Assignment 2

EE 80724, Wide Bandgap Device Physics, Fall 2009

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1 Degenerate Perturbation Theory: Application

#14•3-1: Potential Well with Deformed Bottom

A one-dimensional potential well with infinitely high walls has a sinusoidally deformed bottom with the potential

$$V(x) = \begin{Bmatrix} -A\sin(\pi x/2a) & \text{for } |x| < a \\ \infty & \text{for } |x| > a \end{Bmatrix}, \qquad (14•3–31)$$

shown in **Fig. 14•3–3.**

(a) Calculate the approximate energy eigenvalues for the two lowest energy eigenstates in this potential, using a linear superposition of the two lowest states of the *unperturbed* (flat-bottom) well as the trial wave function. Give closed-form analytic expressions for the two energies, as functions of A.

(b) Assume that $A = \mathcal{E}_1$, where $\mathcal{E}_1$ is the lowest energy eigenstate for the *unperturbed* (flat-bottom) well. For this specific case, indicate the energies of the two states

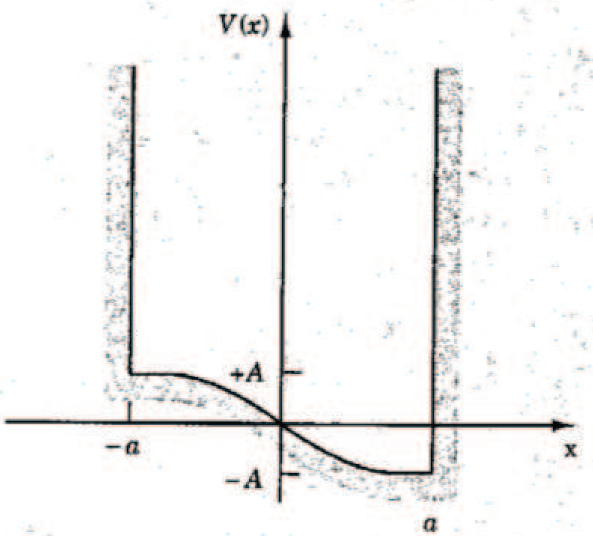


Figure 14•3–3. Potential well with sinusoidal bottom.

on the graph of the potential in Fig. 14•3–3. Give numerical values for the two energies, in eV, assuming that the object has the mass of an electron and that $a = 1$ nm. Make a quantitative plot of the wave functions for the two states.

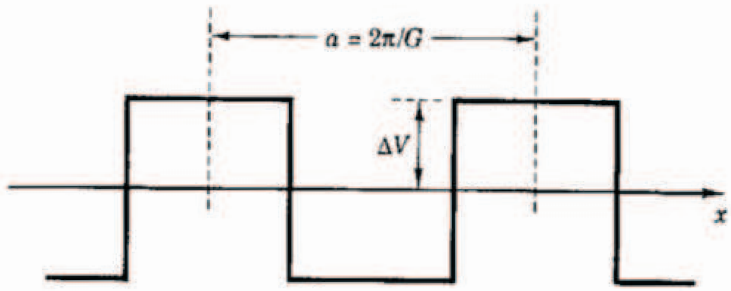
This problem is out of Kroemer's QM Text. Note that the perturbation potential is $V(x) = -A\sin(\pi x/2a)$ for $|x| < a$ (it is hard to read from the figure above).

Contd...

2 Non-Degenerate Perturbation Theory: Application

#15•2-1: Energy Gap of a Square-Wave Periodic Potential

Using second-order Brillouin-Wigner perturbation theory, calculate the energy gap of a square-wave potential with the amplitude $\Delta V = F$, where F is again given by (14•3–17).



This problem is also out of Kroemer's QM Text. Note that $F = \hbar^2 G^2 / 8m_0$ as discussed extensively in class, and it should be clear that the given perturbation potential is applied on the *free electron.* Also test with the Rayleigh-Schrodinger (RS) approximation for the 2nd order energy corrections. Is the RS approximation a good one for this problem?

3 $\mathbf{k} \cdot \mathbf{p}$ Bandstructure models of GaN and AlN

Based on our discussion on the $\mathbf{k} \cdot \mathbf{p}$ model, calculate and plot the bandstructures of wurtzite GaN and AlN and keep this for further usage in the class.

a) First calculate the bands neglecting the spin-orbit interaction.

b) Include the spin-orbit interaction in the second iteration.

c) Investigate (read!) recent literature and quote references where the $\mathbf{k} \cdot \mathbf{p}$ model of GaN and AlN has been addressed. How does the model presented there compare with yours?