APS104 s2015 Test test 1 answer key
QUESTION 1: Atomic Bonding and Crystal Structure (20 pts)
(a) Write out the electron configuration for the following elements:[4 pts]

Boron: $1s^2\, 2s^2\, 2p^1$ [1pt]

Potassium: $1s^2\, 2s^2\, 2p^6\, 3s^2\, 3p^6\, 4s^1$ [1pt]

Chromium: $1s^2\, 2s^2\, 2p^6\, 3s^2\, 3p^6\, 4s^2\, 3d^4$ OR $1s^2\, 2s^2\, 2p^6\, 3s^2\, 3p^6\, 4s^1\, 3d^5$ [2pt]

(b) The potential energy between $Mg^{2+}$ and $O^{2-}$ ions in a MgO crystal (NaCl crystal structure) can be estimated as $E = -\dfrac{A}{r} + \dfrac{B}{r^8}$

where $A = 1.61 \times 10^{-27}$ J m, $B = 3.87 \times 10^{-96}$ J m$^8$, $r$ is the separation (between ion centers) in m, and $E$ is the potential energy in J.

(i) Calculate the equilibrium separation between the ion centers. [5 pts]
2.12 x 10$^{-10}$ m

(ii) Calculate the bonding energy between the Mg and O ions at this equilibrium distance. [2 pts]
-4.14 eV

(iii) If the ionic radius of $Mg^{2+}$ is 0.072 nm, what is the ionic radius of $O^{2-}$ ? [2 pts]
0.14 nm

(iv) What is the lattice constant for MgO? [2 pts]
4.24 x 10$^{-10}$ m

(c) Each of the words or phases on the right is associated with one of the four types of bonding. Choose the most appropriate bonding type for each, and put the corresponding letter in the box. [5 pts]

A) Ionic

B) Covalent

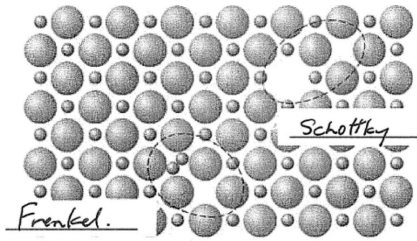C) Metallic

D) van del Waals

silicon

CsCl

Solid Argon

free electrons

nitrogen molecule

B A D C B

QUESTION 2: Crystal Structure and Defects (20 pts)

(a) Name the two defects in the ionic solid shown below [2 pts]



(b) What is the atomic density of copper, in atoms per $cm^3$? [2 pts]
Note: the density of Cu is 8.4 $g/cm^3$

| |
|---|
| 7.96 x $10^{22}$ $cm^{-3}$ |

(c)    Given that copper is FCC, what is the lattice constant?         [4 pts]

| |
|---|
| 3.69 x $10^{-10}$ m |

(d)    Given the the density of vacancies in a metal is given by:

$$N_v = Ne^{-Q/kT}$$        where N is the density of Cu atoms per $cm^3$, and Q = 0.9 eV is the activation energy for vacancy formation.

What is the density of vacancies in Cu at 1000°C?   [4 pts]

| |
|---|
| 2.18 x $10^{19}$ $cm^{-3}$ |

(e) At what temperature is one out of $10^4$ Cu atomic sites a vacancy?         [4 pts]

| |
|---|
| 1134K |

(f) **True / False, one point for each answer**         **[4 pts total]**

**Check one**
**T          F**

F          The tensile strength of an alloy is generally lower than that of either of the constituent pure elements.
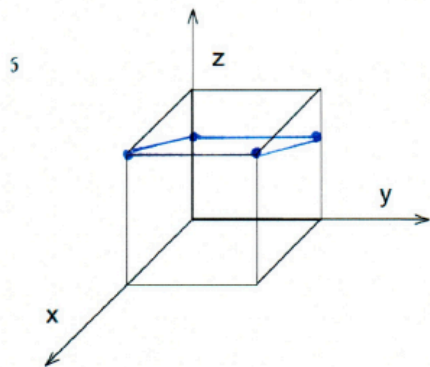
T          For a screw dislocation, the Burgers vector is parallel to the dislocation line.
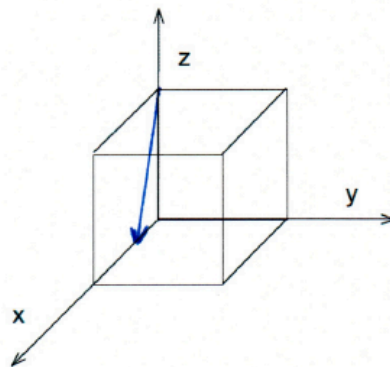
F          In the zincblende crystal structure, the coordination number of the cation and the anion are not the same.

