Name: _____Solutions_____ GTID: _____

MSE 2001 B: Principles and Applications of Engineering Materials

Midterm exam 1, June 3, 2014, 10am – 11am

Please read this cover sheet carefully before continuing with the exam.

Please remove everything from your desk except this test itself, writing instruments, and a calculator.

All pages are numbered at the bottom center of the page. Make sure that you have all 6 pages including this cover page (p.1). Work all problems in the spaces below the problem statement. You can use the back side of the pages for scratch, but I will not grade answers written on the back side. Do not remove the staple or tear out any pages.

I will not grade your exam if you fail to sign on the line below.

I acknowledge the above terms for taking this exam. I commit to uphold the ideals of honor and integrity by refusing to betray the trust bestowed upon me as a member of the Georgia Tech community. I pledge my honor that I have not violated the Honor Code during this examination.

Student's signature: _____

You may find the following formulas useful for this test:

$d(h\ k\ l) = \frac{a_0}{\sqrt{h^2+k^2+l^2}}$ $n\lambda=2d\sin(\theta)$

$reaction\ rate = Ce^{-\frac{Q}{RT}}$ R = 8.314 J/mol-K

Avogadro constant: 6.02×10^{23}

1. Circle the correct answer (15 points)

1. Which type of polymers will char and burn when heated up?
(a) Thermoplastic polymer; (b) Thermoset polymer

2. Which material is more likely to be a single crystal?
(a) A piece of gold; (b) A piece of diamond

3. Which ASTM grain size number represents smaller grain size?
(a) N=5; (b) N=10

4. The bond in Al_2O_3 is primarily
(a) Ionic; (b) Covalent

5. Which atom has a larger electronegativity?
(a) Calcium; (b) Carbon

6. The activation energy of reaction A is larger than that of reaction B. Which reaction is more temperature sensitive?
(a) reaction A; (b) reaction B

7. The coefficient of thermal expansion for Al is $25\times10^{-6}\,°C^{-1}$ and for SiC is $4.3\times10^{-6}\,°C^{-1}$. Which material has the higher melting temperature?
(a) Al; (b) SiC

8. Which polymer is more suitable for hot water piping?
(a) polyethylene, $(-C_2H_4-)_n$ (b) polyvinylchloride $(-C_2H_2Cl_2-)_n$

9. Which direction in a BCC lattice has a larger linear density?
(a) [1 1 1]; (b) [1 1 0]

10. Which structure has a larger coordination number?
(a) BCC; (b) HCP

11. Which plane has the highest planar density in FCC?
(a) {1 1 1}; (b) {1 1 0}

12. Which diffraction peak is absent when X-ray interacts with a BCC crystal:
(a) {0 0 1}; (b) {0 0 2}

13. When a piece of graphite is heated up, it exhibits more thermal expansion along a direction:
(a) Within the "honeycomb" layers; (b) Perpendicular to the "honeycomb" layers

14. The lattice constant of the diamond cubic structure is a. The center-to-center distance between nearest C-C neighbors in diamond is:
(a) $\sqrt{2}a/2$; (b) $\sqrt{3}a/4$

15. No two electrons can have the same set of quantum numbers. This is called:
(a) Pauli exclusion principle; (b) Heisenberg uncertainty principle

2. Fill in the Blank (10 points)

1. Four of the five major classes of materials are _____, _____, _____ and _____. (2pt) [Metals; Ceramics; Polymers; Composites; Semiconductors]

2. Material strength normally _____ with increasing ductility. [decreases]

3. The energy required to detach an electron from a singly charged negative ion is called _____. [electron affinity]

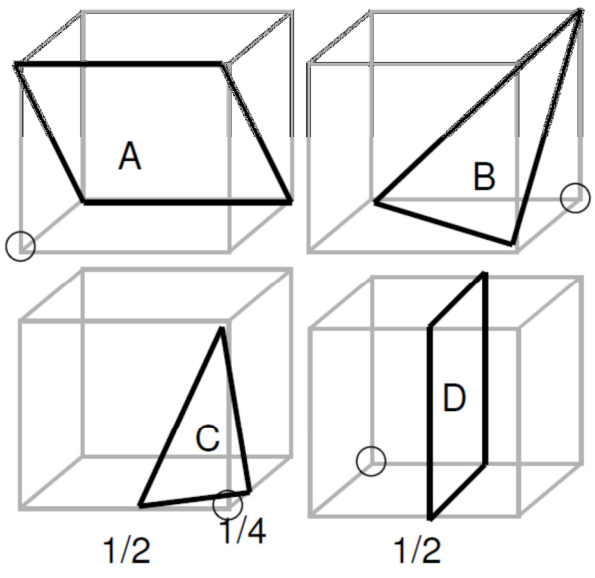
4. Water molecules have _____ dipole moments while the carbon tetrachloride molecules only have _____ dipole moments. (2pt) [permanent; temporary/induced]

5. _____ bond is the strongest type of secondary bond. [Hydrogen]

