1.解：在[100]处导带底

$$\therefore m_n^* = \begin{pmatrix} m_{nx}^* & 0 & 0 \\ 0 & m_{ny}^* & 0 \\ 0 & 0 & m_{nz}^* \end{pmatrix}, \ m_{nx}^* \sim 0.92m,\ m_{ny}^* = m_{nz}^* \sim 0.19m$$

[110]：

$$\vec{F} = \begin{pmatrix} \frac{\sqrt{2}}{2}F \\ \frac{\sqrt{2}}{2}F \\ 0 \end{pmatrix}$$

$$\vec{a} = \begin{pmatrix} \frac{\sqrt{2}}{2}F/m_{nx}^* \\ \frac{\sqrt{2}}{2}F/m_{ny}^* \\ 0 \end{pmatrix} = \begin{pmatrix} \frac{\sqrt{2}F}{1.84m} \\ \frac{\sqrt{2}F}{0.38m} \\ 0 \end{pmatrix}$$，电场力和加速度不同向

$$|\vec{a}| = \frac{\sqrt{2}F}{m}\sqrt{\frac{1}{1.84^2}+\frac{1}{0.38^2}} = 3.8\frac{F}{m}$$

[011]：

$$\vec{F} = \begin{pmatrix} 0 \\ \frac{\sqrt{2}}{2}F \\ \frac{\sqrt{2}}{2}F \end{pmatrix},\ \vec{a} = \begin{pmatrix} 0 \\ \frac{\sqrt{2}}{2}F/m_{ny}^* \\ \frac{\sqrt{2}}{2}F/m_{nz}^* \end{pmatrix} = \begin{pmatrix} 0 \\ \frac{\sqrt{2}F}{0.38m} \\ \frac{\sqrt{2}F}{0.38m} \end{pmatrix}$$ 电场力和加速度同向

$$|\vec{a}| = \frac{F}{0.19m} = 5.26\frac{F}{m}$$

[111]：

$$\vec{F} = \begin{pmatrix} \frac{\sqrt{3}}{3}F \\ \frac{\sqrt{3}}{3}F \\ \frac{\sqrt{3}}{3}F \end{pmatrix},\ \vec{a} = \begin{pmatrix} \frac{\sqrt{3}}{3}F/m_{nx}^* \\ \frac{\sqrt{3}}{3}F/m_{ny}^* \\ \frac{\sqrt{3}}{3}F/m_{nz}^* \end{pmatrix} = \begin{pmatrix} \frac{\sqrt{3}F}{2.76m} \\ \frac{\sqrt{3}F}{0.57m} \\ \frac{\sqrt{3}F}{0.57m} \end{pmatrix}$$ 电场力和加速度不同向

$$|\vec{a}| = \frac{\sqrt{3}F}{m}\sqrt{\frac{1}{2.76^2}+\frac{1}{0.57^2}+\frac{1}{0.57^2}} = 4.34\frac{F}{m}$$

$\therefore a_1 : a_2 : a_3 = 3.8 : 5.26 : 4.34 = 190 : 263 : 217$

~~电场力和加速度在同一方向，均不在同一方向~~

2.解：

$$m_n^* = \begin{pmatrix} m_{nl}^* & 0 & 0 \\ 0 & m_{nt}^* & 0 \\ 0 & 0 & m_{nt}^* \end{pmatrix},\ m_{nl}^* \sim 1.64m,\ m_{nt}^* \sim 0.08m$$

三个轴为[111]方向和[1$\bar{1}$0]、[11$\bar{2}$]方向

$$m_n^* \cdot \vec{v} = \hbar(\vec{k}-\vec{k_0})$$

$$\vec{v} = \begin{pmatrix} v_x \\ v_y \\ v_z \end{pmatrix},\ m_n^* \cdot \vec{v} = \begin{pmatrix} m_{nl}^* v_x \\ m_{nt}^* v_y \\ m_{nt}^* v_z \end{pmatrix} = \begin{pmatrix} 1.64m v_x \\ 0.08m v_y \\ 0.08m v_z \end{pmatrix}$$

1° [100]

~~$\hbar(\vec{k}-\vec{k_0}) = \hbar k$~~

$$\vec{k}-\vec{k_0} = k\begin{pmatrix} \frac{\sqrt{3}}{3} \\ \frac{\sqrt{2}}{2} \\ \frac{\sqrt{6}}{6} \end{pmatrix}$$

$$\therefore v_x = \frac{\hbar k}{1.64\sqrt{3}m},\ v_y = \frac{\hbar k}{0.08\sqrt{2}m},\ v_z = \frac{\hbar k}{0.08\sqrt{6}m}$$

