MAASAI MARA UNIVERSITY

REGULAR UNIVERSITY EXAMINATIONS
2018/2019 ACADEMIC YEAR

FOURTH YEAR SECOND SEMESTER EXAMINATION

FOR

THE DEGREE OF BACHELOR OF SCIENCE IN PHYSICS

COURSE CODE: PHYS 414
COURSE TITLE: SOLID STATE PHYSICS

DATE: 16TH APRIL 2019 **TIME: 1100 - 1300 HRS**

INSTRUCTIONS TO CANDIDATES

1. This paper contains **FIVE** (4) questions.
2. Answer question **ONE (1)** in and any other **Two** (2) questions.
3. Do not forget to write your Registration Number.

This paper has 3 printed pages

QUESTION ONE: [30 marks]

a) Distinguish between phase and group velocity as used in lattice vibrations. [2]

b) An incident monochromatic X-ray beam with wavelength $\lambda = 1.9$ Å. A is reflected from the (111) plane in a 3D solid with a Bragg angle of 32^0 for the n=1 reflection. Compute the distance (in Å) between adjacent (111) planes. [3]

c) The quadratic equation for the 1D diatomic lattice dispersion yields the relation: $\omega^2 = \beta\left(\frac{1}{M_1}+\frac{1}{M_2}\right) \pm \beta\sqrt{\left(\frac{1}{M_1}+\frac{1}{M_2}\right)^2 - \frac{4\sin 2ka}{M_1 M_2}}$, where symbols have their usual meanings.

State and explain the relation that explains:

(i) the acoustic dispersion [3]

(ii) Optic dispersion [2]

d) Aluminum is less dense than uranium. Assuming that these two metals have roughly the same stiffness, what can you say about the expected speeds of sound in these two metals and why? [3]

e) State and explain the Bloch's Theorem. [2]

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f) Explain the Curie temperature. [3]

g) Use phase diagrams to explain essential phenomenological differences between Type I and Type II superconductors. [4]

h) What are the three Shortcomings of the Debye Theory? [3]

i) State one success and one failure of the Drude model [2]

j) Explain by the aid of a diagram the term hysteresis. [3]

QUESTION TWO: [20 marks]

a) Using the free electron model, derive the formula expressing the Fermi energy E_F as a function of electron concentration n. [8]

b) What is the Fermi energy for the 3D metal from part (a) (in eV)? Recall that free electron mass is $m=9.1\times10^{-31}$ kg and Planck's constant is $n=1.05\times10^{-34}$ J·s. [2]

c) Vacancies are missing atoms in an otherwise near-perfect crystal. Since they create disorder and increase the entropy, vacancies are always present at non-zero temperatures in real crystals. How would you expect the X-ray diffraction of a crystal change due to a small number of vacancies? [5]

d) Use the Fourier series expansion of the wave function to derive the Bloch theorem (i.e., show that the wave function can be written as a product of a free electron phase factor and $U_k(X)$, which has the periodicity of the lattice). [5]

QUESTION THREE: [20 marks]

a) Explain the term 'lattice' [3]

b) Derive the dispersion relation $\omega=\sqrt{\frac{4\beta}{m}}\sin\left(\frac{ka}{2}\right)$ for 1D monoatomic lattice. where symbols have their usual meanings [10]

c) Plot a sketch of ω versus K for $(-\frac{2\pi}{a}<k<\frac{2\pi}{a})$. [4]

d) Explain the shape of your plot in c above and show the 1st Brillouin zone. [3]

QUESTION FOUR: [20 marks]

a) Discuss the following:

(i) Vacancy Defects [3]

(ii) Interstitial defects [3]

b) Derive the London penetration depth in Superconductivity. [4]

c) Discuss the magnetic behavior of the following materials

(i) Diamagnetism [5]

(ii) Paramagnetism [5]

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