University of Toronto
Faculty of Applied Science and Engineering
Department of Electrical and Computer Engineering

ECE330F **Semiconductor Physics** **Fall 2001**
http://www.courses.ece.utoronto.ca/ece330f/

Final Examination – December 11, 2001

Exam Type: D
Examiner: Tatiana Allen

Two hand-written aid sheets, written on both sides, are permitted.
Non-programmable calculator allowed.
100 marks constitute a perfect paper; 15 bonus marks available.

ALL WORK TO BE MARKED IS TO BE DONE ON THOSE SHEETS

There are two spare pages at the back

Last name: _____

First name: _____

Student number: _____

Part	Max	Mark
1	5	
2	10	
3	40	
4	20	
5	40	
Total	**115**	**/100**

15 bonus marks

Part 1

1-1

The work function for Na is 2.3 eV.

a) Does Na show a photoelectric effect for yellow light (λ=589 nm)?

2 MARKS

b)What is the cutoff wavelength for photoelectric emission in Na?

λ_{cutoff} =

3 MARKS

Part 2

2-1

The lifetime of an excited state of a nucleus is 10^{-12}s. What is the uncertainty of energy of the γ-ray photon emitted?

$\Delta E =$

3 MARKS

2-2

A thermal neutron has a kinetic energy *(3/2)kT*, where T=300K (room temperature). What is its de Broglie wavelength? Mass of neutron is $1.675\ 10^{-27}$ kg

$\lambda =$

3 MARKS

2-3
Write expressions for group and phase velocities in terms of angular frequency, ω, and wave number, k.

Phase velocity:

Group velocity:

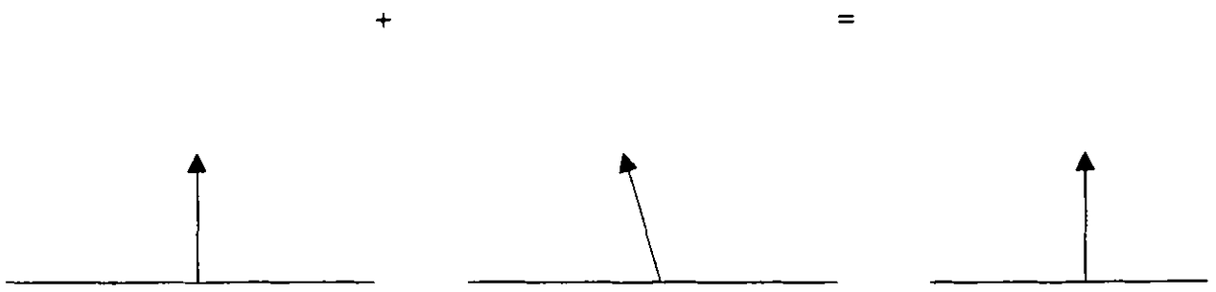
Prove that group velocity is equal to the velocity of the particle, v, whose motion is governed by this group of waves.

4 MARKS

Part 3

3-1

Write one dimensional time-dependent Schroedinger equation and state the physical meaning of each term



3 MARKS

3-2

The electron in Hydrogen atom has the following set of quantum numbers:
$n=2$, $l=1$, $m_l=-1$, $m_s=0.5$. Write down formulae and calculate the values for:

Total electron energy

Total orbital angular momentum

z-component of orbital angular momentum

4 MARKS

3-3

Calculate the expectation value of momentum for a particle in the ground state of 1-dimensional box of width a. The wave-function is

$\Psi(x,t) = (2/a)^{1/2} \cos(\pi x/a) \exp(-iEt/h)$ $\quad -a/2 < x < a/2$

$\Psi(x,t) = 0$ $\quad x < -a/2;\ x > a/2$

<p> =

6 MARKS

3-4

A particle is in the ground state of 1-dimensional box of width a. The wave-function is

$$\Psi(x,t) = (2/a)^{1/2} \cos(\pi x/a) \exp(-iEt/\hbar) \qquad -a/2 < x < a/2$$
$$\Psi(x,t) = 0 \qquad x < -a/2;\ x > a/2$$

Calculate the probability that the particle would be found in a measurement within a distance of a/3 from the right-hand end of the box.

Probability =

10 MARKS

3-5

Particle is approaching a step potential moving from right ($x=\infty$) to left ($x=-\infty$). The potential energy is equal $V(x)=V_0$ for $x>0$ and $V(x)=0$ for $x<0$. The energy of the particle is E, $E>V_0$. Sketch a diagram and derive the expressions for transmission and reflection coefficients.

17 MARKS

Part 4

4-1

Suppose that the dispersion relationship for electrons in the lowest allowed band of a particular one-dimensional crystal is found $E= E_b+C(1-\cos(ka))$, where E_b and C are constants. Find the effective mass for any allowed energy in the band $(-\pi/a< k< \pi/a)$.

Specify the behavior of the effective mass at the following points/regions:

$k= 0$

$k= \pm\pi/2a$

$\pi/2\ a< |k| <\pi/a$

$|k| = \pi/a$

10 MARKS

4-2

Show from the Fermi distribution in a metal at T=0 K that the average energy of an electron is $3E_F/5$.

10 MARKS

Part 5

5-1

A semiconductor is n-type and doped with 10^{15} cm^{-3} donor atoms. The effective densities of states are given by $Nc=Nv=1.5\ 10^{19}$ cm^{-3} and are independent of temperature. The requirement is that at T=400K the electron concentration would be no greater than $1.01\ 10^{15}$ cm^{-3}. What is the minimum acceptable value of the bandgap energy?

Eg =

15 MARKS

5-2

A body-centered cubic (BCC) crystal is made of hard spheres (no overlapping). The lattice parameter is a. Find the packing fraction (P.F. = volume occupied by atoms in unit cell / total volume of the unit cell)

P.F. =

15 MARKS

5-3

Calculate the displacement D of the intrinsic Fermi level of silicon from the center of bandgap at room temperature. Assume $m_n^* = 1.1\ m_0$, $m_p^* = 0.56\ m_0$.

D=

10 MARKS