ELECTRICAL AND COMPUTER ENGINEERING (ECE)

<u>Supplemental Regulations for Graduate Student Programs</u>
May 2008

> General regulation of the Faculty of Graduate Studies governing graduate programs are published in the *University of Manitoba Graduate Calendar* under Graduate Studies Regulations (see also http://www.umanitoba.ca/graduate_studies). Those general regulations shall apply in all cases as minimal requirements. The supplemental regulations appearing below are either reflections of those regulations or additions to them.

General Office

Head:	U. Annakkage, Ph.D.
Graduate Chair:	D.A. Buchanan, Ph.D., P.Eng.
Address:	ECE Department, E2-390 Engineering, 75 Chancellor's Circle. University of Manitoba, Winnipeg, MB R3T 5V6
Inquiries:	(204) 474-9603 Fax: (204) 261-4639

E-mail: enquiries@ee.umanitoba.ca (for individual e-mail addresses of professors, check our website)
Web: http://www.ee.umanitoba.ca (includes application forms and admission information)

1. Academic Staff

Distinguished Professor: **Shafai**, L., B.E.Sc. (Tehran), M.A.Sc., Ph.D. (Toronto), F.I.E.E.E., P.Eng.

Professors Emeriti

Bridges, E., M.Sc. (E.E.) (Manitoba), P.Eng.; **Kao**, K.C., B.Sc.(E.E.) (Nanking), M.Sc. (Michigan), Ph.D., D.Sc. (Birmingham), F.Inst.P., F.I.E.E., C.Eng., P.Eng.; **Martens**, G.O., B.Sc.(E.E.) (Manitoba), M.A.Sc. (Toronto), Ph.D. (Illinois), P.Eng.; **Swift**, G.W., M.Sc.(E.E.) (Alberta), Ph.D. (Illinois Institute of Technology), P.Eng.; **Wexler**, A., B.Sc.(E.E.) (Manitoba), Ph.D., D.I.C. (London) F.R.S.A., P.Eng.

Senior Scholars

Lehn, W.H., B.Sc.(E.P.) (Manitoba), M.Sc.(E.E.) (M.I.T.), **Menzies**, R.W., B.Sc.(E.E.) (Hons.) McMaster), Ph.D. (St. Andrews), P.Eng.; **Onyshko**, S., M.Sc. (Alberta), Ph.D. (Washington), P.Eng. **Raghuveer**, M.R., B.Sc.(Hons.) (Delhi), B.Eng. (Indian Inst. Sci.), M.Sc. (Manitoba), Ph.D. (Windsor), P.Eng.; **Shwedyk**, E., M.Sc.(E.E.) (Manitoba), Ph.D. (New Brunswick), P.Eng.

Professors

Alfa, A.S. B.Eng. (Ahmadu Bello), M.Sc. (Manitoba), Ph.D. (New South Wales); **Annakkage,** U., B.Sc. (Moratuwa), M.Sc., Ph.D. (Manchester IST); **Bridges**, G.E.J., B.Sc.(E.E.), M.Sc., Ph.D. (Manitoba), P.Eng.; **Buchanan,** D.A., B.Sc., M.Sc. (Manitoba), Ph.D. (Durham); **Ciric**, I.M.R., B.Sc., Dipl.Ing., Ph.D., Dr.Ing. (Bucharest), F.I.E.E.E.; **Gole**, A.M., B.Tech. (Bombay), M.Sc.(EE), Ph.D. (Manitoba), P.Eng.; **Kinsner**, W., M.Sc. (Wroclaw-Breslau), Ph.D. (McMaster), P.Eng.; **LoVetri**, J., B.Sc., M.Sc. (Manitoba), Ph.D. (Ottawa); **McLeod**, R.D., B.Sc. (E.E.), M.Sc., Ph.D. (Manitoba); **Pawlak**, M., M.S. (Control and Comp Eng.), Ph.D. (Comp Eng.) (Wroclaw); **Peters**, J.F., B.A. (California), M.S. (Santa Clara), Ph.D. (Kansas).

Associate Professor

Moussavi, Z., B.Sc. (Sharif U.), M.Sc. (Calgary), Ph.D. (Manitoba); **Oliver**, D. R., B.Sc. (Western Australia), Ph.D. (Monash U); **Shafai**, C., B.Sc. (E.E.), M.Sc. (Manitoba), Ph.D. (Alberta); **Thomson**, D.J., B.Sc.(E.E.), M.Sc. (Manitoba), Ph.D. (Stanford).

Assistant Professors

Cai, J. B.Sc. (Xi'an Jiaotong)**,** M.Sc. (Xi'an Jiaotong), Ph.D. (Waterloo); **Fazel,** R. B.Sc. (Sharif), M.Sc.(Amirkabir); Ph.D. (Manitoba); **Ferens**, K., B.Sc.(E.E.), M.Sc., Ph.D. (Manitoba); **Filizadeh**, S. B.Sc., M.Sc. (Sharif), Ph.D. (Manitoba); **Fung**, WK. B.Eng. (Hong Kong), M. Phil. (Hong Kong), Ph.D. (Hong Kong); **Hossain**, A.E., B.Sc., M.Sc., (Buett), Ph.D. (Victoria); **McNeill**, D., B.Sc., M.Sc., Ph.D. (Manitoba); **Noghanian**, S., B.Sc. (Sharif U), M.Sc., Ph.D., (Manitoba); **Okhmatovski,** V., M.Sc., Ph.D. (Moscow Power Eng. Inst.); **Rajapakse**, A. B.Sc. (U. Moratuwa), M.Eng. (Asian Inst. of Tech.), Ph.D. (Tokyo); **Thomas**, G. B.S.E.E. (IETSM, Mexico), M.Sc., Ph.D. (El Paso); **Yahampath**, P., B.Sc. (Moratuwa), M.Sc. (Trondheim), Ph.D. (Manitoba).

