MAASAI MARA UNIVERSITY

REGULAR UNIVERSITY EXAMINATIONS
2023/2024 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: **4th December 2023** **TIME:** **11.00 -14.00**

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 a periodic 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

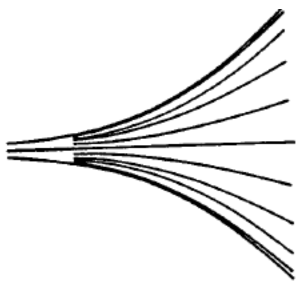

Fig 1

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)**

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

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)**

Question Three (20 marks)

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)**

Question Four (20 marks)

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)**