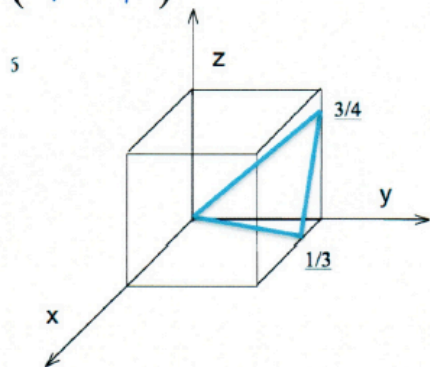a) In the cubic unit cell below sketch the $[10\bar{3}]$ plane. [2 pts]

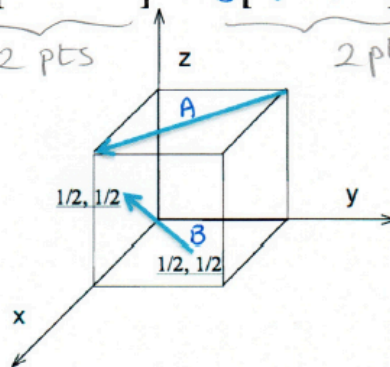b) In the cubic unit cell below sketch the $[10\bar{3}]$ direction. [2 pts]

c) In the cubic unit indicate the Miller indices of the plane shown. [2 pts]
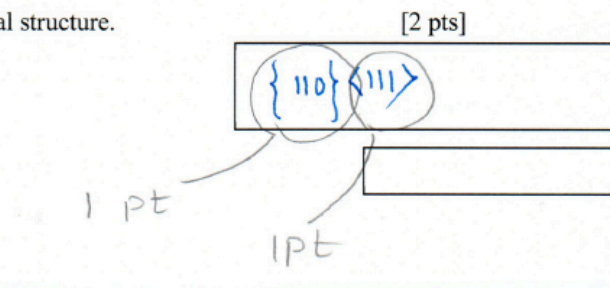
$(9\ \bar{3}\ 4)$

d) In the cubic unit cell below, specify the two directions marked. [4 pts]

A[ $1\bar{1}0$ ],    B[ $0\bar{1}1$ ]

2 pts            2 pts

Iron has a BCC crystal structure with a lattice parameter of 0.407 nm. For this unit cell:

e) Indicate the slip system for the iron crystal structure.    [2 pts]

$\{110\}\langle111\rangle$

1 pt          1pt

.

f) Calculate the planar density of the slip plane, in atoms per nm$^2$

8.54 atoms/nm$^2$

g) The linear density of atoms along the slip direction, in atoms per nm.
 2.84 atoms / nm


QUESTION 4:  Mechanical properties of materials (20 pts)
The stress strain profile of an isotropic material (Material A) with a diameter of 5.0 mm is shown in Figure 1.  The Poisson's ratio is 0.35.

4a. What is the Young's Modulus of this material?          [4 pts]

| |
|---|
| 150 GPa |

4b. Under a constant load, the cylinder diameter increases by $2 \times 10^{-3}$ mm. The deformation is elastic.

The stress is (circle the correct answer):      [2 pts]

| |
|---|
| **Compressive** |

4c.        Determine the load for question 4b:  [4 pts]

| |
|---|
| **3366N** |


4d. Show on Figure 1b how you would determine the 0.2 % offset yield strength. The 0.2% offset yield strength is____**370 MPa**___.  Show your answer on Figure 1b and fill in the box below to receive full credit.   [2pts]

4e) Classify the following Materials as corresponding to curves A, B, C. (circle one)   [2 pts each]
Ceramic (Ionic Material)                                        C
Polymer                                        B

4f) Circle the correct answer:  [2 pts]
        Material        B        has the highest ductility
4g)  Circle the correct answer: [2 pts]
        Material           C        has the highest toughness