Date: March 19, 2015; 2:30-3:30PM Total = 20 marks

PYL-102 (Principles of Electronic Materials)

ALL problems are compulsory. Answer all sub-parts of the same question in one sequence. The exam will be graded on a step-by-step basis, with partial credit being awarded for correct steps and techniques even if the answer is wrong. **FULL** credit will be awarded only if the right answer is obtained for the right reason, **NO** credit will be given if the calculations are not completed and proper units not mentioned.

1. **Fermi energy of a 3 Dimensional Electron Gas (3-DEG)**
The Fermi energy of electrons in a 3-DEG at room temperature is 7.0 eV. The electron drift mobility in the 3-DEG, from Hall effect measurements, is 33 $cm^2V^{-1}s^{-1}$. Use MB statistics, wherever required.
(a) What is the speed v_F of conduction electrons with energies around E_F in the material?
(b) By how many times is this larger than the average thermal speed $v_{thermal}$ of electrons? Comment.
(c) Will the electrons get diffracted by the lattice planes in the 3-DEG, given that interplanar separation in the material is 2.09 Å? [1+2+2]

2. **Fermi Surface and Brillouin Zones**
Consider the case of monovalent Copper (Cu), Silver (Ag); and divalent Magnesium (Mg), Beryllium (Be).
(a) Explain why, in a simple model, the bivalent materials above could be considered to be an insulator.
(b) Now, using band theory, provide the correct explanation of the conductivity of the bivalent metals. Draw figures to explain. [1+4]

3. **X-ray emission spectrum from Sodium**
Structure of Na atom is [Ne]$3s^1$. Figure (A) shows formation of the 3*s* and 3*p* energy bands in Na as a function of inter-nuclear separation. Figure (B) shows the x-ray emission spectrum (called the *L*-band) from crystalline sodium in the soft x-ray range.
(a) Estimate the nearest neighbor equilibrium separation between Na atoms in the crystal if some electrons in the 3*s* band spill over into the states in the 3*p* band.
(b) Qualitatively, estimate the Fermi energy of the electrons in Na.
(c) What is the expected Fermi energy and how does it compare with that in (b)? [1+2+3]

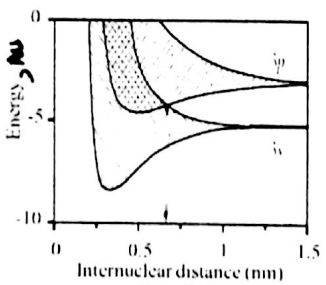

Fig (A)

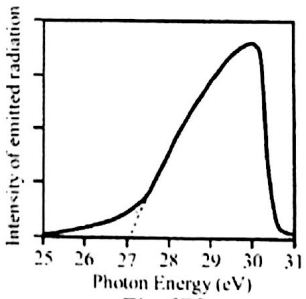

Fig (B)

4. **Nordheim-Fowler field emission in a FED**
The table below shows the results of I-V measurements on a Motorola FED micro-emitter. By a suitable plot, show that the I-V follows the Nordheim-Fowler emission characteristics. What is the cut-off value of V_c?

Tests on a Motorola FED micro field emitter

V_c	40.0	42	44	46	48	50	52	53.8	56.2	58.2	60.4	V
I_{e-mitt}	0.40	2.14	9.40	20.4	34.1	61	93.8	142.5	202	279	367	mA

[4]

$e = 1.6 \times 10^{-19}$ J, $N_A = 6.023 \times 10^{23}$ mol^{-1}, $k_B = 1.381 \times 10^{-23}$ JK^{-1}, $\rho_{Na} = 0.97$ g cm^{-3}, $M_{Na} = 22.99$ g mol^{-1}

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