$v = 10.21\frac{\hbar k}{m}$，$\vec{v}$与$\vec{k}-\vec{k_0}$不同向

2° [110]

$$\vec{k}-\vec{k_0} = k\begin{pmatrix} \frac{\sqrt{6}}{3} \\ 0 \\ \frac{\sqrt{3}}{3} \end{pmatrix}$$

$\therefore v_x = \frac{\sqrt{2}\hbar k}{1.64\sqrt{3}m},\ v_y = 0,\ v_z = \frac{\hbar k}{0.08\sqrt{3}m}$ $\vec{v}$与$\vec{k}-\vec{k_0}$不同向

$\therefore v = 7.23\frac{\hbar k}{m}$

3° [1$\bar{1}$0]

$$\vec{k}-\vec{k_0} = k\begin{pmatrix} 0 \\ -1 \\ 0 \end{pmatrix}$$

$\therefore v_x = 0,\ v_y = -\frac{\hbar k}{0.08m},\ v_z = 0$，$\vec{v}$与$\vec{k}-\vec{k_0}$同向

$\therefore v = 12.5\frac{\hbar k}{m}$

4° [111]

$$\vec{k}-\vec{k_0} = k\begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix}$$

$\therefore v_x = \frac{\hbar k}{1.64m},\ v_y = 0,\ v_z = 0$，$\vec{v}$与$\vec{k}-\vec{k_0}$同向

$\therefore v = 0.61\frac{\hbar k}{m}$

$\therefore v_1 : v_2 : v_3 : v_4 = 10.21 : 7.23 : 12.5 : 0.61$

3.解: $\cancel{DOS_h = \frac{L^3 m_{dp}^{*}\sqrt{2m_{dp}^{*}(E(k_0)-E)}}{\pi^2\hbar^3}}$ $E(\vec{k}) \sim E(\vec{k_0}) - (\vec{k}-\vec{k_0})\cdot\frac{\hbar^2}{2} m_p^{*-1}\cdot(\vec{k}-\vec{k_0})$

$\Delta k = \frac{2\pi}{L}$, $\left|\frac{dZ}{dk^3}\right| = \left(\frac{1}{\Delta k}\right)^3 = \frac{L^3}{8\pi^3}$

$k = |\vec{k}| = \frac{\sqrt{2m(E(\vec{k_0})-E)}}{\hbar}$

$\Delta V = \frac{4}{3}\pi\sqrt{\frac{m_p^{*3}}{m^3}}\left((k+dk)^3 - k^3\right) = 4\pi\sqrt{\frac{m_p^{*3}}{m^3}}\, k^2 dk$

$\left|\frac{dE}{dk}\right| = \frac{\hbar^2 k}{m}$

$|dZ| = 2\cdot\frac{L^3}{8\pi^3}\cdot 4\pi\sqrt{\frac{m_p^{*3}}{m^3}}\, k^2 |d|k||$

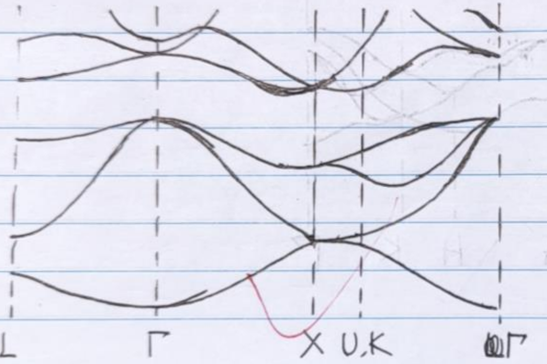
$DOS = \left|\frac{dZ}{dE}\right| = \frac{L^3 \sqrt{2m_p^{*3}(E(\vec{k_0})-E)}}{\pi^2\hbar^3}$

$\therefore \frac{n_{ph}}{n_{pl}} = \frac{DOS_{ph}}{DOS_{pl}} = \sqrt{\frac{m_{ph}^{*3}}{m_{pl}^{*3}}} = \sqrt{\frac{0.4^3}{0.016^3}} = 125$

