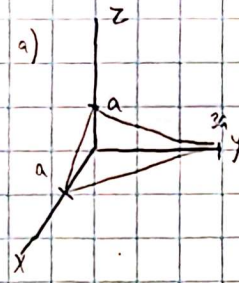
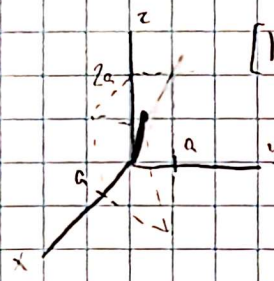
Homework 1 - ECE 3030

1) a)



x	y	z
	3	
	$\frac{1}{3}$	

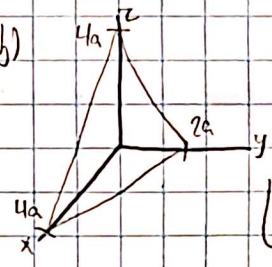
$\boxed{(3\ 1\ 3)}$



[1 1 2]

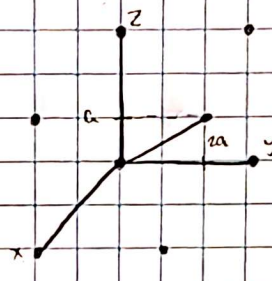
head to draw 3D :)

b)



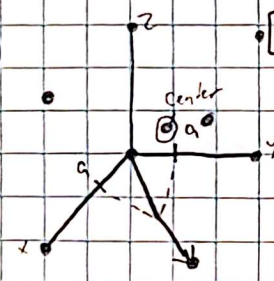
x	y	z
4	2	4
$\frac{1}{4}$	$\frac{1}{2}$	$\frac{1}{4}$

$\boxed{(1\ 2\ 1)}$



[0 2 1]

2)



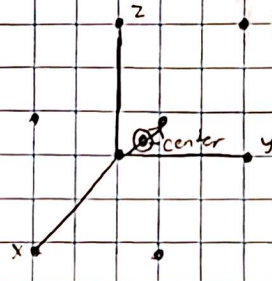
[1 1 0]

Linear Density

$\lambda = \frac{N}{L} = \frac{1}{\sqrt{2}a} = \frac{1}{\sqrt{2}} \cdot \frac{1}{\frac{4}{\sqrt{3}}R} = \boxed{\frac{\sqrt{3}}{\sqrt{2}\,4R}}$

$N = \frac{1}{2} \cdot \frac{1}{2} = 1 \qquad a = \frac{4}{\sqrt{3}}R$

$L = \sqrt{a^2 + a^2} = \sqrt{2}\,a$



[1 1 1]

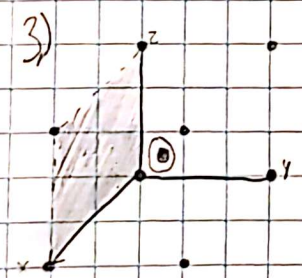
Linear Density

$\lambda = \frac{N}{L} = \frac{2}{\sqrt{3}a} = \frac{2\sqrt{3}}{4\sqrt{3}R} = \boxed{\frac{1}{2R}}$

$N = 1 + \frac{1}{2} + \frac{1}{2} = 2 \qquad a = \frac{4}{\sqrt{3}}R$

$L = \sqrt{a^2 + (\sqrt{2}a)^2} = \sqrt{3}\,a$

3)

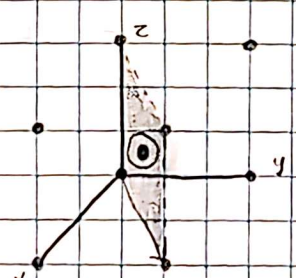


(1 0 0)

$\text{area} = a \cdot a = a^2$

$4 \cdot \frac{1}{4} = 1$

$\boxed{\frac{1}{a^2}\ cm^{-2}}$



(1 1 0)

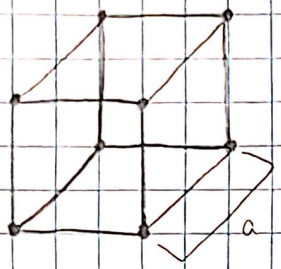
$\sqrt{2}a \cdot a = \sqrt{2}a^2$

$1 + 4 \cdot \frac{1}{4} = 2$

$\boxed{\frac{2}{\sqrt{2}a^2}\ cm^{-2}}$

4)

