UNIVERSITY OF SWAZILAND

FACULTY OF SCIENCE

DEPARTMENT OF PHYSICS.

SUPPLEMENTARY EXAMINATION 2006/2007.

TITLE OF PAPER: SOLID STATE PHYSICS II

COURSE NUMBER: P422

TIME ALLOWED : THREE HOURS

INSTRUCTIONS: ANSWER ANY FOUR QUESTIONS .

EACH QUESTION CARRIES 25 MARKS

MARKS FOR DIFFERENT SECTIONS ARE SHOWN IN THE RIGHT HAND MARGIN

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Question One.

(a) Derive the dispersion relation for a dilute gas stating clearly the assumptions made. (12 marks)

(b) (i) Sketch graphs of refractive index versus frequency and extinction coefficient versus frequency of the dilute gas.

(ii) explain anomalous dispersion. (6 marks)

(c) A gas at room temperature has number density of $10^{17}\,cm^{-3}$, resonance frequency of $3x10^{15}$ Hz and a band width of 10^{11} Hz. Calculate:

(i) the plasma frequency

(ii) the maximum value of the refractive index. (7 marks)

[assume the damping constant = 0 and $\omega_0^2 - \omega^2 = 2\,\omega_0\,(\omega_0 - \omega_0)$]

Question Two.

(a) With the help of band diagrams discuss briefly the quantum process of photoelectric emission in materials with particular reference to metals and semiconductors. (9 marks)

(b) (i) Define quantum efficiency of a material (2 marks)

(ii) Explain why diamond is transparent to visible light given that it has a binding energy of 5.6 eV (6 marks)

(c) The electron and hole concentrations in a semiconductor sample increases by $10^{15}\,cm^{-3}$ when irradiated with light.

(i) Calculate the change in conductivity of the sample. (5 marks)

(ii) number of photons falling on the sample per second. (3 marks)

[electron and hole mobilities of the sample are : 1350 $cm^2V^{-1}s^{-1}$ and 480 $cm^2V^{-1}s^{-1}$ respectively, carrier life time = 10^{-6} s]

Question Three.

(b) (i) Derive the classical Langevin equation for the diamagnetic susceptibility

$$\chi = -\frac{\mu_0 NZe^2}{6m}\langle r^2 \rangle$$ (12 marks)

(c) (i) Explain how conduction electrons cause magnetization in metals (4 marks)

(ii) Calculate the density of states corresponding to the Fermi energy of Lithium. (Fermi energy of lithium = 2.05 eV) (5 marks)

(iii) Use the result in (ii) to find the susceptibility of Lithium. (4 marks)

Question Four.

(a) (i) The superconducting state of a material can be destroyed by the application of a critical magnetic field which is a function of temperature. Write down the equation relating the critical field and temperature. stating what each term represent. (4 marks)

(ii) Sketch a graph of the critical field versus temperature in (i) above and comment. (4 marks)

(iii) By deriving appropriate expression for the change in entropy show that the super conducting phase is more ordered than the normal phase of a material.

(Given : $dG_S = -S_S dT + \frac{H}{4\pi} dH$, $dG_n = -S_n dT$) (5 marks)

(b) (i) What is Meissner effect in a superconductor? (3 marks)

(ii) State the London equation in superconductors and show how it leads to Meissner effect. (5 marks)

(iii) It is known that an exponentially varying magnetic field can exist in a superconductor. Justify this statement mathematically. (4 marks)

Question Five.

(a) (i) Define 'mobility' of a charge carrier. (2 marks)

(ii) With the help of a sketch explain the band diagram of an amorphous semiconductor. (6 marks)

(iii) Discuss briefly the four conductivity mechanisms in an amorphous semiconductor. (Derivation of equations not needed) (10 marks)

(b) Discuss the main features observed in the thermal conductivity of amorphous materials. (7 marks)

PHYSICAL CONSTANTS

Quantity	Symbol	Value
Angstrom unit	Å	1 Å = 10^{-8} cm = 10^{-10} m
Avogadro number	N	6.023×10^{23}/mol
Boltzmann constant	k	8.620×10^{-5} eV/K = 1.381×10^{-23} J/K
Electronic charge	q	1.602×10^{-19} C
Electron rest mass	m_o	9.109×10^{-31} kg
Electron volt	eV	1 eV = 1.602×10^{-19} J
Gas constant	R	1.987 cal/mole-K
Permeability of free space	μ_o	1.257×10^{-6} H/m
Permittivity of free space	ε_o	8.850×10^{-12} F/m
Planck constant	h	6.626×10^{-34} J-s
Proton rest mass	m_p	1.673×10^{-27} kg
$h/2\pi$	$\hbar$	1.054×10^{-34} J-s
Thermal voltage at 300 K	V_T	0.02586 V
Velocity of light in vacuum	c	2.998×10^{10} cm/s
Wavelength of 1-eV quantum	λ	1.24 μm