Electrical and Computer Engineering

This section presents the requirements for programs in:

- M.A.Sc. Electrical and Computer Engineering
- M.Eng. Electrical and Computer Engineering
- M.A.Sc. Electrical and Computer Engineering with Concentration in Modeling and Simulation
- M.Eng. Electrical and Computer Engineering with Concentration in Modeling and Simulation
- M.A.Sc. Electrical and Computer Engineering with Concentration in Software Engineering
- M.Eng. Electrical and Computer Engineering with Concentration in Software Engineering
- M.A.Sc. Electrical and Computer Engineering with Collaborative Specialization in Climate Change
- M.Eng. Electrical and Computer Engineering with Collaborative Specialization in Climate Change
- M.A.Sc. Electrical and Computer Engineering with Collaborative Specialization in Cybersecurity
- M.Eng. Electrical and Computer Engineering with Collaborative Specialization in Cybersecurity
- M.A.Sc. Electrical and Computer Engineering with Collaborative Specialization in Data Science
- M.Eng. Electrical and Computer Engineering with Collaborative Specialization in Data Science
- Cooperative Master's Degree
- Ph.D. Electrical and Computer Engineering
- Ph.D. Electrical and Computer Engineering with Concentration in Software Engineering

Program Requirements

Subject to the approval of the departmental chair, a student may take up to half of the course credits in the program in other disciplines (e.g., Mathematics, Computer Science, Physics).

Master's programs with a thesis earn the Master of Applied Science degree, while other master's programs earn the Master of Engineering degree.

M.A.Sc. Electrical and Computer Engineering (5.0 credits)

Requirements:
1. 2.5 credits in courses 2.5
2. 2.5 credits in Thesis 2.5
Total Credits 5.0

M.Eng. Electrical and Computer Engineering (4.5 credits)

Requirements - by project:
1. 0.5 credit in: SYSC 5902 [0.5] Research Methods for Engineers 0.5
2. 4.0 credits in courses 4.0
Total Credits 4.5

M.A.Sc. Electrical and Computer Engineering with Concentration in Modeling and Simulation (5.0 credits)

Requirements - by coursework:
1. 0.5 credit in: SYSC 5902 [0.5] Research Methods for Engineers 0.5
2. 4.0 credits in courses 4.0
Total Credits 4.5

Requirements - by thesis (5.0 credits)
1. 1.5 credits from modeling and simulation core courses:
   - SYSC 5001 [0.5] Simulation and Modeling
   - SYSC 5004 [0.5] Optimization for Engineering Applications
   - SYSC 5101 [0.5] Design of High Performance Software
   - SYSC 5103 [0.5] Software Agents
   - SYSC 5104 [0.5] Methodologies For Discrete-Event Modeling And Simulation
   - SYSC 5207 [0.5] Distributed Systems Engineering
   - SYSC 5405 [0.5] Pattern Classification and Experiment Design
   - SYSC 5703 [0.5] Integrated Database and Cloud Systems
   Total Credits 1.5
2. 1.0 credit in courses 1.0
3. 2.5 credits in:
Total Credits 5.0

M.Eng. Electrical and Computer Engineering with Concentration in Modeling and Simulation (4.5 credits)

Requirements - by project
1. 0.5 credit in:
   - SYSC 5902 [0.5] Research Methods for Engineers 0.5
2. 0.5 credit in project:
   - SYSC 5900 [0.5] Systems Engineering Project (in the area of modeling and simulation) 0.5
3. 2.0 credits from modeling and simulation core courses:
   - SYSC 5001 [0.5] Simulation and Modeling
   - SYSC 5004 [0.5] Optimization for Engineering Applications
   - SYSC 5101 [0.5] Design of High Performance Software
   - SYSC 5103 [0.5] Software Agents
   - SYSC 5104 [0.5] Methodologies For Discrete-Event Modeling And Simulation
   - SYSC 5207 [0.5] Distributed Systems Engineering
   - SYSC 5405 [0.5] Pattern Classification and Experiment Design
   - SYSC 5703 [0.5] Integrated Database and Cloud Systems
Total Credits 2.0
4.  **1.5 credits in** courses, which may include up to an additional 0.5 credit in project  

<table>
<thead>
<tr>
<th>Course</th>
<th>Credits</th>
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<tbody>
<tr>
<td>SYSC 5909</td>
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</table>