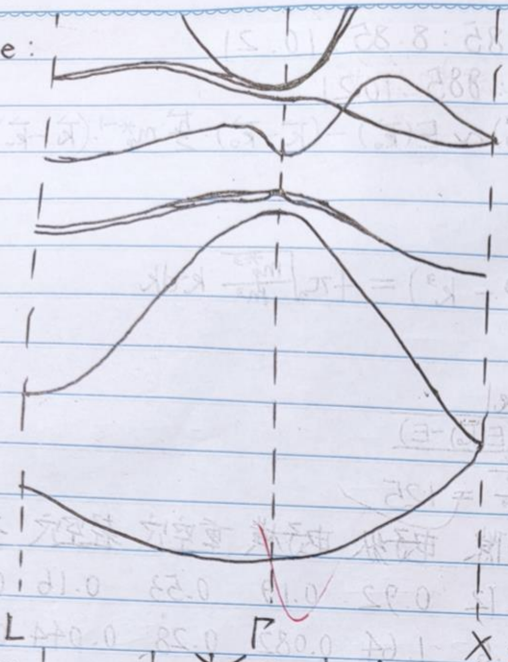
4.解:

	导带底	价带顶	带隙	电子纵	电子横	重空穴	轻空穴	3号带
Si	ΓX某处	Γ	1.12	0.92	0.19	0.53	0.16	0.245
Ge	L	Γ	0.6	1.64	0.082	0.28	0.044	0.077
GaAs	Γ	Γ	1.42	0.063		0.50	0.076	远离
GaN	Γ	Γ	3.39	0.20		1.4	0.3	0.6

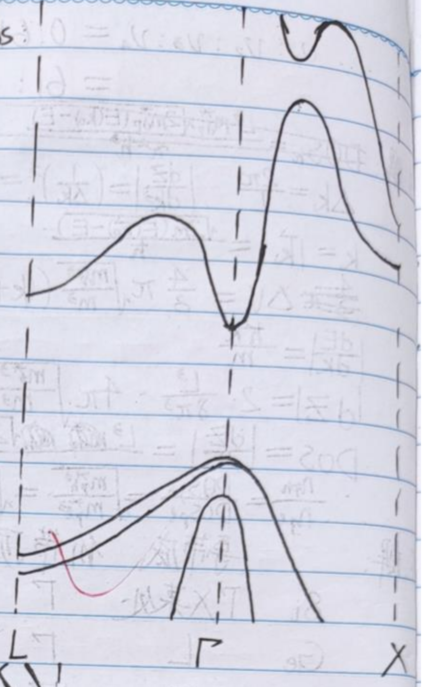
Si:



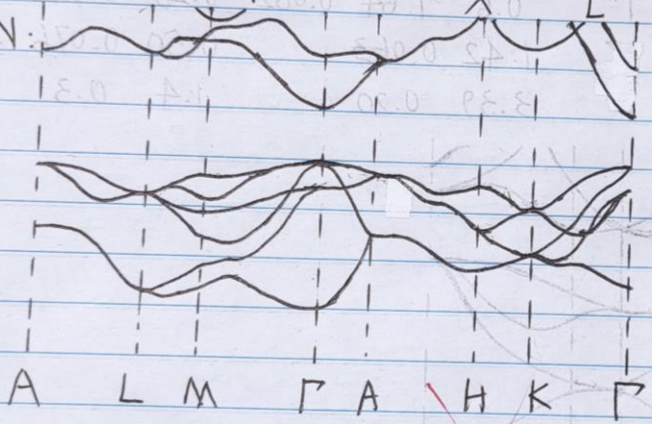
Ge:



GaAs:



GaN:



5.解：已知 InSb 带隙为 0.18eV
∵ CdTe 相对于 InSb 共价键极性增大
∴ 近邻原子波函数交叠减少，能带展宽减小，带隙变大
∵ HgTe 相对于 CdTe 原子序数增大，近邻原子波函数交叠增多，能带展宽增大，带隙变小，且影响比共价键极性影响更大，使能隙小于0
"负能隙"材料不是半导体

6.解：ZnO 中价带以 O 原子轨道为主，导带以 Zn 原子轨道为主
O 原子序数小，原子波函数交叠少，能带展宽小，故空穴有效质量大，空穴比电子难以移动，很难导电

7.解：[100]：等能面中回旋轨道大小相同，有1个峰
[110]：等能面中有2种回旋轨道大小，有2个峰
[111]：等能面中有2种回旋轨道大小，有2个峰
∵ Ge 价带顶各向同性
∴ 等能面为球面
∴ 仅有1种回旋轨道
∴ 重空穴有1个峰

空穴有两种等能面（轻空穴，重空穴），所以 B 沿任意方向都有2个峰。

8.解：GaN 带隙为 3.39eV，Si 带隙为 1.12eV
可见光能量为 $h\nu$，范围为 1.57eV～3.10eV
∴ GaN 不吸收任何光，透明
Si 可吸收部分光，不透明
∵ GaP 带隙为 2.3eV ∴ 频率大于 $5.56\times10^{14}Hz$ 的光被吸收
∴ 绿、蓝、紫光被吸收
∴ 为橙色

10