6. There are _____ (fill in a number) octahedral sites and _____ (fill in a number) tetrahedral sites in an FCC unit cell. (2pt) [4; 8]

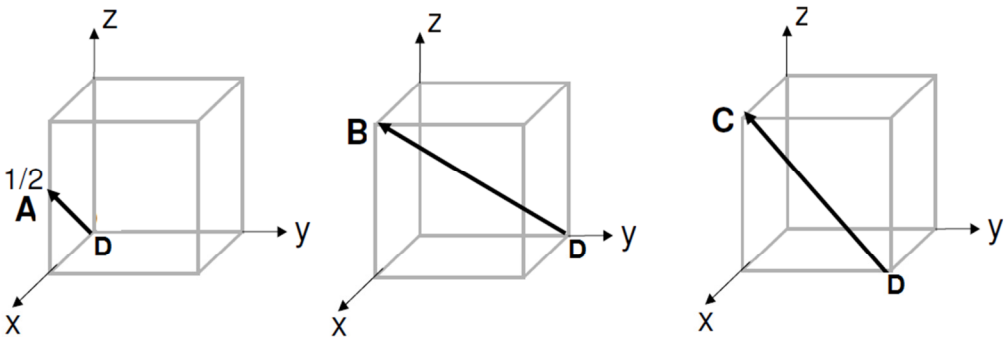
7. _____ is the ability of a solid material to exist in more than one form of crystal structure. [polymorphism]

3. Miller indices. (20 points)

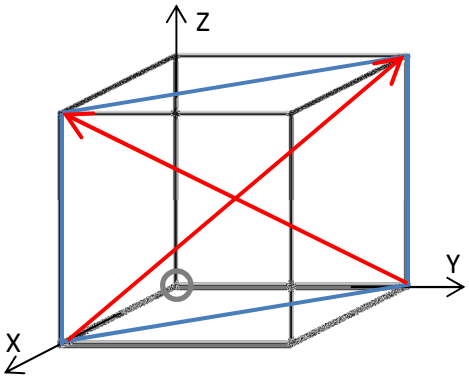


(a) For the figures on the left, define the coordinate system for each unit cube (clearly label x, y and z axes; the empty circles indicate the origin points) and determine the Miller indices for Planes A through D. (8 points)

[
One possible answer:
A: (0 1 1)
B: (1 1 1)
C: (2 4 1)
D: (0 2 0)
]



(b) For the unit cubes above and the axes as labeled, determine the Miller indices for direction DA, DB, and DC? (6 points)
[: A: [2 0 1]; B: [1 $\bar{1}$ 1]; C: [0 $\bar{1}$ 1]]

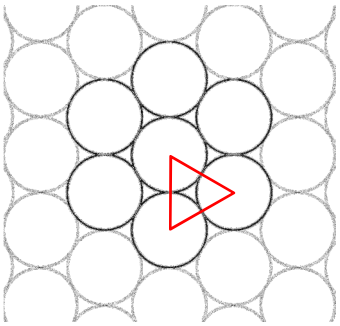


(c) In the unit cube, draw the (110) plane. Also draw two <111> directions within that plane.
(6 points)

4. Packing factors (15 points)

Packing factor, a dimensionless quantity, is defined as the ratio between the volume of the atoms in a unit cell and the volume of the unit cell for the three dimensional case. Volume is reduced to area for the two dimensional case.

(a) Calculate the packing factor for a two-dimensional system with hexagonal structure. Assume that atoms touch each other, so the lattice parameter a=2R. (5 pt)



[a = 2r; (1/2)*pi*r^2/(sqrt(3)/4*a^2) = 0.91]

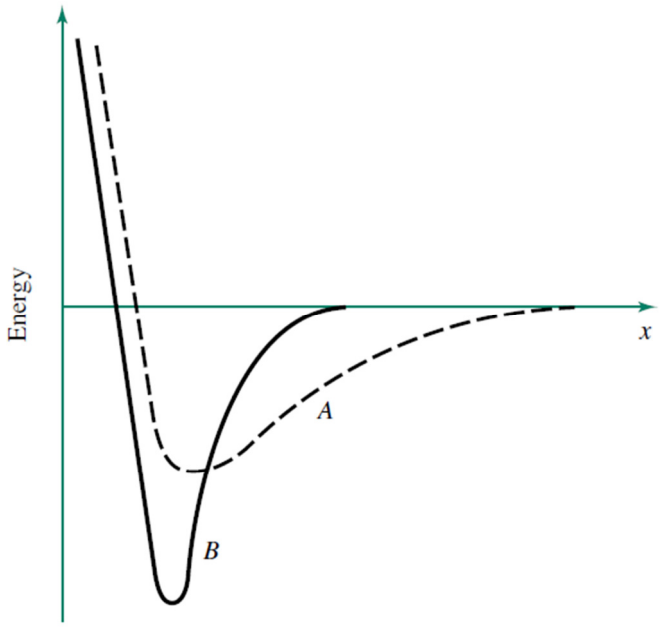
(b) Calculate the packing factor for FCC structure. (5 pt)

[sqrt(2)*a = 4 r; PF = 4*(4/3)*pi*r^3/a^3 = 0.74;]

(c) Calculate the packing factor for BCC structure. (5 pt)

[sqrt(3)*a = 4 r; PF = 2*(4/3)*pi*r^3/a^3 = 0.68;]

5. Bond Energy Curve (10 points)



The bond-energy curves for two engineering materials are shown in the figure.