**Total Credits**  

4.5

**Requirements - by coursework:**

1.  **0.5 credit in:**  
   SYSC 5902 [0.5] Research Methods for Engineers

2.  **2.0 credits from** modeling and simulation core courses:
   - SYSC 5001 [0.5] Simulation and Modeling
   - SYSC 5004 [0.5] Optimization for Engineering Applications
   - SYSC 5101 [0.5] Design of High Performance Software
   - SYSC 5103 [0.5] Software Agents
   - SYSC 5104 [0.5] Methodologies For Discrete-Event Modeling And Simulation
   - SYSC 5207 [0.5] Distributed Systems Engineering
   - SYSC 5405 [0.5] Pattern Classification and Experiment Design
   - SYSC 5703 [0.5] Integrated Database and Cloud Systems

3.  **2.0 credits in courses**

<table>
<thead>
<tr>
<th>Course</th>
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<tbody>
<tr>
<td>SYSC 5001</td>
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</table>

**Total Credits**  

4.5

**M.A.Sc. Electrical and Computer Engineering with Concentration in Software Engineering (5.0 credits)**

**Requirements - thesis pathway:**

1.  **1.5 credits from Software Engineering core:**  
   SYSC 5001 [0.5] Simulation and Modeling
   SYSC 5004 [0.5] Optimization for Engineering Applications
   SYSC 5101 [0.5] Design of High Performance Software
   SYSC 5103 [0.5] Software Agents
   SYSC 5104 [0.5] Methodologies For Discrete-Event Modeling And Simulation
   SYSC 5105 [0.5] Software Quality Engineering and Management
   SYSC 5206 [0.5] Resource Management on Distributed Systems
   SYSC 5207 [0.5] Distributed Systems Engineering
   SYSC 5500 [0.5] Designing Secure Networking and Computer Systems
   SYSC 5701 [0.5] Operating System Methods for Real-Time Applications
   SYSC 5703 [0.5] Integrated Database and Cloud Systems
   SYSC 5705 [0.5] Model-Driven Development of Real-Time and Distributed Software
   SYSC 5805 [0.5] Advanced Topics in Software Engineering
   SYSC 5807 [0.5] Advanced Topics in Computer Systems
   SYSC 5809 [0.5] The Internet of Things

2.  **1.0 credit in courses**

<table>
<thead>
<tr>
<th>Course</th>
<th>Credits</th>
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<tbody>
<tr>
<td>SYSC 5909</td>
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3.  **2.5 credits in:**

<table>
<thead>
<tr>
<th>Course</th>
<th>Credits</th>
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<tbody>
<tr>
<td>SYSC 5909</td>
<td>2.5</td>
</tr>
</tbody>
</table>

**Total Credits**  

5.0

**M.Eng. Electrical and Computer Engineering with Concentration in Software Engineering (4.5 credits)**

**Requirements (by coursework):**

1.  **0.5 credit in:**  
   SYSC 5902 [0.5] Research Methods for Engineers

2.  **2.0 credits from software engineering core courses:**
   - SYSC 5001 [0.5] Simulation and Modeling
   - SYSC 5004 [0.5] Optimization for Engineering Applications
   - SYSC 5101 [0.5] Design of High Performance Software
   - SYSC 5103 [0.5] Software Agents
   - SYSC 5104 [0.5] Methodologies For Discrete-Event Modeling And Simulation
   - SYSC 5105 [0.5] Software Quality Engineering and Management
   - SYSC 5206 [0.5] Resource Management on Distributed Systems
   - SYSC 5207 [0.5] Distributed Systems Engineering
   - SYSC 5500 [0.5] Designing Secure Networking and Computer Systems
   - SYSC 5701 [0.5] Operating System Methods for Real-Time Applications
   - SYSC 5703 [0.5] Integrated Database and Cloud Systems
   - SYSC 5705 [0.5] Model-Driven Development of Real-Time and Distributed Software
   - SYSC 5805 [0.5] Advanced Topics in Software Engineering
   - SYSC 5807 [0.5] Advanced Topics in Computer Systems
   - SYSC 5809 [0.5] The Internet of Things

3.  **2.0 credits in courses**

<table>
<thead>
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<tr>
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</table>

**Total Credits**  

4.5

**Requirements (by project):**

1.  **0.5 credit in:**  
   SYSC 5902 [0.5] Research Methods for Engineers

2.  **0.5 credit in:**  
   SYSC 5900 [0.5] Systems Engineering Project in the area of Software Engineering

