

## Introduction to Solid State Physics 2017

1. (a) Please describe the two examples, electron and phonon, in Solid State, which have the physical properties of Band Dispersion and Energy Gap. (10%)  
(b) Please conceptually describe their physical origins of the existence of Energy Gap, respectively, by drawing the corresponding scheme of band structure. (10%)  
(c) Please briefly describe the similarity and difference in both examples. (10%)  
(d) Please show how to construct the Brillouin Zones in the band structure for both examples. Are all of Brillouin Zones are physically meaningful for both examples? Why? (10%)  
(e) Please use a schematic energy band and band gap to describe the different materials of insulator, metal, semimetal, n-type and p-type semiconductor. (15%)
2. (a) Please use the form of Newton's second law to define/derive the **effective mass**  $m^*$  in semiconductor. (20%) (b) Can the effective mass be negative? If yes, please give a brief explanation. (10%)
3. (a) In the ground state of a three-dimensional system of N free electrons at 0 K, the occupied orbitals may be represented as points inside a sphere in  $\mathbf{k}$  space. Please derive

$$k_F = \left( \frac{3\pi^2 N}{V} \right)^{\frac{1}{3}},$$

where  $k_F$  is the wave vector at the Fermi surface and V is volume. (15%)