LAIKIPIA UNIVERSITY

UNIVERSITY EXAMINATIONS

FIRST SEMESTER 2025/2026 ACADEMIC YEAR

FOURTH YEAR EXAMINATION FOR THE DEGREES OF BACHELOR OF EDUCATION (SCIENCE) AND BACHELOR OF SCIENCE (GENERAL)

PHYS 412: SOLID STATES PHYSICS

STREAMS: R ***TIME: 2 HRS***

DAY: TUESDAY [14.30 – 16.30 P.M] ***DATE: 03/02/2026***

THIS QUESTION PAPER CONSISTS OF FIVE (5) PAGES

PLEASE DO NOT OPEN UNTIL THE INVIGILATOR SAYS SO.

Instructions:

i. Answer questions one and any other two questions. Question one has 40 marks and the rest of the questions 15 marks each.

ii. You may use the following constants;

$\varepsilon_o = 8.85x10^{-12}\,F/m$

$1ev = 1.60x10^{-19}\,J$

$\mu_o = 1.26x10^{-6}\,H/m$

$h = 6.63x10^{-34}\,J/s$

$k = 1.38x10^{-23}\,J/°K$

$e = 1.60x10^{-19}\,C$

Avogadro number; $N_A = 6.022x10^{23}\,Atoms/m^3$

Concentration for copper; $n = 8.4x10^{22}/cm^3$

QUESTION ONE (40 MARKS)

.(a) Define the following terms with due regard to crystal structure

(i) Lattice

(ii) Color Centre

(iii) Primitive cell

(iv) Brillouin Zone

(v) Reciprocal Lattice **(5 Marks)**

(b) Distinguish between the n-type and the p-type semi- conductor **(2 Marks)**

(c) Show that in a simple cubic lattice, the distance between adjacent planes of miller indices (h k l) is

$$d_{hke} = \frac{a}{\left(h^2 + k^2 + l^2\right)^{1/2}}$$ where ***a*** is the lattice constant (the separation distance between the neighboring points on the lattice). **(4 Marks)**

(d). Distinguish between the following types of bonding while giving an example for each

(i). Covalent & Ionic bond **(2 Marks)**

(ii). Metallic & Van der waals bond **(2 Marks)**

(e). What is the difference between the Hall Effect observations in an ordinary metal and a semiconductor? **(2 Marks)**

(f). Explain what is meant by radiative recombination **(2 Marks)**

(g). Explain the **two** factors which according to Langevin's theory determine the state of magnetization of a material. **(4 Marks)**

(h). Define and state the necessary conditions required for superconductivity to occur **(3 Marks)**

(i) Explain three different mechanisms of polarization **(6 Marks)**

(j). The region between capacitor plates is filled with amorphous selenium with dielectric constant of 6.0 and a concentration of 3.67×10^{28} atoms/ cm^3

(i). Estimate the polarizability of the selenium atom **(4 Marks)**

(ii). Estimate the local field at a selenium atom if the charge on the plates produces a field of 1500 v/m **(4 Marks)**

QUESTION TWO (15 MARKS)

(a) What are the miller indices of the plane that contain the three lattice points

(i) $\hat{r}_1 = \hat{a} - \hat{b}$

(ii) $\hat{r}_2 = 2\hat{a} + \hat{c}$

(iii) $\hat{r}_3 = 3\hat{b} + \hat{c}$? **(6 Marks)**

(b) Find the concentration of lattice points on a (111) plane of a face – centered cubic lattice **(3 Marks)**

(c) For a simple cubic lattice with cube edge a; Sketch the lattice points along the lines in the following directions

(i) $[110]$ (ii) $[320]$ (iii) $[321]$. **(6 Marks)**

QUESTION THREE (15 MARKS)

(a) State and describe the mechanisms by which dielectric breakdown may occur **(3 Marks)**

(b) Distinguish between the **five** types of magnetic materials encountered in nature **(5 Marks)**

(c) State and explain the four types of dielectric crystals **(4 Marks)**

(d) State and distinguish between the **three** types of solid materials encountered in nature. **(3 Marks)**

QUESTION FOUR (15 MARKS)

(a) Describe two experiments which can be used to determine the energy gap in a superconductor. **(4 Marks)**

(b) A capacitor is to be made from a dielectric having a breakdown field strength ε_b and relative permittivity ε_r. the electrodes are metal plates fixed to the sides of a slab (thickness 0.5mm) of the dielectric . owing to a slight distortion of one of the plates, one third of its area is separated from the dielectric by an air filled gap of thickness 1μm. The remaining two thirds of the plate and the whole of the second plate are in intimate contact with the dielectric. The breakdown field ε_b = 2.0 MV/m for the dielectric and 3.0 MV for air. ε_r is 1000. Discuss the effect of the gap (compared to a gap free capacitor) on;

(i) The capacitance **(3 Marks)**

(ii) The breakdown voltage **(3 Marks)**

(iii) Express the change in percentage. **(1 Mark)**

(c). Find the mobility of electrons in copper assuming that each atom contributes one free electron for conduction. Given that resistivity of copper = $1.7 \times 10^{-4}\Omega$cm, Atomic weight = 63.54, Density = 8.96 gm/cm^3 **(4 Marks)**

QUESTION FIVE (15 MARKS)

(a) (i) Derive a dispersion relation for a vibrational linear diatomic chain. Sketch the dispersion curve **(5 Marks)**

(ii) Distinguish between the optical branch and the acoustic branch**.** **(6 Marks)**

(b) If the potential energy function is expressed as: $u(r) = \frac{\alpha}{r^6} + \frac{\beta}{r^{12}}$ show that:

(i) The internuclear distance r_0 for which the potential energy is zero is given by $\left(\frac{2\beta}{\alpha}\right)^{1/6}$ **(2 Marks)**

(ii) The minimum potential energy is given by

$$u_{\min} = \frac{\alpha^2}{4\beta}$$ **(2 Marks)**