2. Programs and Facilities

Introduction

The Department offers graduate programs leading to the Master of Engineering, Master of Science, and Doctor of Philosophy. The Department has well-equipped research and teaching laboratories. Students may also select a research program in collaboration with industry or research centres in Canada.

Fields of Research

The areas of research in the Department which are internationally recognized are listed below:
Applied Electromagnetics Atmospheric Optics Biomedical Engineering Communications Engineering Computer Architecture and Software Systems Microelectronics Power Apparatus and Systems Engineering Signal and Image Processing

ECE Research Facilities

The Applied Electromagnetics Laboratories has two anechoic chambers in the frequency range of 500 MHz to 50 GHz for antenna research. The larger one is equipped with an automated data acquisition and compact range measurement system; the smaller one has a near-field scanning system. In addition to the anechoic chambers, there is an outdoor antenna measurement range, which is equipped for testing large antenna units. The microwave area has two laboratories for high frequency circuit design and measurements research. The measurement laboratory has a Wiltron 360 network analyzer for measurements up to 65 GHz. The electromagnetic compatibility laboratory is equipped with a large GTEM Cell, an 8 GHz EMI Spectrum Analyser with tracking generator, various high power amplifiers and various calibrated EMC antennas.

The Biomedical Engineering Laboratory includes image acquisition/ processing stations and a fully instrumented 3-dimensional human movement lab including EMG acquisition and analysis. The lab is equipped to monitor and acquire respiratory sounds simultaneously with respiratory airflow as well as video capturing and processing and EMG/ECG signal conditioning and acquisitions. The acoustical research group is aimed at developing a non-invasive technique as an alternative for videoradiography that currently is the only objective assessment for swallowing dysfunction. The Department of Radiology maintains a breeding colony of a species of salamander, the axolotl Ambystoma mexicanum. These are being used to analyze the mechanical and electrical components of the development of axolotl embryos, which provide a good model system for normal development and major birth defects in humans. Equipment for computer controlled time-lapse microscopy is being assembled.

The Software Systems and VLSI laboratory is an area that represents a strong research program in the Department. The VLSI lab is an important component of both Electrical and Computer Engineering, in particular supporting research areas such as electronics, signal processing, control systems, pattern recognition and communications. The laboratory includes a network of Sparc workstations for research and education. The laboratory has access to the fabrication of chip designs, via silicon foundries under the auspices of the Canadian Microelectronics Corporation. The current implementation technologies include fullcustom CMOS, gate arrays including field-programmable devices such as FPGAs, and integrated sensors. CAD packages available include

CADENCE and various circuit and logic simulators. There are also facilities for experimental work with mobile robots and other embedded computing systems hardware. The software systems lab also includes an internet software development component. This aspect of the lab is orientated to developing and improving upon IP based protocols and applications. A number of projects are undertaken ranging from improving the transport layer for the delivery of large amounts of data to web applications incorporating commercial databases and e-commerce.

The Computational Intelligence (CI) Laboratory has a collection of robots (two Kheperas, and a number of individual hexapod and tractor robots). In addition, the CI Laboratory has two Sun workstations, three Pentium workstations, two PowerPC workstations and two printers. Research is carried out in the design of intelligent systems (both hardware and software), data acquisition and classification of data using a number of technologies commonly associated with computational intelligence; namely, fuzzy measure theory, fuzzy sets, fuzzy Petri nets, granular computing, neural networks and, especially, rough neural networks, rough Petri nets, and rough sets. Research in software and hardware system design and measurement using CI technologies is aided by a number of tools such as Rosetta, Rough Set Exploration System (RSES), DesignCPN, and Matlab.

The Power Systems and Machine Laboratories are well equipped with several workstations, a real time digital power system simulator (developed at the HVDC Research Centre), a large variable frequency supply and several well instrumented machine sets. Facilities for developing DSP-based controllers and protection devices are available.

The McMath High Voltage Power Transmission Research Laboratory is the largest of its kind amongst Canadian universities and is equipped with generating and measuring apparatus, including digital data acquisition systems for research on insulation, HV phenomena and diagnostics.

The Data and Signal Compression Laboratory has dedicated and network computers, a high resolution scanner, a video capture facility, a digital camera, a CD-ROM mastering system, and an FPGA development facility. It also has access to a large ATM facility for research.

The Microprobe and Microfabrication Laboratory is a well-equipped laboratory with three faculty members. Topics of interest include scanning probe microscopy, micromachining and microfabrication, semiconductor manufacturing, and high frequency microelectronics and microwave circuit testing. Probe microscopy systems include tunnelling (STM), ultra high vacuum STM, atomic force (AFM), resistive (SRM), capacitive (SCM), and dynamic electrostatic force microscopes used for in situ IC testing. CAD platforms include four SUN Ultra workstations, two Pentium III computers, and G3 and G4 Macintosh computers. CAD tools used are Cadence, L-EDIT and MEMSPro for IC design, and Libra, Spice, Ensemble and HFSS for high frequency modelling. RF test equipment includes 50 GHz sampling scopes, a 6 GHz Network Analyser and on-wafer probing facilities. Microfabrication capabilities include a clean-room, thermal evaporation, 3 inch mask aligner, wet etching, oxidation furnaces, electroplating, UHV system, and an inspection microscope. Equipment to be added in the years 2000-2001 includes a 1000 sq. foot clean-room, 6 inch two-sided mask aligner, ICP plasma etching, XeF2 etching, RF sputtering, E-beam evaporation, Alpha-Step surface profiler, 50 GHz millimeter wave probe station, and a wafer saw.

