KABARAK UNIVERSITY

SUPPLEMENTARY/SPECIAL EXAMINATIONS

2008/2009 ACADEMIC YEAR

FOR THE DEGREE OF BACHELOR OF EDUCATION SCIENCE

COURSE CODE: **PHYS 411**

COURSE TITLE: **SOLID STATE PHYSICS**

STREAM: **SESSION VI & VIII**

DAY: **WEDNESDAY**

TIME: **9.00 – 11.00 A.M**

DATE: **08/04/2009**

INSTRUCTIONS

Part I: Question 1 is compulsory and carries 30 marks. Part II: Each question carries 20 marks. Attempt any two questions.

PLEASE TURN OVER

Part I: Question 1 is compulsory and carries 30 marks
Question 1

(a) State any two phenomena (other than the specific heat paradox) observed in the properties of solids that could not be explained by the classical free electron theory (2 marks)

(b) Classical theory states that when thermal energy is applied to a solid at temperature *T*, each electron would attain energy *KT*. The implication is then that the observed specific heat at constant volume would be much larger than the known 3*R*. Explain why this prediction is never observed experimentally (4 marks)

(c) (i) Explain the origins of magnetism in atoms. (3 marks)

(ii) Define the terms paramagnetism, ferromagnetism and diamagnetism. Indicate the sign and typical order or size of the magnetic susceptibility associated with each case (6 marks)

(d) Describe using relevant diagrams the following terms used to identify imperfections in crystals: Schottky defects, Frenkel defects, H-centres and F-centres (8 marks)

(e) Define the phenomenon of superconductivity and state the conditions under which it occurs. Mention the latest development in this area with regard to the temperature at which this phenomenon occurs (4 marks)

(f) Describe three mechanisms by which polarization may occur (3 marks)

Part II: Each question carries 20 marks. Attempt any two questions.

Question 2

(a) (i) Discuss the Kronig-Penny model stating clearly the problem being solved, the results and the implications in trying to address the inadequacies of the Drude model in explaining the properties of solids (7 marks)

(ii) Use energy band diagrams to differentiate between a semiconductor, an insulator and a metal. (6 marks)

(b) Provide relevant arguments and come up with an expression for the effective mass of charge carriers in a periodic potential. Are these arguments of classical, quantum or semi-classical in nature? (7 marks)

Question 3

(a) Name and describe, using relevant diagrams, the phenomenon which asserts that a superconductor is a perfect diamagnet. (6 marks)

(b) (i) According to London's theory the current density is defined as

$$\acute{J} = -\frac{1}{\mu\lambda_L^2}\acute{A},$$

where λ_L and A are the London's penetration depth and magnetic vector potential, respectively. Show that the magnetic field induction obeys the equation

$$\nabla^2 \acute{B} = \frac{B}{\lambda_L^2}.$$

(Hint: use an appropriate vector identity and one of Maxwell's equations) (8 marks)

(ii) How does the solution of the equation in (i) account for this phenomenon? (4 marks)

(iii) Name two applications for superconductors (2 marks)

Question 4

(a) (i) What is charge compensation? (1 mark)

(ii) Explain how charge compensation gives rise to colour centres (2 marks)

(iii) Give examples of materials where colour centres occur naturally (1 mark)

(iv) Suppose the energy required to remove a sodium atom from the inside of a bulk sodium crystal is 1 eV. Calculate the concentration of Schottky defects at 300 K. Assume that Na atomic weight = 23 and density = 1013 kgm^{-3} (3 marks)

(b) (i) Differentiate between point defects and dislocations (2 marks)

(ii) Describe the effect of lattice defects on thermal conductivity of electrical conductors, plastic deformation and diffusion in solids (3 marks)

(c) State two optical methods that can be used to detect and study lattice defects (2 marks)

(d) (i) What are the ferroelectric materials (1.5 marks)

(ii) Describe piezoelectric materials and give an example (3 marks)

(iii) State an application for each of the materials described in (i) and (ii) above (1.5 marks)