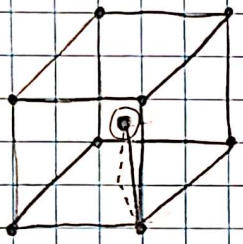
SC

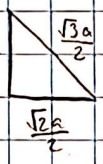


$8 \cdot \frac{1}{8} =$ 1 atom per cell

nearest neighbor distance: a

BCC

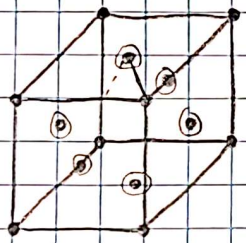


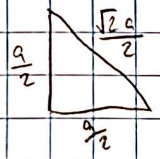


$1 + 8 \cdot \frac{1}{8} =$ 2 atoms per cell

nearest neighbor: $\frac{\sqrt{3}a}{2}$

FCC





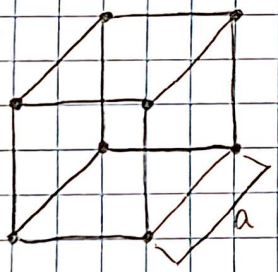
$6 \cdot \frac{1}{2} + 8 \cdot \frac{1}{8} =$ 4 atoms per cell

nearest neighbor: $\frac{\sqrt{2}a}{2}$

Lattice Constant - radius (r) = 1.95 Å

5) a)

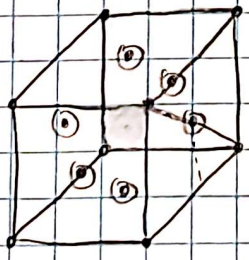
SC

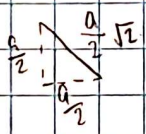


$a = 2r = 2 \cdot 1.95 =$ 3.9 Å

b)

FCC

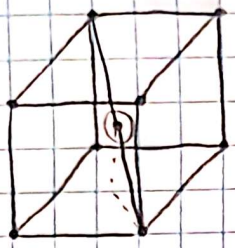


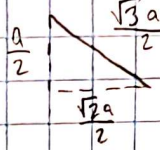


$\frac{\sqrt{2}a}{2} \cdot 2 = \sqrt{2}a = 4R$

$a = \frac{4R}{\sqrt{2}} = \frac{4 \cdot 1.95}{\sqrt{2}} =$ 5.515 Å

c)

BCC 



$2 \cdot \frac{\sqrt{3}a}{2} = \sqrt{3}a = 4R$

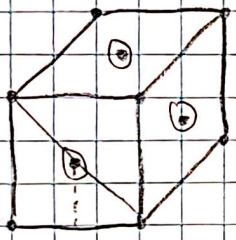
$a = \frac{4R}{\sqrt{3}} = \frac{4 \cdot 1.95}{\sqrt{3}} = \boxed{4.503\ \text{Å}}$

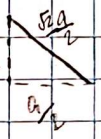
d) Diamond Lattice

$\frac{\sqrt{3}a}{4} = 2R \qquad a = \frac{8R}{\sqrt{3}} = \frac{8 \cdot 1.95}{\sqrt{3}} = \boxed{9.006\ \text{Å}}$

(6) Germanium = 5.65 Å = a

a) Distance from center Ge atom to center nearest neighbor

FCC 



$2R = \frac{\sqrt{3}a}{4} \qquad R = \frac{\sqrt{3}a}{8} = \frac{\sqrt{3} \cdot 5.65}{8} = 1.223\ \text{Å}$

$1.223 \cdot 2 = \boxed{2.446\ \text{Å}}$

b) # density of Ge

$FCC \cdot 2 = (\frac{1}{8} \cdot 8 + \frac{1}{2} \cdot 6) \cdot 2 = (1+3) \cdot 2 = 8$

