MAASAI MARA UNIVERSITY

REGULAR UNIVERSITY EXAMINATIONS
2022/2023 ACADEMIC YEAR
FIRST YEAR *SECOND* SEMESTER

SCHOOL OF PURE, APPLIED AND HEALTH SCIENCES
MASTER OF SCIENCE IN PHYSICS

COURSE CODE: PHY 8211

COURSE TITLE: SOLID STATE PHYSICS

DATE: 5th September 2018 **TIME: 1100-1400**

INSTRUCTIONS TO CANDIDATES

1. Answer Question **ONE** and any other **TWO** questions
2. Use of sketch diagrams where necessary and brief illustrations are encouraged.
3. Read the instructions on the answer booklet keenly and adhere to them.

*This paper consists of **three** printed pages. Please turn over.*

Question one (20 marks)

a) State and explain the theorem due to Bloch that says an electron moving in the potential of this lattice has traveling wave functions. What boundary conditions must be used with this theorem? **(6mks)**

b) What are the assumptions of tight binding approximation that differentiates them from the assumptions that are made for the weak binding approximation. **(4mks)**

c) The phenomenon shown in fig 1 occurs when atoms are brought together

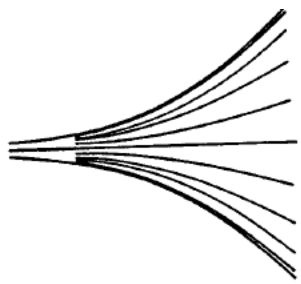

Fig 1

i. What happens when the interatomic distance decreases? **(2mks)**

ii. What is the characteristic of the energy levels formed. **(1mk)**

d) The energy eigenvalues $E(\vec{k})$ in the tight binding approximation for a non-degenerate state is simply given by $E(\vec{k}) = \frac{\langle \vec{k}|H|\vec{k}\rangle}{\langle \vec{k}|\vec{k}\rangle}$. What is the name given to the denominator and why is it put in the equation? **(1mk)**

e) Starting with $\psi_j(\vec{r}) = \sum_{n=1}^{N} C_{j,n}\phi_j(\vec{r}-\vec{R}_n)$, show that the wave functions for the unperturbed problem as a linear combination of atomic functions $\phi_j(\vec{r}-\vec{R})$ labeled by quantum number *j* is $\psi_{j,\vec{k}}(\vec{r}) = \xi_j \sum_n e^{i\vec{k}.\vec{R}_n}\phi_j(\vec{r}-\vec{R}_n)$. **(6mks)**

Question Two (20 marks)

a) With the help of equations state the two approximations that eases in solving the Boltzmann's equation. **(4mks)**

b) One of the approximations in 2(a) involves relaxation time. What is the physical interpretation of relaxation time **(1mk)**

c) The solution to the relaxation time approximation follows a Poisson distribution indicating that collisions relax the distribution function exponentially to f_0 with a time constant τ. Use this argument to show that the equilibrium state $f_0(E)$ is a Fermi distribution function. **(5mks)**

d) The simple Drude model $\sigma = \frac{ne^2\tau}{m^*}$ can be recovered for a semiconductor from the general relation $\ddot{\sigma} = -\frac{e^2}{4\pi^3}\int r\vec{v}\vec{v}\frac{\partial f_0}{\partial E}d^3k$ (where $\ddot{\sigma}$ is symmetric second rank conductivity tensor, $\sigma_{ij} = \sigma_{ji}$) , using a simple parabolic band model and a constant relaxation time. By stating relevant equations discuss the three approximations applied in deriving the Drude model. **(6mks)**

e) Illustrate the electron and hole states of an intrinsic semiconductor on specific diagrams
   i. Location of EF in an intrinsic semiconductor. **(1mk)**
   ii. The corresponding density of electron and hole states. **(1mk)**
   iii. The Fermi functions for electrons and holes. **(1mk)**
   iv. The occupation of electron and hole states in an intrinsic semiconductor. **(1mk)**

<u>Question Three (20 marks)</u>

a) Define the Hall effect **(1mk)**

b) Show that the Hall coefficient $R_{\text{Hall}} = 1/nec$. **(10mks)**

c) State the importance of Hall coefficient **(3mks)**

d) Relate Hall mobility to Hall coefficient for:
   i. one carrier type **(3mks)**
   ii. two carrier type **(3mks)**

<u>Question Four (20 marks)</u>

a) With the aid a diagram, describe interband transition **(3mks)**

b) Discuss the salient features of interband transition **(5mks)**

c) Show that Hagen-Rubens relation for small frequencies is given by $R = 1 - 4\sqrt{\frac{\nu}{\sigma_0}\pi\varepsilon_0}$ **(6mks)**

d) Calculate the characteristic penetration depth in aluminum for Na light ($\lambda = 589$ nm; k = 6). **(2mks)**

e) The transmissivity of a piece of glass of thickness d = 1 cm was measured at $\lambda = 589$ nm to be 89%. What would the transmissivity of this glass be if the thickness were reduced to 0.5 cm? (Note: Neglect the reflectance of the glass.) **(4mks)**