Embedded Systems Laboratory: The vast majority of computing systems in operation today are not of the desktop variety, but rather are embedded in other devices in order to endow that device with some needed control, communication or signal processing capabilities. The Embedded Systems Laboratory (ESL) focuses on advancing the state-of-the-art in the design of these digital systems through the development and application of novel signal processing and control techniques for non-desktop computing devices and environments. Its facilities include both UNIX and PC based CAD workstations for system design along with prototyping and test equipment. A number of FPGA and microcontroller development tools are available, together with commercial hardware platforms for embedded systems prototyping and evaluation.

Computing facilities: The department has substantial computing facilities used for research. These include a network of over 67 SUN and HP workstations and six undergraduate laboratories with a

total of 84 Pentium computers. A large number of microcomputers are also distributed throughout the department's research laboratories. These computers, as well as those of individual researchers, are networked by Ethernet.

3. General Admission Information

Application for Admission

<mark>All persons wishing to be considered for entry into the graduate program in the Department of Electrical and Computer Engineering *must* complete the online application (http://umanitoba.ca/faculties/graduate_studies). Student applications will be reviewed periodically by members of the academic staff as vacancies become available. Only if an academic staff member has space available and he/she determines that a pre-applicant qualify for graduate work under their supervision, will the student be formally contacted by the Faculty of Graduate Studies Department that they have been accepted as a student in the Department of Electrical and Computer Engineering.</mark>

Grade Point Average (GPA)

The minimum admission standard to be eligible for consideration as a Graduate Student in Electrical and Computer Engineering is a GPA of 3.00, or equivalent, based on the most recent 60 credit hours of required courses (including technical elective courses) taken at or above the 300 level in a relevant degree program. Complementary studies electives are not required courses and therefore will **not** count towards the 60 credit hours.

University of Manitoba students, whose GPA does not meet the minimum requirement for admission as a Graduate Student in ECE, may take a maximum of two extra courses at or above the 300 level from their undergraduate degree program, including technical electives, but excluding complementary studies electives. The two courses may be repeats or new courses and they may be taken either as a Special Student in Engineering or in Continuing Education, subject to admission into one of those faculties. If the substituted grades result in a revised GPA of 3.00 or higher, then the student may apply for admission into the Faculty of Graduate Studies. However, having an eligible GPA does not guarantee acceptance into a Graduate Program.

Students, who received an undergraduate degree from a university other than the University of Manitoba and whose GPA does not meet the minimum requirement for admission as a Graduate Student in ECE, may take a maximum of two extra courses at the University of Manitoba. The two courses must be equivalent to required courses at or above the 300 level from their undergraduate degree program, including technical electives but not complementary studies electives. Courses may be taken as a Special Student in Continuing Education, subject to admission into that faculty. If the substituted grades result in a revised GPA of 3.00 or higher, then the student may apply for admission into the Faculty of Graduate Studies. However, having an eligible GPA does not guarantee acceptance into a Graduate Program.

Financial Support

The advisor may provide financial support to the student in the form of a research assistantship (this is a matter for direct discussion with the advisor). The Faculty of Graduate Studies issues formal letters of acceptance, which do not include financial assistance. Scholarships and fellowships are available as detailed under Awards at the Faculty of Graduate Studies web site www.umanitoba.ca/faculties/graduate_studies/. After admission and registration, students are eligible to apply and compete for Teaching Assistant positions. These positions pay a nominal amount and preference is given to students with seniority.

Program Fees

For information on program fees, refer to www.umanitoba.ca/student/records/fees/grad_fees.shtml. For the purpose of fee assessment only, the Master's program in ECE is considered a one-year program.

4. Qualifying Program (Pre-Master's)

Students who do **not** hold a B.Sc. in Electrical or Computer Engineering, but who wish to pursue a graduate program in the Department of Electrical and Computer Engineering, must apply to the Faculty of Graduate Studies for admission into a qualifying (pre-Master's) program. These students must have an advisor in the ECE Department who will recommend them for admission and provide supervision.

Admission Requirements
The student must hold an undergraduate degree with a minimum Grade Point Average (G.P.A.) of 3.00 in the last two years of full-time study, normally in engineering or a related discipline, from a recognized university.

Program Requirements
The Qualifying Program will be comprised of at least 24 credit hours of advisor-approved course work at the 400 level, **all** from this Department. Upon successful completion of the Qualifying Program with a G.P.A. of 3.00, the student is eligible for application to the Faculty of Graduate Studies for the M.Eng. or M.Sc. program in the Department of Electrical and Computer Engineering. The credit hours from the qualifying program are not transferable to a Master's degree program.

Fees
Tuition fees for the Pre-Master's program are assessed on a per-course basis (or per credit hour basis) from undergraduate faculty fees. Applicants should be aware that the fees for a qualifying program are not transferable for later credit towards a Master's program fee. For details, please refer to www.umanitoba.ca/student/records/fees/grad_fees.shtml

5. Master of Engineering (M.Eng.)
This program is meant to satisfy the particular needs of students and practicing engineers wishing to extend their studies on a broad basis of coursework and an engineering project.

Admission Requirements
In order to be admitted into the M.Eng. degree program in the department, a student must hold a B.Sc. degree in Electrical or Computer Engineering from a recognized University with a Grade Point Average (G.P.A.) of at least 3.00 in the last two full years of their undergraduate program. Students who have completed a Qualifying program at The University of Manitoba with a G.P.A. of at least 3.00 are also eligible for application. Students who have completed pre-Master's or Qualifying programs at other recognized universities may be recommended for admission at the discretion of the departmental Graduate Studies Committee.

