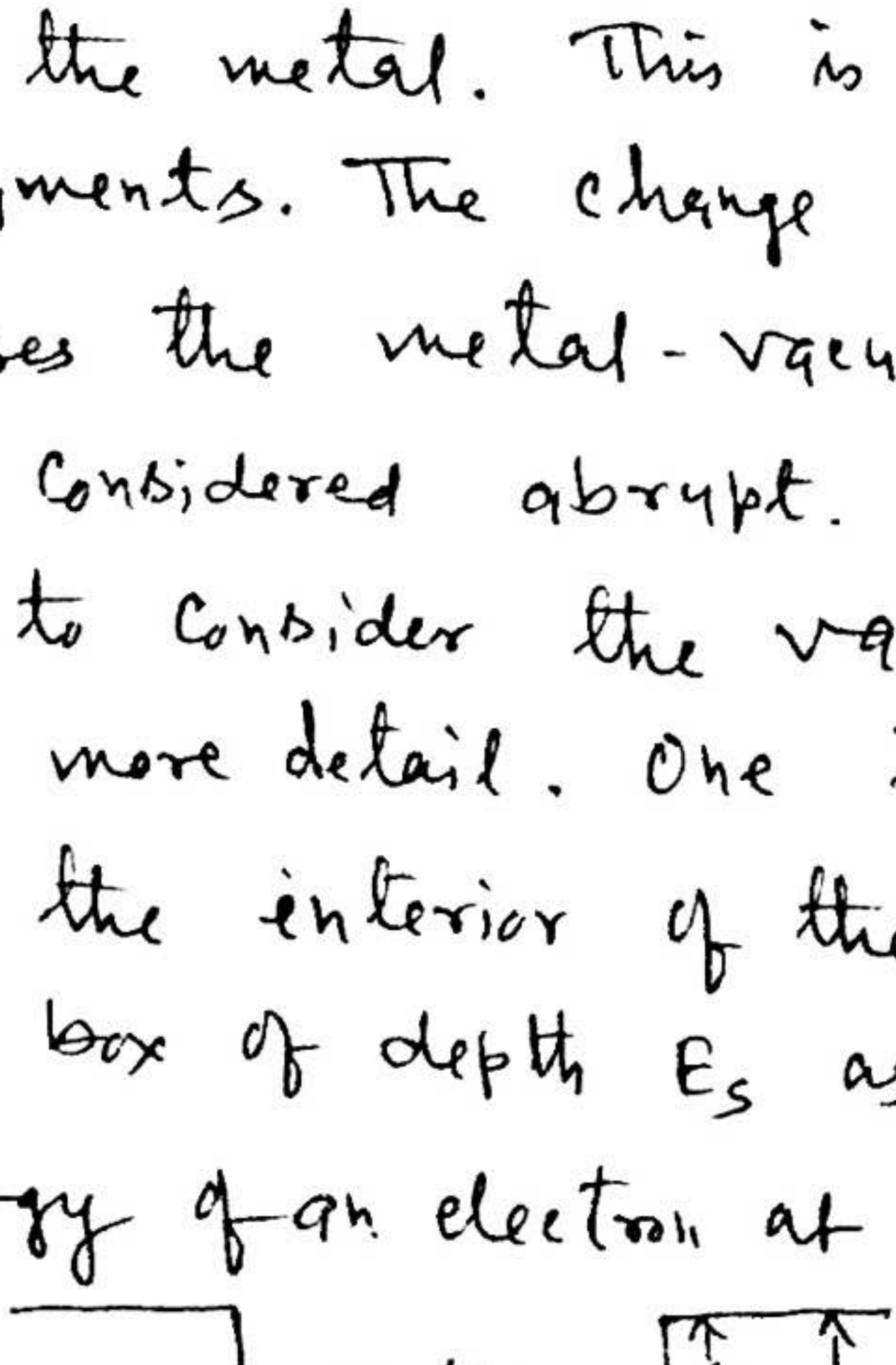
Paper (202)
Condensed matter physics

Free electron theory of Metals

Free electron model: An electron in a metal, or for that matter in any solid, finds itself in the field of all nuclei and all other electrons. The potential energy for such an electron may therefore be expected to be periodic, the periodicity being that of the lattice. In the model employed by Sommerfeld, however, it is assumed that the "free" electrons, i.e., those giving rise to the conductivity, find themselves in a potential which is constant everywhere inside the metal. Since one does not observe electron emission from metals at room temperature, it seems evident that the potential energy of an electron at rest inside the metal must be lower than that of an electron at rest outside the metal. This is confirmed by relatively simple theoretical arguments. The change in potential energy of an electron E_s as one crosses the metal-vacuum boundary may, for a number of problems, be considered abrupt. For some problems, however, it is necessary to consider the variation of potential at the surface in some more detail. One thus arrives at a physical model in which the interior of the metal is represented by a potential energy box of depth E_s as indicated in the following figure; the energy of an electron at rest outside the metal is used



as a reference and is commonly referred to as the vacuum level. It may be of interest to note that E_s may be determined experimentally from electron diffraction experiments with slow electrons. An electron impinging on the metal from the outside with an initial energy E_0 gains an amount E_s upon entering the metal. It may be shown that the position of the diffraction maxima is determined by the quantity $[(E_0+E_s)/E_0]^{\frac{1}{2}}$. Thus from a knowledge of the lattice structure and E_0, it is possible to determine E_s. For nickel one has found in this way $E_s = 14.8$ ev. In general, E_s is of the order of 10 ev.

In the Sommerfeld model, the free electrons are assumed to be the valence electrons of the composing atoms. Thus the alkali metals are assumed to contain one free electron per atom; aluminium supposedly has three free electrons per atom.

The first problem to be discussed now is the energy distribution of a "free electron gas" with a density of the order of 10^{22} per cm^3.