NANYANG TECHNOLOGICAL UNIVERSITY
SCHOOL OF ELECTRICAL & ELECTRONIC ENGINEERING

ACADEMIC YEAR 2023
Term 1

H3 Semiconductor Physics & Devices

TUTORIAL 1

Crystal Structure

Question 1

Calculate the surface density of atoms on (111) and (110) planes for the following crystal structure. a) simple cubic, b) body-centered cubic, c) face-centered cubic. Assume the lattice constant is a.

[$1/(\sqrt{3}a^2)$, $1/(\sqrt{3}a^2)$, $4/(\sqrt{3}a^2)$]
[$\sqrt{2}/2a^2$, $\sqrt{2}/a^2$, $\sqrt{2}/a^2$]

Question 2

For the unit cell of the silicon crystal with lattice constant of 5.43 Å,

a) determine the number of atoms in the unit cell,
b) calculate the shortest distance between any two atoms,
c) calculate the volume density of silicon atoms (number of atoms/cm^3) in the crystal,
d) calculate the mass density of silicon, given that the atomic weight of silicon is 28.09 and Avogadro's number is 6.02×10^{23} atoms or molecules/mole.
e) calculate the density of valence electrons in silicon.

[8, 2.35 Å, 5.0×10^{22} atoms/cm^{-3}, 2.33 g/cm^3, 2.0×10^{23} cm^{-3}]

Question 3

The lattice constant of GaAs is 5.65 Å,

a) determine the number of Ga atoms and As atoms per cm^3.
b) calculate the mass density of GaAs crystal, given that the atomic weights of Ga and As are 69.7 and 74.9 respectively.
c) calculate the density of valence electron in GaAs.

[2.22×10^{22} atoms/cm^3, 5.33 g/cm^3, 1.78×10^{23} electrons/cm^3]

Question 4

Assume that each atom is a hard sphere with the surface of each atom in contact with the surface of its nearest neighbor. Determine the percentage of total unit cell volume that is occupied in a (a) simple cubic lattice, and (b) face-centered cubic lattice.

[52.4%, 74%]

Question 5

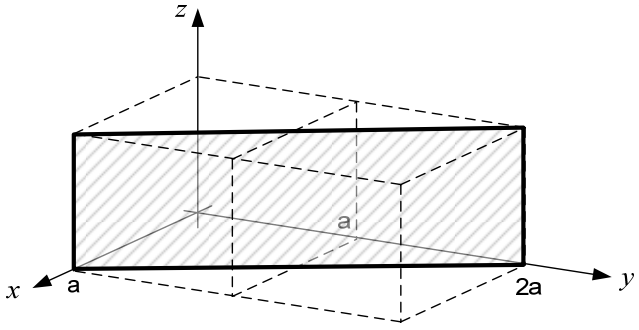
The lattice constant of a body-centered cubic structure is 4 Å. Calculate the surface density of atoms for (a) a (100) plane and (b) a (110) plane.

[6.25×10^{14} /cm^2, 8.84×10^{14} /cm^2]

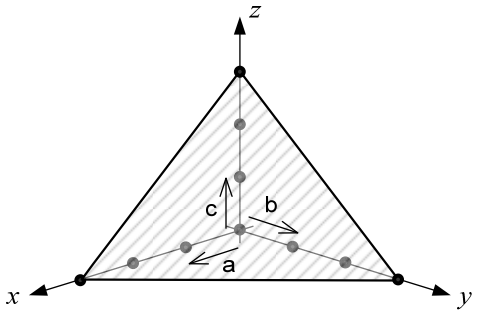
Question 6

Determine the Miller indices of the planes illustrated in the following figures:

a)



b)



Question 7

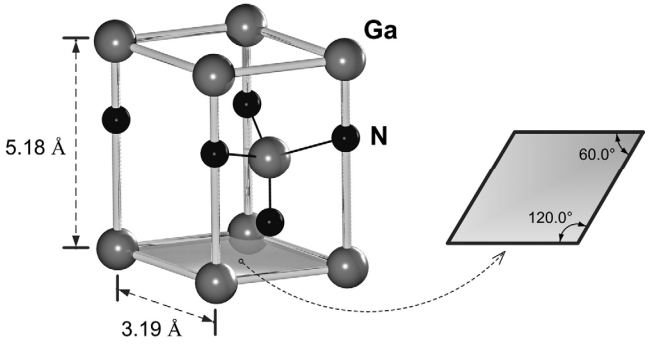
Sketch the crystal plane indicated by the following Miller indices:

a) (2 1 4)

b) (2 3 3)

Question 8

The figure below shows the unit cell of the GaN crystal, a wide bandgap III-V semiconductor that is used in blue and white LEDs. The unit cell depicts a wurtzite lattice with a pair of Ga and N atoms, i.e. basis of two atoms, located at each lattice point. The top and bottom planes are rhombuses with internal angles given in the figure. The atomic weights of Ga and N are 69.72 and 14.01 respectively.



(a) Determine the volume density of Ga and N atoms (in units of atoms/cm^3) in the semiconductor.

(b) Hence calculate the mass density of GaN (in units of g/cm^3).

[(a) 4.381×10^{22} cm^{-3}, (b) 6.092 g/cm^3]