Program Requirements
A minimum of 24 credit hours of advisor-approved coursework is required as follows: a minimum of nine credit hours at the 700 level or above from this department; a maximum of nine credit hours of elective courses from this department at the 400 level or above; and a maximum of 12 credit hours from other departments at the 300 level or above. The student may be allowed to take 200 level courses from other departments in exceptional cases (anatomy, etc.) if pre-approved by the advisor. In addition, the student is required to complete an advisor-approved engineering project (see below). The effort involved in this project should be at least the equivalent of six credit hours of coursework. See section 8 for list of approved courses.

Comprehensive/Qualifying examinations
These examinations are not required in the M.Eng. program.

Performance in Coursework
A minimum G.P.A. of 3.00 with no grade less than "C+" must be maintained for continuance in the Master's program. Students who fail to meet this standing may be allowed to continue in the Master's program if departmental remedial action (outlined below), recommended by the student's

advisor, is approved by the Departmental Graduate Studies Committee and the Faculty of Graduate Studies.

(1) Students with failing grades (grade "C" or less) in six hours of credit or more will be required to withdraw from the Faculty.
(2) Students with failing grades in three credit hours will be allowed to repeat the course or to take an equivalent substitute course. In this event the higher grade will be used to compute the student's G.P.A. If a grade of less than "C+" is obtained, again the student will be required to withdraw.
(3) Students are allowed to remove deficiencies in grades, as explained above in #2, only once.

Performance in Project
The student's performance is evaluated by the advisor. An annual progress report is made to the Faculty of Graduate Studies. The report is signed and dated by both the advisor and the student. If performance is deemed to be unsatisfactory, the student will meet with the Department Head alone. If the Department Head confirms that performance is unsatisfactory, then the student will be required to withdraw from the Faculty of Graduate Studies. The student may appeal the Department's decision to the Dean of Graduate Studies.

Project Proposal
The student shall submit a one-page proposal which outlines the nature and scope of the work to be undertaken. This proposal must be submitted within thirteen months of initial registration in the Master's Program. If the proposal is satisfactory, the advisor will recommend its acceptance to the head.

M.Eng. Project (6 credit hours)
The project report shall be written in a style as practised in the Department. The student should submit the project report to all examining committee members at least three weeks prior to the conduct of the oral examination in which the student presents and defends the findings presented in the project report.

The oral examination is chaired by the student's advisor. The examining committee will consist of the advisor, another faculty member from this department and one other faculty member normally either from another department at this university or an approved member from the professional community. The student is expected to present a report in a 30 to 35 minute period, after which the chair invites questions from all members of the examining committee and then the audience. The entire proceedings will normally not exceed 90 minutes in duration. Closed examinations will not be allowed unless approved by the Dean of the Faculty of Graduate Studies.

Expected Time to M.Eng. Graduation: 2 years.

6. Master of Science (M.Sc.)
Admission Requirements
In order to be admitted into the M.Sc. degree program in the department, a student must hold a B.Sc. degree in Electrical or Computer Engineering from a recognized University with a G.P.A. of at least 3.00 in the last two full years of their undergraduate program. Students who have completed a Qualifying program at The University of Manitoba with a G.P.A. of at least 3.00 are also eligible for application. Students who have completed pre-Master's or Qualifying programs at other recognized universities may be recommended for admission at the discretion of the departmental Graduate Studies Committee.

Program Requirements
The M.Sc. shall consist of a minimum of 18 credit hours of advisor-approved course work comprised of a minimum of 12 credit hours at or above the 700 level and six credit hours at or above the 300 level from other departments or 400 level elective courses from this Department. **At least 12 of the 18 credit hours must be from this Department.** See section 8 for list of approved courses.

An M.Sc. thesis, which is based on research work normally carried out at this University, is required. All fulltime M.Sc. students are also required to present a paper, at least once during their program, at the Department's annual graduate student conference, as outlined at the website www.ee.umanitoba.ca/~gradcon/.

Comprehensive/Qualifying examinations
These examinations are not required.

Performance in Coursework
A minimum G.P.A. of 3.00 with no grade less than "C+" must be maintained for continuance in the Master's program. Students who fail to meet this standing may be allowed to continue in the Master's program if departmental remedial action (outlined below), recommended by the student's advisor, is approved by the Departmental Graduate Studies Committee and the Faculty of Graduate Studies.
(1) Students with failing grades ("C" or less) in six hours of credit or more will be required to withdraw from the Faculty.
(2) Students with failing grades in three credit hours will be allowed to repeat the course or to take an equivalent substitute course. In this event the higher grade will be used to compute the student's G.P.A. If a grade of less than "C+" is obtained again the student will be required to withdraw.
(3) Students are allowed to remove deficiencies in grades, as explained above in #2, only once.

Performance in Research
Research performance is evaluated by the advisor and an annual progress report is made to the Faculty of Graduate Studies. The report is signed and dated by both the advisor and the student. If performance is deemed to be unsatisfactory, the student will meet with the Department Head alone. If the Department Head confirms that performance is unsatisfactory, then the student will be required to withdraw from the Faculty of Graduate Studies. The student may appeal the Department's decision to the Dean of Graduate Studies.

Master of Science Thesis Proposal
The student shall submit a one-page proposal which outlines the nature, and scope of the work to be undertaken. This proposal must be submitted within thirteen months of initial registration in the Master's Program. If the proposal is satisfactory the advisor will recommend its acceptance to the head.

