MAASAI MARA UNIVERSITY

REGULAR UNIVERSITY EXAMINATIONS
2017/2018 ACADEMIC YEAR
FIRST YEAR *SECOND* SEMESTER

SCHOOL OF SCIENCE
MASTER OF SCIENCE IN PHYSICS

COURSE CODE: PHY 8212

COURSE TITLE: ENERGY BANDS, MAGNETISM AND AMORPHOUS MATERIALS

DATE: **TIME:**

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.

Question one (30 marks)

a) If an iron crystal were totally magnetized spontaneously, estimate the resulting magnetization using plausible values for the parameters required. (specific weight of iron = 7.9, atomic weight of iron = 56, Bohr magnetron = 9.3×10^{-24} Am^2) **(5mks)**

b) Discuss the Bloch theorem and its relation to the symmetry of the crystal lattice. **(5mks)**

c) What is an iteration process **(2mks)**

d) Briefly describe a magnon **(3mks)**

e) How does study of amorphous solids differ from one that obeys Bloch condition **(3mks)**

f) State the Hartree equations, what were the strengths and weaknesses of these equations. **(4mks)**

g) i. Magnetism in condensed matter manifests itself in various forms for different materials and at different temperatures. Name the different types of magnetic behaviour. **(4mks)**

ii. Using magnetic susceptibility, distinguish between the different types of magnetisms in (i) above. **(4mks)**

Question Two (20 marks)

Figure 1.1 shows a hypothetical two-dimensional crystal consisting of atoms arranged on a square grid.

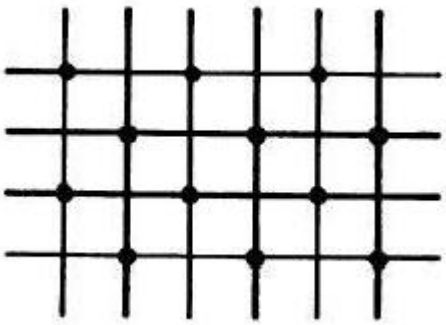

Fig 1.1

a) Describe and show on the grid an example of a primitive unit cell. **(3mks)**

b) Define "the reciprocal lattice" and explain its relation to Bragg reflection. **(3mks)**

c) Show the reciprocal lattice and the first Brillouin zone. How is this zone related to Bragg reflection? **(4mks)**

d) 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)**

e) The free electron wavefunction are plane waves of the form $\psi_k = e^{i\mathbf{k}.\mathbf{r}}$. Show that a combination of wavefunctions of electrons in a periodic potential are standing waves **(3mks)**

Question Three (20 marks)

The method of orthogonalized plane waves (OPW, closely associated with the method of pseudo-potential) is very often used to make band structure calculations for electron states in metals. It explains successfully why the nearly free electron approximation can be used although the actual lattice potential acting on the electrons is not weak at all. Discuss the essential physical ideas and mathematical steps in this method by including, among others, descriptions of a

a) Construction of Bloch function out of core states and its properties, **(4mks)**
b) Construction of the orthogonalized plane wave states and their properties, **(4mks)**
c) Construction of the pseudopotential and its non-uniqueness, **(8mks)**
d) Physical explanation why the pseudopotential can be treated as small. **(4mks)**

Question Four (20 marks)

i. The orienting tendency of an electric field E on a permanent dipole is opposed by thermal agitation.

a) Using classical statistical mechanics, calculate the total polarization of a gas of *N* independent permanent dipoles of moment *P.* **(6mks)**

b) Show that for small fields, the orientational polarization per dipole is inversely proportional to the temperature. **(3mks)**

c) Discuss the effect of this phenomenon on the dielectric constant of water, a polarizable molecule, at high frequencies and at low frequencies. **(7mks)**

ii. The spin susceptibility has a weak temperature dependence of the form $\chi(T)=\chi(0)\left(1+\alpha T^2\right)$. Would you expect α to be positive or negative? (Qualitative arguments only are expected.) **(4mks)**