Exercise Solid-State Physics (ET2908 and 8027) 2009-20010Q1: dr. R. Ishihara, DIMES-TC00.0044, r.ishihara@tudelft.nl

# Solution for Exercise-sheet 6

## I. Electrical Conduction in Solids

**(I.1)**

**Solution**

$E$ versus $k$ has a parabolic relationship.

$$E_V - E = \frac{k^2\hbar^2}{2m} \tag{1}$$

$$k = 0.1[\text{Å}^{-1}] = 10^9[\text{m}^{-1}] \tag{2}$$

For the curve A:

$$(0.07)(1.6 \times 10^{-19}) = \frac{(10^9)^2(1.054 \times 10^{-34})^2}{2m} \tag{3}$$

which yields

$$m_A = 4.96 \times 10^{-31}[\text{kg}] \quad \rightarrow \quad \underline{\frac{m_A}{m_0} = 0.544} \tag{4}$$

For the curve B:

$$(0.7)(1.6 \times 10^{-19}) = \frac{(10^9)^2(1.054 \times 10^{-34})^2}{2m} \tag{5}$$

which yields

$$m_B = 4.96 \times 10^{-32}[\text{kg}] \quad \rightarrow \quad \underline{\frac{m_B}{m_0} = 0.0544} \tag{6}$$

**(I.2)**

**Solution:**

Points A, B: $\frac{\partial E}{\partial k} < 0$, which means velocity in -x direction

Points C, D: $\frac{\partial E}{\partial k} > 0$, which means velocity in +x direction

Points A, D: $\frac{\partial^2 E}{\partial k^2} < 0$, which means negative effective mass;

Points B, C: $\frac{\partial^2 E}{\partial k^2} > 0$, which means positive effective mass.

**(I.3)** (a) (b) $\partial E/\partial k$ and $\partial^2 E/\partial k^2$ versus $k$ can be plotted as Figure 1.

(c) The effective mass as a function of $k$ is plotted as Figure **??**. Curve A: Effective mass is a constant. (Free electron belongs to this case) Curve B: Effective mass has a positive around $k = 0$ and increases to infinite positive at $k = \pm\frac{\pi}{2a}$. The mass is negative around $k = \pm\frac{\pi}{a}$ and decreases to infinite negative around $k = \pm\frac{\pi}{2a}$.

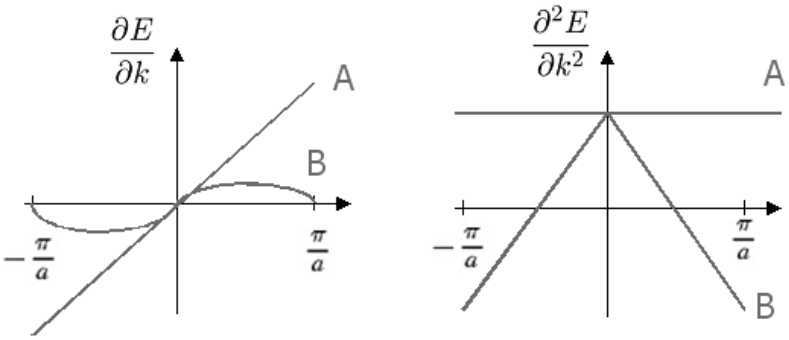


Figure 1: $\partial E/\partial k$ and $\partial^2 E/\partial k^2$ versus $k$ of Figure 3.39 in Neaman page 100

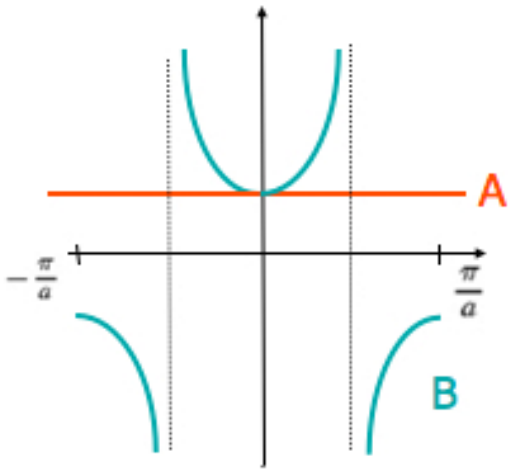


Figure 2: Effective mass versus $k$ of Figure 3.39 in Neaman page 100