HW2

1. Consider a rectangular piece of a conducting material of cross-sectional area A and length L. A voltage $V$ applied at one end of the bar results in a current $I$. Start with Ohm’s Law $V = R I$ and show that it can be written as $J = \sigma E$, where $R$ is the resistance, $J$ is the current density, $\sigma$ is the conductivity, and $E$ is the electric field.

2. Carefully sketch or copy $E$-$k$ diagrams for

   a. Si
   b. GaAs
   c. InAs
   d. InP

Specify the energy band gap for each material and determine the wavelength of the emitted photon when an electron transitions from the bottom of the conduction band to the top of the valence band.
1. Consider a rectangular piece of conducting material. A voltage \( V \) is applied to one end. Start with Ohm's Law \( V = RI \) and show that it can be written as \( J = \sigma E \) where, \( \sigma \rightarrow \text{conductivity} \) and \( E \rightarrow \text{electric field} \).

Solve:

\[
V = RI, \quad E = \frac{V}{L}, \quad R = \rho \frac{L}{A}, \quad J = \frac{I}{A}
\]

\[
\Rightarrow \quad E = \rho J \Rightarrow J = \sigma E
\]

Carefully Sketch or Copy E-k diagram for:

(a) Si, (b) GaAs, (c) InAs, (d) InP.

Solve: See notes Page 32 for E-k diagrams for Si and GaAs.

Also see the diagrams on page 2.

Note that the above two band structures look identical. These are simply schematics. To see more details, you will need to dig a little deeper. See the next three pages for more information.
each level in the same direction, except \( x_3 \). In this table, all the levels are measured with respect to the level \( \Gamma_{2s} \). On an absolute scale the \( x_1 \) level is least sensitive to changes in the form factors.

The calculated band structures are given in Figs. 1 through 14. The symmetry assignments are according to Herring\(^{18} \) and to Parmenter,\(^{19} \) The bands are computed along the symmetry directions\(^{20} \Lambda, \Delta, \Sigma, \) and the line between \( X \) and \( U(K) \). The last two are done by going directly from \( (1,1,0) \) to \( \Gamma \). Most of the structure in the optical data appears to arise from states near these symmetry lines.

Several trends are conspicuous in the band structures. In the conduction band the \( \Gamma_{2s} \) level comes

---

\(^{18} \) C. Herring, J. Franklin Inst. 233, 525 (1942).
rapidly down in energy as one proceeds from the lighter to the heavier semiconductors. Also, the $L_I$ level comes down with respect to the $X_I$ level. The antisymmetric potential causes the $X_I$ level in a homopolar substance to be split into an $X_1$ and an $X_3$ level in heteropolar substances. This splitting appears to be a measure of $V^4$. Both the transverse and longitudinal masses of the $X_I$ level are considerably greater than those of the $X_3$ level. This is manifested in the weakness of the $X_5-X_3$ peak in reflectivity, seen for example in GaAs.\textsuperscript{23} As a result of an increasing $V^4$, the splittings between the conduction and valence bands become progressively larger, and this follows crudely the $\lambda^2$ law.\textsuperscript{22} However, $\lambda^2$ extrapolations should not be treated as data. The conduction bands tend to become flattened out, as do the valence bands.

---


\textsuperscript{22} F. Herman, J. Electronics 1, 103 (1955).