Master of Science Thesis
The thesis shall be written in a style as practiced in the Department and recommended by the advisor. The student should submit the thesis to all examining committee members at least four weeks prior to the conduct of the oral examination in which the student presents and defends the findings presented in the thesis. The oral examination is chaired by the student's advisor. The examining committee will consist of a minimum of three members: the student's advisor, another faculty member from this department and one other faculty member normally either from another department at this university or from a department at another university or an approved member from the professional community. At least one member of the examining committee must be a full time faculty member of the Electrical and Computer Engineering Department. The student is expected to present the report in a 30 to 35 minute period, after which the chair invites questions from all members of the examining committee and then the audience. The entire proceedings will normally not exceed 90 minutes in duration. Closed examinations will not be allowed unless approved by the Dean of the Faculty of Graduate Studies.

Expected Time to M.Sc. Graduation: 2 years.

7. Doctor of Philosophy (Ph.D.)
Admission Requirements

In keeping with the admission requirements of the Faculty of Graduate Studies found in the Graduate Studies Regulations Section of this calendar, a student must hold a Master of Science degree in Electrical or Computer Engineering from a recognized university. Provisional acceptance of students nearing completion of the M.Sc. degree in Electrical or Computer Engineering may be considered.

In exceptional cases, a transfer into the Ph.D. program from the M.Sc. program may be recommended for students holding a B.Sc. degree in Electrical or Computer Engineering, provided the following three conditions are met: the transfer occurs within 12 months of initial registration in the M.Sc. program; the student has successfully completed at least nine credit hours of approved course work at or above the 700 level, **all** from this Department; and the transfer is recommended by the departmental Graduate Studies Committee. In this case, the time spent in the Master's program will normally be counted as time in the Ph.D. program.

If preliminary admission into a Master's program is being recommended by the advisor with the intention of reviewing the student's status for possible upgrading to a Ph.D. admission, then this must be indicated on the application form at the time of admission. Otherwise, the student will be required to pay both M.Sc. and Ph.D. program fees (the M.Sc. fees are not transferable to the Ph.D. program).

Qualifying examinations
Such examinations are not normally required.

Advisory Committee
This Committee will be established by the student's advisor in consultation with the head of the department within one month of admission of a student into the Ph.D. program. The departmental Graduate Studies Committee will not be expected, under any circumstances, to carry out duties associated with the Advisory Committee. The Advisory Committee approves the plan of coursework as submitted by the advisor. All course and program changes initiated by the advisor must be approved by the Advisory Committee. The Advisory Committee must consist of a minimum of three members which will include the student's advisor, another faculty member from this department and one other faculty member either from another department at this university or an approved member from the professional community. At least one member of the advisory committee must be a full-time faculty member of the Electrical and Computer Engineering Department.

Program Requirements
In keeping with the minimum course requirements of the Faculty of Graduate Studies found in the Graduate Studies Regulations Section of this calendar, the Ph.D. program in Electrical and Computer Engineering depends on student classification as follows: **(1)** For students who hold an M.Sc. degree in Electrical or Computer Engineering and who have been admitted directly into the Ph.D. program, a minimum of 12 credit hours of Advisory Committee-approved course work is required at or above the 700 level. **At least 9 of the 12 credit hours must be from this Department. (2)** For students who hold a B.Sc. degree in Electrical or Computer Engineering and who are recommended for transfer into the Ph.D. program from the M.Sc. program in Electrical and Computer Engineering at this university, a minimum of 24 credit hours of Advisory Committee-approved course work is required, of which 18 credit hours must be at or above the 700 level, and the balance of 6 credit hours may be at or above the 300 level from other departments or 400 level elective courses from this department. **At least 15 of the 24 credit hours must be from this Department.** Credit will be given for approved course work completed at the M.Sc. level. **(3)** For all other categories of students, a minimum of 18 credit hours of Advisory Committee-approved course work is required, of which 12 credit hours must be at or above the 700 level and the balance of 6 credit hours may be at or above the 300 level from other departments or 400 level elective courses from this department. **At least 12 of the 18 credit hours must be from this Department.** See section 8 for list of approved courses.
A Ph.D. thesis, which is based on research work normally carried out at this university, is required. All fulltime Ph.D. students are also required to present a paper every year of their program at the Department's annual graduate student conference, as outlined at the web site: www.ee.umanitoba.ca/~gradcon/.

Performance in Coursework

A minimum G.P.A. of 3.00 with no grade less than "C+" must be maintained for continuance in the Ph.D. program. Students who fail to meet this standing may be allowed to continue in the Ph.D. program if departmental remedial action (outlined below), recommended by the student's advisory committee, is approved by the Departmental Graduate Studies Committee and the Faculty of Graduate Studies.

(1) Students with failing grades ("C" or less) in six hours of credit or more will be required to withdraw from the Faculty.

(2) Students with failing grades in three credit hours will be allowed to repeat the course or to take an equivalent substitute course. In this event the higher grade will be used to compute the student's G.P.A. If a grade of less than "C+" is obtained, again the student will be required to withdraw.

(3) Students are allowed to remove deficiencies in grades, as explained above in #2, only once.

Performance in Research

This is evaluated annually though a meeting of the Advisory Committee with the student. The decision is conveyed to The Faculty of Graduate studies using the "Ph.D. Annual Progress Report". Members of the Advisory Committee and the student are required to sign and date this form. Students who receive a rating of "unsatisfactory" will be required to withdraw from the Faculty of Graduate Studies.

