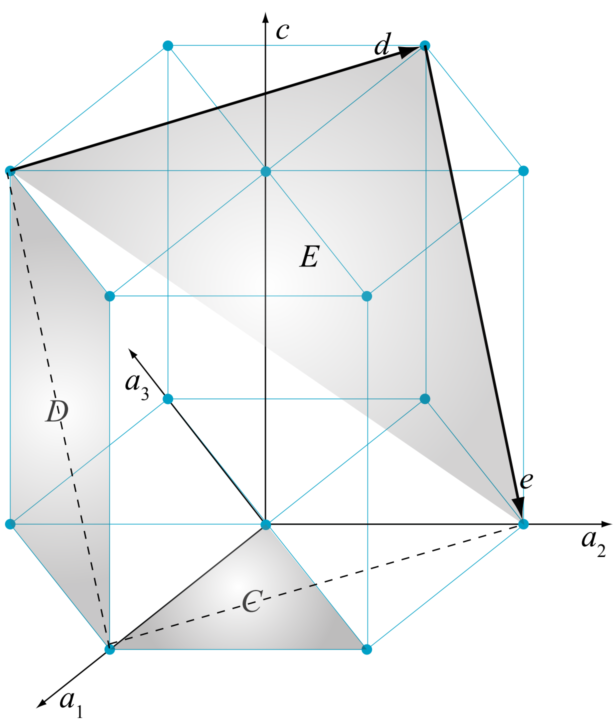
[1] "Study of Regular Division of the Plane with Human Figures, 1944" in *The World of M.C. Escher*, J.L. Locher, Ed., Harry N. Abrams, Inc., Publishers, New York (1971), p. 90.

4. Lattice Directions and Planes (20 points)

Identify the indices of the directions labeled in lower case letters (at heads of the arrows) and the Miller indices of the planes labeled in upper case letters (at the center of the planes) for the simple cubic and simple hexagonal lattices below. Note that plane *A* is contains directions *a*, *b*, and *c* and plane E contains directions *d* and *e*.





a	$[210]$
b	$[01\bar{2}]$
c	$[\bar{1}\bar{1}1]$
d	$[\bar{1}100]$
e	$[11\bar{2}\bar{3}]$

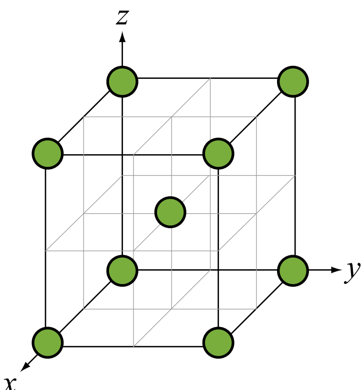
A	$(1\bar{2}\bar{1})$
B	(221)
C	(0001)
D	$(1\bar{1}00)$
E	$(11\bar{2}2)$

5. Common Crystal Structures (20 points)

Indium (In) is a metal with a tetragonal structure (a = b < c; α = β = γ = 90°) that is at times defined in two (2) different variants, namely,

(**a**) Two (2) atoms per unit cell, one at 0,0,0 and another at ½, ½, ½.

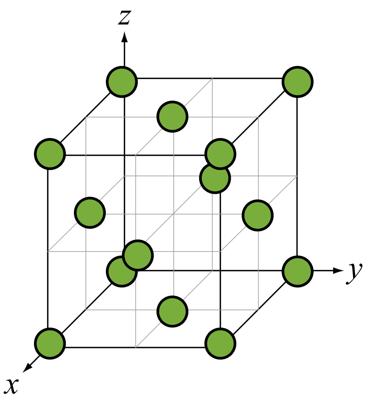
(**b**) Four (4) atoms per unit cell, one at 0,0,0, another at 0, ½, ½, another at ½, 0, ½, and another at ½, ½, 0.



Sketch all of the atoms within the unit cell described in (**a**). Specify the lattice and motif.

Lattice = **body-centered tetragonal**

Motif = **one In atom per lattice point**

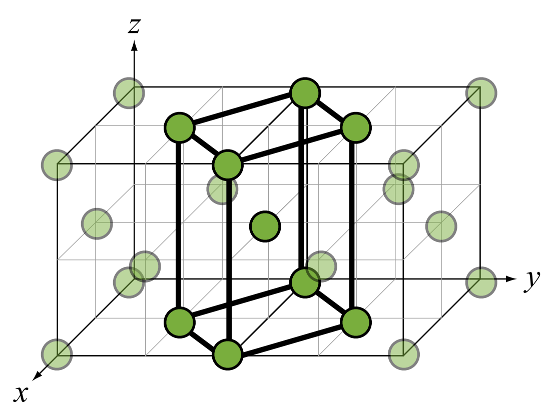


Sketch all of the atoms within the unit cell as described in (**b**). Specify the lattice and motif.

Lattice = **face-centered tetragonal**

Motif = **one In atom per lattice point**

(**c**) Now show with a sketch how both of these two descriptions are equivalent. (*HINT*: The *c* lattice parameter is the same in both cases, but *a* and *b* are different).



(d) What are the indices of the first diffraction peak from a simple tetragonal structure with the same parameters as indium? (HINTS: Bragg's Law applies, that is, $n\lambda = 2d \sin\theta$, and all reflections are "allowed" by structure factor rules.) Ans: __**001**__