# CARLETON UNIVERSITY

FINAL
**EXAMINATION**
December 2002

**DURATION: 3 HOURS**

Department Name & Course Number: Electronics 97.475

Course Instructor(s): Tom Smy

AUTHORIZED MEMORANDA
CALCULATOR (Not Programmable)

Students **MUST** count the number of pages in this examination question paper **before** beginning to write, and report any discrepancy immediately to a proctor. This question paper has 12 pages.

This examination question paper **MAY NOT** be taken from the examination room.

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There are six questions on the exam. Attempt all questions - marks for each part are given in the question. Note that the questions are not equally weighted.

1. Basic Quantum Mechanics:

   (a) (15 Marks) **(Don't get stuck on this question – if you find it difficult leave it to last!)** For an electron incident on the energy barrier shown below with E less than the barrier height:

      i. Write down the time independent Schrodingers equations for the appropriate regions (do not solve them!).

      ii. Write down the boundary conditions that must be satisfied at points A, B, C and $x = -infinity$

Basic Quantum Mechanics:(cont.)

iii. Sketch the expected waveforms in the three regions for an electron energy less then $V_O$.

iv. Explain the concept of "QM tunneling" with respect to this problem. Contrast it with the classical problem.

v. Give an actual example of when quantum wells are technologically important.

(b) (10 Marks) What is a wave packet for a free electron? What are group and phase velocities of the wave packet?

2. Band Structures:

   (a) (10) What is the potential description that we use for describing an electron in a piece of semiconductor.

   Specifically:

   - Sketch the potential.
   - Include the variation in the potential due to the atoms in the crystal
   - Show the effect of the finite size of the crystal on the potential.
   - Identify the work function of the metal crystal on the sketch.

   (b) (5) Draw a sketch of the band structure for a simple semiconductor. Identify the features of this sketch with the potential sketched above. Clearly note the effect of the atomic structure and the finite crystal size on the band structure.

   (c) (5) If an intrinsic semiconductor has 8 valance electrons how many bands will be filled with electrons at 0 K. What will happen as the temperature is raised?

   (d) (5 Marks) Sketch the band diagrams of intrinsic and extrinsic (n or p -make your choice) semiconductors and explain the basic differences.

Band Structures (Cont.)

3. (8 Marks) Light:

   (a) (10) A complete description of light requires two complimentary descriptions or models.

      i. Briefly describe physically what each model is and the parameters that are use to characterize each model.

      ii. When modeling the optical fibre which model would we use? Why?

      iii. When modeling an optical amplifier using fibre which model would we need to use? Why?

Light (Cont.)

(b) (10) When light passes through a material we use the index of refraction to account for the material influence.

i. If n is a simple real number how does it effect the light propagation?

ii. If n is a complex number how does it effect the light propagation and what additional physical process is being accounted for?
(Draw some pictures!)

4. MOSFET:

   (a) (5 Marks) Draw the physical structure of an n channel MOSFET.

   (b) (5 Marks) Describe the operation of the device as voltage controlled resistor.

   (c) (5 Marks) If we wish to use the device as an amplifier how do we operate the device and what happens to the channel?

5. Optical communication links:

   (a) (5 Marks) Draw a schematic representation of a basic optical communication system and briefly explain its operation.

   (b) (5 Marks) What are the most important features to consider when determining the wavelength to use in an optical communication system ?

Optical communication links: (cont.)

(c) (5 Marks) What are optical modes and why do we want a fiber to operate in a single mode ?

(d) (3 Marks) What is dispersion in a fibre and how can we minimise it.

(e) (10 bonus) Can you think of a device or way of reversing dispersion? **Leave this to last you will need to be clever!**

6. Optical Devices:

   (a) (10 Marks) What are the basic components of a laser?

   (b) (3 Marks) What determines the wavelength of the laser light?

   (c) (2 Marks) What do we mean by "pumping" a laser?

   (d) (5 Marks) Would it be possible to make a "fibre laser" using optical fibre. How? Can you see any advantages of such a device?

Optical Devices: (cont.)

(e) (10 Marks) What are the basic limitations of a p-n laser diode (homojunction) and how are they solved by using a heterostructure.

(f) (4 Marks) Draw the basic physical structure of a heterojunction laser diode.