Candidacy Examination and Thesis Proposal

The purpose of the Candidacy examination and thesis proposal defence is to ascertain if the student has sufficient knowledge in the chosen area of research, to assess the quality of the work done by the student, and to examine the student's future research plan and direction through examination of the research proposal. Normally, this examination must take place within 27 months of initial registration in the Ph.D. program. The student will submit a written report of about 40 pages. It is the advisor's responsibility to ensure that all members of the Advisory Committee have at least three weeks to study the report before attending an oral presentation by the student. This presentation is chaired by the advisor. The student is expected to present the report in a 30 to 35 minute period after which the chair invites questions from all members of the examining committee and then the audience. The entire proceedings will normally not exceed 90 minutes in duration. The decision of the examiners will fall into one of two categories:

(i) The student passes the candidacy examination and thesis proposal with or without any revisions in the student's research plan.

(ii) The student fails the candidacy examination and thesis proposal defense.

No student may sit for this examination and defense more than twice. Any student who fails the examination twice will be required to withdraw from the Faculty of Graduate Studies. The interval between the two examinations shall not be less than six months. On successful completion of the candidacy examination the student will be considered a candidate for the Ph.D. degree.

Ph.D. Thesis Regulations

The Candidacy Examination/Thesis Proposal defense shall constitute the thesis proposal requirement. The proposal must be approved by the Advisory Committee on the Ph.D. Thesis Proposal Approval Form and sent to the Faculty of Graduate Studies. The thesis shall be written in a style as practiced in the Department and recommended by the advisor. The student shall submit copies of the advisor-approved thesis and a completed form "PhD Thesis Title & Appointment of Examiners" to the Faculty of Graduate Studies at least six weeks prior to the conduct of the oral defense. Sufficient copies must be submitted for distribution to each member of the examining committee. The student is required to present the results and report of the thesis in a 30 to 35 minute period after which the chair invites questions from all members of the examining committee as provided for in the "Guidelines for the Scheduling and Conduct of the Ph.D. Oral Examination" by the Faculty of Graduate Studies. The entire proceedings will normally not exceed 120 minutes in duration. Closed examinations will not be allowed unless approved by the Dean of the Faculty of Graduate Studies. The final examination for the Ph.D. degree shall be carried out in accordance with the regulations of the Faculty of Graduate Studies.

Thesis Examiners

The student's advisor, in consultation with the advisory committee, will forward, to the Head of the Department, the names of at least three internal thesis examiners for recommendation to the Dean of Graduate Studies. These thesis examiners will include the student's advisor, another faculty member from this department, and one other faculty member either from another department at this university or an approved member from the professional community. At least one member of the examining committee must be a full-time faculty member of the Electrical and Computer Engineering Department. Under normal circumstances the internal examiners will be members of the student's advisory committee. The choice of an external examiner is made by the advisory committee and nominated by the Head to the Dean of Graduate Studies who issues the formal invitation to the external examiner. The external examiner should be encouraged to attend the oral examination. Financial assistance may be available from the University to help make this possible.

Expected Time to Ph.D. Graduation: 3.5 years

8. ECE Course Descriptions

For the list of ECE graduate courses being offered in the current year, please refer to the department website under Programs, Graduate, Course Descriptions. Below is a complete list of developed courses, but they are not all offered in any given year.

Computer Science Courses
74.781 Computer Networks
74.785 Advances in Parallel Computing
74.795 Advanced Topics in AI: Humanoid Robotics
74.795 Advanced Topics in AI: Mobile Robotics

ECE 7010 High Voltage Techniques and Insulation Design Criteria (3) Laboratory generation and measurement techniques related to ac and dc high voltages, conventional and steep front high voltage pulses, composite voltages and pulsed currents. Charge measurements. Test techniques for assessing insulation quality and life.

ECE 7020 Power Transmission Lines: Phenomenon and Insulation Design (3) High voltage dc, ac and hybrid transmission line corona modes, electrostatic and ionized field calculations, field effects of overhead transmission lines. Surge propagation including corona effect. Transmission line insulation design to withstand normal/abnormal voltages and conditions. Modern and conventional arrestors. Principles and practice of insulation co-ordination.

ECE 7040 Signal and Data Compression (3) The course presents the theory of signal and data compression with their applications in engineering, including lossless compression (Shannon-Fano, Huffman, arithmetic and dictionary) and lossy compression, including scalar and vector quantization. References to sub-band and transform coding (wavelets and fractal) and analysis-synthesis coding will be made.

ECE 7050 Switching and Automata Theory (3) The course presents basic material in discrete mathematics and the theory of switching circuits. It provides electrical and computer engineering students with a firm basis in the modern theory of logic design, and illustrates some applications through formal characterization of combinational functions and sequential machines, using contemporary techniques for the automatic synthesis and diagnosis of digital systems.

ECE 7060 Power System Protection (3) History and philosophy of power system protection; typical protection schemes; instrument transformers; protection hardware and application; hardware testing techniques; software models and their use in simulation studies.

ECE 7070 Power System Analysis (3) Power system operation; load flow analysis; transient stability modelling and simulation using the classical model; detailed machine models for transient stability analysis, modelling of exciters, governors, and FACTS devices for transient stability analysis; methods of transient stability analysis; voltage stability concepts and assessment.

ECE 7210 Fractal and Chaos Engineering (3) This course presents the general theory of fractals and their applications in engineering, including fractal modelling of complex phenomena, such as dielectric discharges, and fractal image compression. It also relates fractals to chaos and dynamics.

ECE 7220 Topics in VLSI Test and Fault Tolerance (3) Faults and fault models for VLSI. Test generation algorithms. Design for testability: scan design for sequential circuits; built-in test; testable PLA design. Totally self-checking logic. Fault tolerance in VLSI: yield and performance enhancement through redundancy. System level diagnosis: applications to VLSI processor arrays.

ECE 7230 Artificial Neural Circuits and Networks (3) Examination of electronic neural networks and related computational systems, both from a circuit theory and from a system-theory perspective. Digital and analog VLSI implementations of neural systems are presented and compared. Connections with other systems from physics, biology and computer science are made.

