Equation of plane
\[ \vec{r} \cdot \vec{n} = d \]
\( \vec{r} \) is any point on the plane
\( \vec{n} \) is a unit vector normal to the plane
\( d \) is the distance from the origin to the plane

Let \( \vec{n} \parallel [h \ k \ l] \)
\[ \vec{r} \cdot \vec{n} = hx + ky + lz + d \]
intercepts are: \( \frac{1}{h}, \frac{1}{k}, \frac{1}{l} \)

\[ \Rightarrow (h \ k \ l) \ \text{is the plane} \]

\[ \Rightarrow [h \ k \ l] \parallel \vec{n}, (h \ k \ l) \]
(a) (0 0 1)

(b) (1 1 1)

(c) (1 2 3)

(d) (1 1 0)
(f) \( (1 \ T \ T) \)

\[ z \]
\[ -a \]
\[ -a \]

(g) \( (2 \ 2 \ 1) \)

\[ z \]
\[ 2a \]
\[ a \]

(h) \( (0 \ T \ 0) \)

\[ z \]
\[ -a \]
\[ -a \]
(a) \([010]\)
(b) \([101]\)
(c) \([001]\)
(d) \([101]\)
(e) \([001]\)
(f) \([110]\)
1.9 (a) Let's assume that \([h \ k \ l]\) is perpendicular to \([1 \ 0 \ 0]\).

Then the dot product of \([h \ k \ l]\) and \([1 \ 0 \ 0]\) is zero.

\[h \cdot 1 + k \cdot 0 + l \cdot 0 = 0\]

\[\Rightarrow h = 0\]

\[\therefore [h \ k \ l] \perp [1 \ 0 \ 0]\]

Any direction of this form \([h \ k \ l]\) is perpendicular to \([1 \ 0 \ 0]\).

Eg: \([0 \ 1 \ 0], [0 \ 0 \ 1], [0 \ 0 \ 1]\]
1.9 (b) Assuming \([h k l] \perp [1 1 1]\)

then the dot product of \([h k l] \& [1 1 1]\) is zero

i.e. \(h + k + l = 0\)

when \(h = x\) then \(k + l = -x\)
\(k = x\) then \(h + l = -x\)
\(l = x\) then \(h + k = -x\)

Any direction satisfying the above conditions is \(\perp\) to \([1 1 1]\)

Example: \([1 7 0]\), \([2 1 7]\), \([1 0 7]\)

\([0 1 7]\)

5. (i) The directions in \(<1 1 0>\) are \([0 1 1]\), \([1 0 1]\), \([1 1 0]\),
\([0 1 1]\), \([1 0 1]\), \([1 1 0]\), \([0 1 1]\), \([1 0 1]\), \([1 1 0]\), \([0 1 1]\), \([1 0 1]\), \([1 1 0]\), \([0 1 1]\), \([1 0 1]\), \([1 1 0]\)

assume \([h k l] \perp\) to \([0 0 1]\)

\(\Rightarrow\) the dot product of \([h k l] \& [0 0 1]\) is zero

\(h \cdot 0 + k \cdot 0 + l \cdot 1 = 0\)

\(\Rightarrow l = 0\)

Any direction of this form \([h k 0]\) is perpendicular to \([0 0 1]\)
The directions \( \langle 110 \rangle \) that are perpendicular to \([0 0 1]\) are
\[
[1 \ 1 \ 0] \ [1 \ 1 \ 0] \ [1 \ 1 \ 0] \ [1 \ 1 \ 0]
\]

(i) Assume \([h \ k \ l]\) is \( \perp \) to \([1 \ 1 \ 0]\)
\[
h \cdot 1 + k \cdot 1 + l \cdot 0 = 0
\]
\[
h + k = 0
\]
\[
\Rightarrow k = -h \quad \text{or} \quad h = -k
\]
\[\text{i.e.} \quad k = \overline{h}\]
\[\therefore \quad \text{The directions in the } \langle 110 \rangle \text{ that are perpendicular to } [1 \ 1 \ 0] \text{ will be in the form of } [h \ \overline{h} \ 0]
\]
\[\text{i.e. } [1 \ T \ 0] \ \text{ and } [1 \ 1 \ 0]
\]