(1) Which material is more suited to be used for a crucible for high-temperature applications? [B]

(2) Which material is more suited to be used as a structure material with minimal distortion when loaded? [B]

(3) Which material can better serve as a temperature sensor? [A]

(4) Which material has a higher vaporization temperature? [B]

(5) Which material has a larger Young's modulus? [B]

6. Electronic Configuration (10 points)

Determine the electronic configuration for the following atoms. The atomic number is given in the parentheses.

C (6) _____

Ar (18) _____

Ca (20) _____

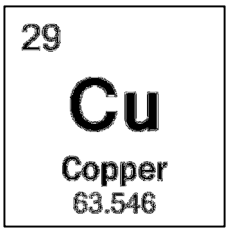
Br (35) _____

Cs (55) _____

[C: $1s^2\ 2s^2\ 2p^4$; Ar: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$; Ca: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$; Br: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^5$

Cs: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6 4d^{10}\ 5s^2\ 5p^6\ 6s^1$]

7. Calculate the mass density (10 points)



Calculate the mass density (unit: g/cm^3) of FCC copper based on the following parameters:

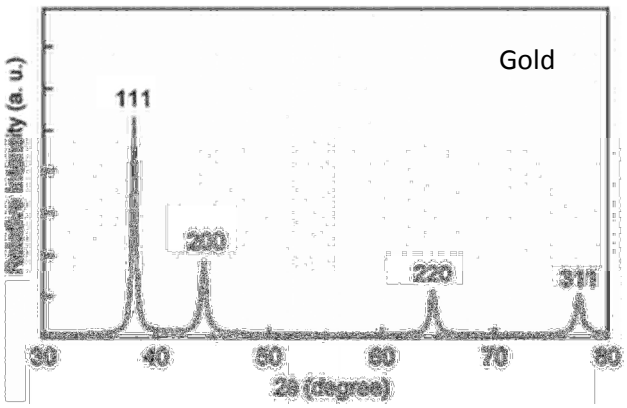
Atomic weight: 63.546 g/mol

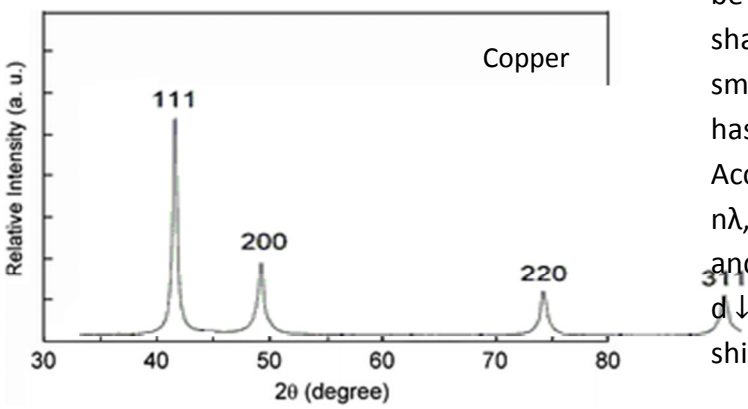
Atomic radius: 0.1278 nm

FCC $\Rightarrow$ 4 atoms/unit cell $FCC\ \_a_o\sqrt{2} = 4r\ \_a_o = 3.615A$

$$\rho = (Mass/Vol.)_{unit\ cell} = \frac{(4\ atoms\ x\ 63.55g/mole)/(6.023\ x\ 10^{23}\ atoms/mole)}{(3.615\ x\ 10^{-8}\ cm)^3} = 8.94g/cm^3$$

8. X-Ray Diffraction (10 points)





The figure shows the x-ray diffraction pattern of gold. Roughly sketch the x-ray diffraction pattern of copper.

Hint: Both gold and copper have the FCC crystal structure. The interplanar spacing in the two metals is of course different because they have different atomic radius. The atomic radii for gold and copper are 0.144 nm and 0.128 nm, respectively.

[The x-ray diffraction patters should be very similar, because Au and Cu share the same FCC structure. Cu has smaller atomic radius, and therefore has smaller d-spacing than Au. According to the Bragg law 2dsinθ = nλ, for the same x-ray wavelength and the same diffraction order, θ ↑ as d ↓. So the pattern should slightly shift to larger-θ side.]

$$2\theta_{Cu} = 2 \times \sin^{-1}\left(\frac{0.144}{0.128}\sin(\theta_{Au})\right)$$