ECE 7240 Signal Theory (3) Representation and analysis of deterministic signals: Continuous and Discrete; Random processes and spectral analysis; Band-limited signals and systems.

ECE 7250 Information Theory and Applications (3) Development of information theory and the engineering implications for the design of communication systems and other information handling systems.

ECE 7270 Scattering and Diffraction of Electromagnetic Waves (6) Formulation and analysis of scattering problems by classical methods. Radar cross section of smooth bodies by geometrical and physical optics. Diffraction by edges. Impedance and Leontovitch boundary conditions.

ECE 7280 Static Compensation in Power Systems (3) Requirements for Static Compensation in Power Systems. The thyristor controlled reactor (TCR) and thyristor switched capacitor (TSC). Advanced GTO thyristor compensators. Operation and control of compensators. Load Compensation, filter design and specifications.

ECE 7310 Power System Transient Simulation (3) Methods of Network Equation Formulation; Modeling of network nonlinearities and transmission lines; Modeling of electrical machines and controls.

ECE 7320 Sampled-Data Control Systems (3) Analysis and design of discrete-time systems, compensation to improve stability and performance, introduction to digital logic control. Note: Credit not to be held with ECE 4420.

ECE 7330 Experimental Methods for Electronic Materials (3) Methods for growing and analyzing electronic materials. Growth will include chemical vapour deposition, diffusion, and plasma processing. Analysis will include capacitance, voltage and current voltage techniques.

ECE 7340 Topics in Modern Control Theory (3). **Not currently offered.**

ECE 7370 Memory Devices and Systems (3) Review of computing system architectures. Memory structures and implementations: static, dynamic, synchronous, asynchronous, single and multiport. Testability of memories. Smart memories. Memories for VLSI: configurable and reconfigurable. Case study of a CMOS self-synchronizing RAM.

ECE 7400 Neural Nets and Neurocomputing (3) Foundations of neural networks. Basic architecture and different structures. Associative networks. Mapping networks. Spatio-temporal networks. Learning and adaptability. Supervised and unsupervised learning. Stability. Adaptive resonance networks. Self-organization. Examples of existing systems. Applications.

ECE 7410 Phased Array Antennas (3) Linear and Planar Arrays Theory; Pattern Synthesis Techniques, Analysis and Design of Radiating elements, Phase Shifters and Beam-Forming Network; Scanning Techniques; Effect of phase, amplitude and mechanical errors on Array Performance.

ECE 7430 Experimental Methods of Microwave Engineering (3) Methods for determining: scattering parameters; insertion, mismatch and return loss; cavity parameters. Detector and mixer performance characteristics. Power measurement. System noise determination. Antenna radiation pattern and gain measurements.

ECE 7440 Current Research Issues in Electrical Engineering (3) Presentation of important research developments in the area of Electrical Engineering, selected to complement other established graduate courses. *Approval of the Head of the Department is required to register for this course.*

ECE 7450 High Frequency Integrated Circuit Design and Analysis (3) Monolithic microwave integrated circuit fabrication and circuit design techniques. Analysis and modeling of microwave passive components and GaAs active devices. High frequency circuit simulation techniques. Basic circuit examples.

ECE 7460 Real time Process Engineering (3) Identification, description, and analysis of the behaviour of systems of real-time communicating processes, and the application of real-time process algebra in the design of hardware and software systems. *Prerequisite: 074.343*

ECE 7480 Digital Electronics (3). **Not currently offered.**

ECE 7490 Verification Tools (3) Study of automated reasoning systems useful in describing and reasoning about properties of hardware and software systems. Investigate mechanizations of

process algebra, representations of communicating processes, time-critical process constructors, time-outs, communication constructs, sequential and parallel computation. *Prerequisite: 074.343.*

ECE 7540 Selected Topics of Solid State Electronics (3) Homojunction and heterojunction phenomena; Gunn effect, organic semiconductors, properties of thin films, quantum electronic devices, space charge limited current devices, and newly developed solid state electronic devices.

ECE 7550 ELD EHV and UHV-AC Transmission Line Design (3). Not currently offered.

ECE 7590 Telecommunication Networking (3) This course will cover issues in the design and analysis of telecommunication networks and systems in terms of physical implementation, protocols, routing algorithms, management, software interfaces, and applications. Focus will be on high speed LAN, WAN and Telecommunication networks using a systems engineering perspective. *Prerequisites: although no prerequisites are required, either course ECE.425 or 074.430 would be recommended.*

ECE 7600 System Protection (3) The fundamentals of fault detection for transmission lines, generators and buses, especially using digital microchip realizations.

ECE 7650 Current Research in Computer Engineering (3) Presentation of important research developments in the area of Computer Engineering, selected to complement other established graduate courses in this area.

ECE 7660 Logic Problem Solving (3) Introduction to declarative techniques in symbolic problem solving with emphasis on relational representations, query construction, and recursive formulations of knowledge structures in engineering.

ECE 7670 Optimization Methods for Computer-aided Design (3) Constrained optimization of functions of several variables. Optimization methods suitable for the solution of engineering problems by modern digital computers. Both gradient and direct search methods are included.

ECE 7680 Dielectric Properties and Phenomena (3) Elementary structure of matter, polarization, response of dielectrics to static and periodic fields, ionization and decay processes, electrical breakdown of gases, liquids, and solids.

ECE 7700 Nonlinear Systems Analysis I (3) Introduction to nonlinear phenomena; linearization; statespace methods — quantitative and qualitative; introduction to the principal methods of determining stability.

ECE 7720 Optimal Control I (3) Introduction to optimal control systems; topics will include statement of thecontrol problem, controllability, calculus of variations, Pontryagin's Maximum Principle, and design of optimal controls.