(ii) Assume \([h \ k \ l]\) is \( \perp \) to \([1 \ 1 \ 1]\)
\[
h + k + l = 0
\]
\[
\text{But the directions in } \langle 110 \rangle \text{ that are } \perp \text{ to } [1 \ 1 \ 1]
\]
\[
\Rightarrow \begin{align*}
& i f \ l = 0, \ h + k = 0; \\
& i f \ k = 0, \ h + l = 0; \\
& i f \ h = 0, \ l + k = 0
\end{align*}
\]
\[\therefore \quad \text{the directions are } [1 \ T \ 0], [1 \ 1 \ 0], [1 \ 0 \ 1], [1 \ 0 \ 1], [0 \ T \ 1], \text{ and } [0 \ 1 \ T]
\]
Angle between $[0\ 1\ 1]$ and $[0\ 0\ 1]$ is $45^\circ$

It can be seen that it is a simple cubic lattice.

(b) Number of atoms per unit volume in the crystal is $1\ \text{atom}/a^3$.

(c) Number of atoms per unit area

$$\text{No. of atoms per unit area} = \frac{1\ \text{atom}}{(a \times \sqrt{2}a)} = \frac{1\ \text{atom}}{a^2 \sqrt{2}}$$
The direction of the vector from the origin through the center of the atom is \([1 \ 1 \ 1]\).

Packaging density = \(\frac{\text{Volume occupied by the atoms}}{\text{Total available Volume}}\)

Total available Volume = \(a^3\)

Volume occupied by the atoms = \(\frac{4}{3} \pi \gamma^3\)

\(\gamma = \text{radius of the atom}\)

<table>
<thead>
<tr>
<th>Structure</th>
<th>Radius</th>
<th>Packaging density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple Cubic</td>
<td>(\frac{a}{2})</td>
<td>(\frac{\pi}{6} \times 100 = 52%)</td>
</tr>
<tr>
<td>Body Centered Cubic</td>
<td>(\frac{\sqrt{3}}{4} a)</td>
<td>(\frac{\pi \sqrt{3}}{8} \times 100 = 68%)</td>
</tr>
<tr>
<td>Face Centered Cubic</td>
<td>(\frac{\sqrt{2}}{4} a)</td>
<td>(\frac{\pi \sqrt{2}}{6} \times 100 = 74%)</td>
</tr>
<tr>
<td>Diamond</td>
<td>(\frac{\sqrt{3}}{8} a)</td>
<td>(\frac{\pi \sqrt{3}}{16} \times 100 = 34%)</td>
</tr>
</tbody>
</table>
Solution to problem 2-1
Eg versus T
Parameters

EGO = 1.170;
a = 4.730e-4;
b = 636;

Parabolic Computation and plotting

T = [0:5:600];
EG = EGO - a.* (T.^2) ./ (T+b);
EG300_P = EGO - a.* (300^2) ./ (T+b);

No semicolon, displays the value of EG300_p

plot(T, EG)
axis([0 600 1.0 1.2]);

Display options
grid;

xlabel('T(k)'); ylabel('EG(ev)');
title('PLOT VERSUS TEMPERATURE --- (Prob2.1)');
text(20, 1.15, 'Parabolic Comp');
text(120, 1.18, 'Linear Comp');

hold on

Linear Computation and Plotting
EGO = 1.205;
a = 2.8e-4;
EG = EGO - a.*T;
EG300_L = EGO - a.*300
plot(T, EG, 'k-.')

hold off
PLOT VERSUS TEMPERATURE --- (Prob2.1)

Linear Comp

Parabolic Comp
Ga has 3 valence electrons removing that results in 5 dangling bonds.

As has 5 valence electron removing that we have 3 dangling bonds.

(c) n-Type. Since Ga has 3 valence electrons, while Si has 4 valence electrons. So when a Si atom replaces a Ga atom, there results in an extra electron, which increases the electron concentration.
(d) P-type. Since a bond is missing when As is replaced by Si, which increases the hole concentration.

(e) (i) \[ \text{E}_c \quad \text{E}_F \quad n\text{-type} \]

\[ \text{E}_i \quad \text{E}_V \]

(ii) \[ \text{E}_c \quad \text{P-type} \]

\[ \text{E}_i \quad \text{E}_F \quad \text{E}_V \]