$5.65^3 = 180.362\ \text{Å} \qquad \text{density} = \frac{8}{180.362} = \boxed{4.435 \times 10^{-22}\ \frac{\text{atoms}}{\text{cm}^3}}$

c) Mass density of Ge

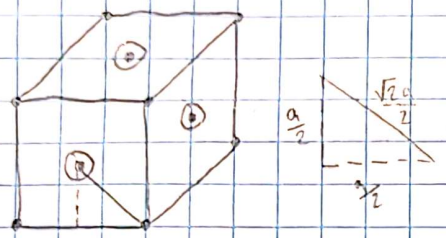
mass per Ge atom = 72.64 g/mol

$\text{mass of atom} = \frac{\text{mol}}{\text{avog.}} = \frac{72.64}{6.022 \times 10^{23}} = 1.21 \times 10^{-22}\ \text{g}$

$\text{density} = \text{atom density} \cdot \text{mass} = 4.435 \cdot 1.21 \times 10^{-22}$

$= \boxed{5.37 \times 10^{-22}\ \text{g/cm}^3}$

7) lattice constant of silicon $a = 5.43\,\text{Å}$



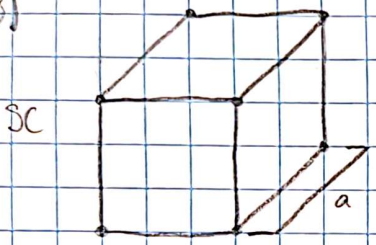
2 FCC per unit cell vol of cell $= a^3 = 5.43^3 = 160.103\,\text{Å}$

4 valence electrons per atom

$2 \cdot FCC = 8$ atoms 4 electrons per atom $= 32$ electrons

$$\text{density of } e^- = \frac{e^- \text{ per cell}}{\text{Volume of cell}} = \frac{32}{160.103 \times 10^{-24}} = \boxed{1.9987 \cdot 10^{25}\ e^-/cm^3}$$

8)



Atomic weight $= 35.2$ g/mol

density $= 3.65$ g/cm^3

$a = 2r$ $r = \frac{a}{2}$ $\rho = \frac{nA}{V_c N_a}$

$$V_c = a^3 = \frac{nA}{\rho N_a} = \frac{1 \cdot 35.2}{3.65 \cdot 6.022 \times 10^{23}} = a^3 = 1.6014 \times 10^{-23} \quad a = \sqrt{1.6014 \times 10^{-23}} = 2.53\,\text{Å}$$

$$r = \frac{a}{2} = \frac{2.53}{2} = \boxed{1.265\,\text{Å}}$$

9) Composition of $AlSb_xAs_{1-x}$ to lattice match InP

$a_{lattice} = 5.85\,\text{Å}$

Vegard's law: $a_{A(1-x)B_x} = (1-x) \cdot a_A + x a_B$

$a_{AlAs} = 5.67$

$a_{AlSb} = 6.13$

$$a_{alloy} = (1-x) \cdot a_{AlAs} + x a_{AlSb}$$

$$5.85 = 5.67 - 5.67x + 6.13x \rightarrow 0.18 = 0.46x \rightarrow \boxed{x = 0.3913}$$ composition

Band Gap $E_g(x) = (1-x)\,E_g(AlAs) + x\,E_g(AlSb) - bx(1-x)$

AlAs = 2.16 ev

AlSb = 1.58 ev

b = 0.7 ev

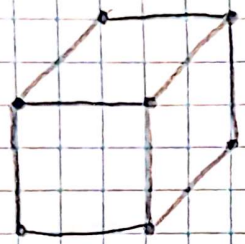
x = 0.3913

$$E_g(0.3913) = (0.6086)\,2.16 + (0.3913)\,1.58 - 0.27391(0.6086)$$

$$E_g(0.3913) = \boxed{1.71\ eV}$$

10)

SC



atomic weight = 35.2 g/mol

atomic density = 3.65 g/cm^3

$$r = \left(\frac{3}{4\pi} \cdot \frac{A}{\rho N_A}\right)^{\frac{1}{3}} = \left(\frac{3}{4\pi} \cdot \frac{35.2}{3.65 \cdot 6.022 \times 10^{23}}\right)^{\frac{1}{3}}$$

$$\boxed{r = 1.5637 \text{ cm}}$$