ECE 7740 Physical Electronics I (3) Fundamental principles. **Not currently offered.**

ECE 7750 Physical Electronics II (3) Properties of materials. Semiconductors, junction phenomena; ferroelectrics, magnetic materials, superconductivity, optical processes, effects of radiation. *Prerequisite: 360 and 419 or equivalent.*

ECE 7780 Microwave Circuits (3) Circuit properties of microwave transmission systems. Matrix representation and analysis of microwave networks, microwave junctions, resonators, and impedance matching networks.

ECE 7810 Solution of Fields by Numerical Methods I (3) Numerical integration, differentiation. Finite difference solutions of the Poisson, Laplace and Helmholtz equations. Initial-value problems. The eigen problem. Examples chosen from electromagnetic, thermal, fluid-flow, stress, and other fields.

ECE 7890 Power System Control (3). Not currently offered.

ECE 7920 Human Physiology for Engineers (3) The analysis and measurements of human physiological systems. Anatomical descriptions are limited to those required to support the functional analysis. Mathematical modeling is reinforced by analog and digital computer models.

ECE 7990 HVDC Transmission I (3) Rectifier-inverter fundamentals. Compounding and regulation. Grid firing control systems. Reactive power requirements. Ground return and electrode design. Transmission lines. Economics and efficiency.

ECE 8000 HVDC Transmission II (3) Protection. Harmonics: telephone interference. Corona: radio and television interference. Analytical methods. Conversion equipment, the use of solid devices. Selected topics from current literature. *Prerequisite: 799.*

ECE 8010 Advanced Network Synthesis (3). Not currently offered.

ECE8050 Topics in Microelectronics (3) Equilibrium and non-equilibrium processes in semiconductors, properties of junctions and thin films, carrier transport phenomena, effects of traps, and selected topics pertinent to recent literature in microelectronics.

ECE8110 Digital Systems Design (3) Fixed-instruction-set microprocessor design; microprogramming, bitslice based design; parallel processing and multiprocessing; applications to data acquisition, data logging, and data communications.

ECE 8130 Statistical Communication Theory (3) Representations of random processes; signal detection and estimation techniques.

ECE 8140 Digital Communications and Coding (3) Fundamentals of information theory; source and channel coding; digital modulation techniques.

ECE 8150 Digital Signal Processing (3) Discrete-time linear system theory, digital filter design techniques, discrete Fourier transforms including FFT, discrete Hilbert transform, Walsh-Hadamard transforms high-speed convolution and correlation techniques.

ECE 8160 Digital Filters (3) Theories, techniques and procedures used to analyze, design and implement digital filters in both software and hardware.

ECE 8190 Topics in Antenna Theory and Design (3) Antennas as a boundary value problem, antenna parameters, analysis and synthesis methods, antenna measurements.

ECE 8200 Advanced Engineering Electromagnetics (3) Solution of wave equation; special theorems and concepts, computer aided analysis.

ECE 8210 Power Electronic Circuits (3) Thyristor properties, ac controllers, controlled rectifiers, dc to dc converters (choppers), and inverters. Permission of instructor required. Credit not to be held with ECE 4370.

ECE 8220 Digital Image Processing (3) Digital representation of images. Two-dimensional operations and transforms. Image enhancement, restoration, and coding. Reconstruction from projections. *Prerequisite: 006.3430 or equivalent (ECE 3580 or equivalent desirable).*

ECE 8230 Pattern Recognition and Scene Analysis (3) Supervised and unsupervised learning techniques. Linear discriminant analysis. Scene analysis methods. *Prerequisite: 005.2500 or equivalent (006.3430 or equivalent desirable).*

ECE 8240 Parallel Processing Architecture (3) Abstract parallel processing system (APPS), Flynn's classification, pipelining, crossbar switches, associative parallel processors, Bene's network, multistage interconnection networks (MIN), alternating sequential parallel processing.

ECE 8270 Computer Communication Networks (3) Overview of existing computer networks. Elements of queueing theory. Error, delay, cost and capacity analysis. Fixed assignment schemes. Packet and switched networks. Random access. Satellite networks. Hybrid protocols.

ECE 8280 Electromagnetic Field Modelling (3) Coulombian and amperian models for polarized media and magnetized media; uniqueness theorems, formulation and classical methods of analysis of static, stationary and quasistationary field problems; modelling of electromagnetic fields in the presence of moving solid conductors; elements of relativistic electrodynamics.

ECE 8300 Computer Vision (3) This course is an extension of ECE.822 "Digital Image Processing". Techniques of image modelling, segmentation, texture analysis, matching and inference will be studied.

ECE 8310 Computer-Aided Design in Biomedical Engineering (3). Not currently offered.

ECE 8320 Advanced Topics in Power Systems (3) Study of selected topics of recent advances in electrical power systems.

ECE 8360 VLSI Design Methodology (3) Design of custom and semi-custom Very Large Scale Integrated (VLSI) circuits and systems including design for testability. Static and dynamic VLSI circuits; software design tools, layout, logic and timing simulation. *Prerequisites: 2220, 3620, 4240, 4180 or equivalent.*

ECE 8370 Topics in Biomedical Engineering (3) A discussion of current topics in biomedical engineering. The latest in instrumentation, procedures and practices relevant both to clinical engineering and ongoing research are covered. *Prerequisite: ECE .4400 or consent of instructor.*

ECE 8380 Reflector Antennas (3). Not currently offered.

ECE 8400 Intelligent Systems (3) Continuation of ECE.766 "Resolution Problem Solving", plan formation, default and temporal reasoning as applicable to engineering.