Mansoura University
Faculty of Engineering
Department of Electronics and Communications Engineering
1st Year Electronics and Comm.

First Semester (Final Exam.)
Exam Time: 3 Hours
Subject: Solid State Electronics
Course code: COM 9112
Exam Date: 4-1-2014

Attempt all questions. Assume any missed data. Full mark is 100

Q.1.a) State Bohr's postulates for the hydrogen atom. Sketch the energy level diagram showing Lyman, Balmer, and Paschen series on the diagram. What is the maximum photon wavelength emitted in Balmer series in *μm*? **[5 Marks]**

Q.1.b) Define each of the following terms: *ionization energy – excitation energy*
Calculate the ionization energy of an electron in hydrogen atom in *eV*. **[5 Marks]**

Q.1.c) Define *the photoelectric* effect. An electron is emitted with velocity $5*10^3$ m/s from a metal surface whose work function is *5 eV*. What is the wavelength of the incident photon? What is the cut-off frequency of this metal? **[5 Marks]**

Q.1.d) Starting with Planck's formula, show that the radiation energy formula is equivalent to Rayleigh-Jeans formula for long wavelengths. Support your answer with sketches. **[5 Marks]**

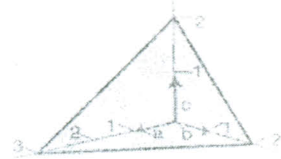
Q.2.a) An α-particle moves with velocity *v* along the x-axis inside an infinite potential well of width $L=1 \mu m$. Assuming that the potential is zero between $x=0$ and $x=L$. Use wave properties of particles to determine each of the following:

- The relation between particle's associated wavelength and *L*.
- The allowed values for *v*.
- The possible energy values of the particle.
- The energy of this particle in its ground state in *eV*. **[5 Marks]**

Q.2.b) Derive an expression for the Compton shift, the difference between incident and scattered photon wavelengths, in terms of the scattering angle Θ. **[5 Marks]**

Q.2.c) Assuming that the crystal structure of sodium is *BCC*, calculate the density of sodium. Assume that the atomic weight of sodium is *22.99 gm/mole* and the lattice constant is $4.3\ A^{O}$. Calculate the nearest neighbor distance and the maximum fraction of the unit cell volume that can be filled by hard spheres. **[5 Marks]**

Q.2.d) *Define* Miller indices. The shown figure represents a part of a plane (the shaded triangle) which intersects the three axes *x*, *y*, *z* of a coordinate system. Find Miller indices for the shown plane. **[5 Marks]**



Q.3.a) Define each of the following terms:

i. *Electron affinity.* Consider a sample of p-type gallium arsenide which has a bandgap of *1.4eV*. Assume it has been doped such that the dopant energy level is *0.8eV* below the conduction-band edge. What is the activation energy of this sample?

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ii. *Work function for semiconductors.* Sketch the energy band diagram.
iii. *Drift velocity.* Is it greater than thermal velocity?
iv. *Diffusion current.* Write equations for its major components.
v. *Optical generation.* Would photons of wavelength *1300 nm* be absorbed by gallium arsenide of bandgap *1.4eV*? **[10 Marks]**

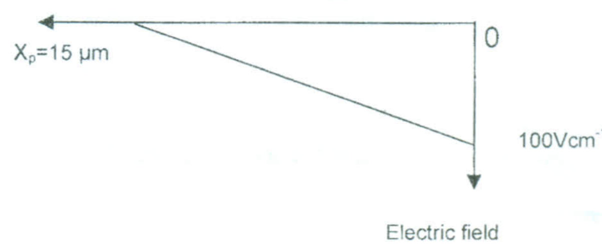
Q.3.b) A semiconductor sample is provided with four contacts and placed in a *10 kG* magnetic field. The current is *5 mA*. The sample dimensions are *w = 0.5 cm, t = 500 pm,* and *L = 1 cm*. The following data are measured: *Hall voltage = 2.4 mV* and *applied voltage = 2 V*. Is the sample n-type or p-type? Find the concentration of the majority carrier and its mobility. **[5 Marks]**

Q.3.c) Derive an expression for the contact potential of a *pn* junction in terms of hole concentration in n-side and p-side. **[5 Marks]**

Q.4.a) Using sketches ***only***, compare between the distributions of voltage, electric field, and charge across a symmetrical p-n junction and a one-sided abrupt p^+n junction. **[5 Marks]**

Q.4.b) A silicon pn^+ junction has the electric field distribution shown. Calculate the following:

i. Contact potential
ii. Acceptor density
iii. Junction capacitance at zero bias, forward bias of *0.2 V*, and reverse bias of *5 V*. **[5 Marks]**



Q.4.c) Starting with Fermi-Dirac distribution function, $f(E)=\dfrac{1}{1+\exp[(E-E_f)/kT]}$, sketch the variation of $f(E)$ versus *E*, for $T=0^\circ K$, $500^\circ K$, $1000^\circ K$, $E_f=1\ eV$ **[5 Marks]**

Q.4.d) Using *E-K* diagram, compare briefly between direct band-gap and indirect band-gap semiconductors. Give examples for each. **[5 Marks]**

Q.5.a) Sketch a simple half-wave rectifier circuit. Apply a sinusoidal signal $V=10\sin(\pi t)$ to the input. Sketch the output waveform. **[5 Marks]**

Q.5.b) Sketch the *V-I* characteristics of zener diode. Sketch a voltage regulation circuit. Suggest suitable values for main circuit components. **[5 Marks]**

Q.5.c) compare briefly between each pair of the following: **[10 Marks]**

- Avalanche breakdown and zener breakdown
- Photo-detector and solar cell
- LED and laser diodes

You may need some or all of the following constants:

Electron mass = $9.1*10^{-31}$ Kg	Avogadro's number = $6.023*10^{23}$ atoms/mole
Electron charge = $1.6*10^{-19}$ C	Proton mass = $1.66*10^{-27}$ Kg
Planck's constant = $6.625*10^{-34}$ J.s.	Boltzman's Constant = $1.38*10^{-23}$ J/K°

My best wishes to all of you! *Assis. Prof. Hossam El-Din Moustafa*
