Chapter 3

Problem Solutions

3.1 If a_- were to increase, the bandgap energy would decrease and the material would begin to behave less like a semiconductor and more like a metal. If a_- were to decrease, the bandgap energy would increase and the material would begin to behave more like an insulator.

3.2

Schrodinger's wave equation

$$\frac{-\hbar^2}{2m}\cdot\frac{\partial^2\Psi(x,t)}{\partial x^2}+V(x)\cdot\Psi(x,t)=j\hbar\frac{\partial\Psi(x,t)}{\partial t}$$

Let the solution be of the form

$$\Psi(x,t)=u(x)\exp\left[j\left(kx-\left(\frac{E}{\hbar}\right)t\right)\right]$$

Region I, $V(x)=0$, so substituting the proposed solution into the wave equation, we obtain

$$\frac{-\hbar^2}{2m}\cdot\frac{\partial}{\partial x}\left\{\ jku(x)\exp\left[j\left(kx-\left(\frac{E}{\hbar}\right)t\right)\right]+\frac{\partial u(x)}{\partial x}\exp\left[j\left(kx-\left(\frac{E}{\hbar}\right)t\right)\right]\right\}=j\hbar\left(\frac{-jE}{\hbar}\right)\cdot u(x)\exp\left[j\left(kx-\left(\frac{E}{\hbar}\right)t\right)\right]$$

which becomes

$$\frac{-\hbar^2}{2m}\left\{\ (jk)^2u(x)\exp\left[j\left(kx-\left(\frac{E}{\hbar}\right)t\right)\right]+2jk\frac{\partial u(x)}{\partial x}\exp\left[j\left(kx-\left(\frac{E}{\hbar}\right)t\right)\right]+\frac{\partial^2u(x)}{\partial x^2}\exp\left[j\left(kx-\left(\frac{E}{\hbar}\right)t\right)\right]\right\}=+Eu(x)\exp\left[j\left(kx-\left(\frac{E}{\hbar}\right)t\right)\right]$$

This equation can then be written as

$$-k^2u(x)+2jk\frac{\partial u(x)}{\partial x}+\frac{\partial^2u(x)}{\partial x^2}+\frac{2mE}{\hbar^2}\cdot u(x)=0$$

Setting $u(x)=u_1(x)$ for region I, this equation becomes

$$\frac{d^2u_1(x)}{dx^2}+2jk\frac{du_1(x)}{dx}-\left(k^2-\alpha^2\right)u_1(x)=0$$

where

$$\alpha^2=\frac{2mE}{\hbar^2}$$

Q.E.D.

In region II, $V(x)=V_{o-}$. Assume the same form of the solution

$$\Psi(x,t)=u(x)\exp\left[j\left(kx-\left(\frac{E}{\hbar}\right)t\right)\right]$$

Substituting into Schrodinger's wave equation, we obtain

$$\frac{-\hbar^2}{2m}\left\{\ (jk)^2u(x)\exp\left[j\left(kx-\left(\frac{E}{\hbar}\right)t\right)\right]+2jk\frac{\partial u(x)}{\partial x}\exp\left[j\left(kx-\left(\frac{E}{\hbar}\right)t\right)\right]+\frac{\partial^2u(x)}{\partial x^2}\exp\left[j\left(kx-\left(\frac{E}{\hbar}\right)t\right)\right]\right\}+V_{o-}u(x)\exp\left[j\left(kx-\left(\frac{E}{\hbar}\right)t\right)\right]=Eu(x)\exp\left[j\left(kx-\left(\frac{E}{\hbar}\right)t\right)\right]$$

This equation can be written as

$$-k^2u(x)+2jk\frac{\partial u(x)}{\partial x}+\frac{\partial^2u(x)}{\partial x^2}-\frac{2mV_{o-}}{\hbar^2}u(x)+\frac{2mE}{\hbar^2}u(x)=0$$

Setting $u(x)=u_2(x)$ for region II, this equation becomes

$$\frac{d^2u_2(x)}{dx^2}+2jk\frac{du_2(x)}{dx}-\left(k^2-\alpha^2+\frac{2mV_{o-}}{\hbar^2}\right)u_2(x)=0$$

where

$$\alpha^2=\frac{2mE}{\hbar^2}$$

Q.E.D.

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Michael Hoelscher

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