3.  **2.0 credits from software engineering core courses:**
   - SYSC 5001 [0.5] Simulation and Modeling
   - SYSC 5004 [0.5] Optimization for Engineering Applications
   - SYSC 5101 [0.5] Design of High Performance Software
   - SYSC 5103 [0.5] Software Agents
   - SYSC 5104 [0.5] Methodologies For Discrete-Event Modeling And Simulation
   - SYSC 5105 [0.5] Software Quality Engineering and Management

<table>
<thead>
<tr>
<th>Course</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYSC 5001</td>
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</tr>
</tbody>
</table>
### M.A.Sc. Electrical and Computer Engineering with Collaborative Specialization in Climate Change (5.0 credits)

**Requirements:**

1. **1.0 credit in:**
   - CLIM 5000 [1.0] Climate Collaboration

2. **0.0 credit in:**
   - CLIM 5800 [0.0] Climate Seminar Series

3. **1.5 credits in courses**

4. **2.5 credits in:**

**Total Credits** 5.0

### M.A.Sc. Electrical and Computer Engineering with Collaborative Specialization in Cybersecurity (5.0 credits)

**Requirements:**

1. **1.0 credit in:**
   - CYBR 5000 [1.0] Science and Social Science of Cybersecurity

2. **0.5 credits in courses**

3. **2.5 credits in:**

**Total Credits** 5.0

### M.Eng. Electrical and Computer Engineering with Collaborative Specialization in Climate Change (4.5 credits)

**Requirements - coursework pathway (4.5 credits)**

1. **1.0 credit in:**
   - CLIM 5000 [1.0] Climate Collaboration

2. **0.0 credit in:**
   - CLIM 5800 [0.0] Climate Seminar Series

3. **1.5 credits in courses**

4. **2.5 credits in:**
   - SYSC 5902 [0.5] Research Methods for Engineers
   - SYSC 5900 [0.5] Systems Engineering Project (in the area of climate change)

**Total Credits** 4.5

### M.Eng. Electrical and Computer Engineering with Collaborative Specialization in Cybersecurity (4.5 credits)

**Requirements - coursework pathway (4.5 credits)**

1. **0.5 credit in:**
   - SYSC 5902 [0.5] Research Methods for Engineers

2. **1.0 credit in:**
   - CYBR 5000 [1.0] Science and Social Science of Cybersecurity

3. **2.5 credits in courses**

4. **0.5 credit in:**
   - SYSC 5900 [0.5] Systems Engineering Project (in the area of cybersecurity)

**Total Credits** 4.5
4. **3.0 credits in** courses, including 0.5 credit in approved elective in the area of the specialization 3.0

**Total Credits**: 4.5

### M.A.Sc. Electrical and Computer Engineering with Collaborative Specialization in Data Science (5.0 credits)

**Requirements - by Thesis (5.0 credits)**

1. **0.5 credit in**: 0.5
   - DATA 5000 [0.5] Data Science Seminar

2. **0.5 credit from** data science elective courses: 0.5
   - SYSC 5001 [0.5] Simulation and Modeling
   - SYSC 5004 [0.5] Optimization for Engineering Applications
   - SYSC 5101 [0.5] Design of High Performance Software
   - SYSC 5103 [0.5] Software Agents
   - SYSC 5104 [0.5] Methodologies For Discrete-Event Modeling And Simulation
   - SYSC 5201 [0.5] Computer Communication
   - SYSC 5207 [0.5] Distributed Systems Engineering
   - SYSC 5303 [0.5] Interactive Networked Systems and Telemedicine
   - SYSC 5306 [0.5] Mobile Computing Systems
   - SYSC 5401 [0.5] Adaptive and Learning Systems
   - SYSC 5405 [0.5] Pattern Classification and Experiment Design
   - SYSC 5407 [0.5] Planning and Design of Computer Networks
   - SYSC 5500 [0.5] Designing Secure Networking and Computer Systems
   - SYSC 5703 [0.5] Integrated Database and Cloud Systems

3. **2.5 credits in** courses, which may include up to an additional 0.5 credit in project 2.5

4. **0.5 credit in**: 0.5
   - SYSC 5900 [0.5] Systems Engineering Project in the area of data science

**Total Credits**: 4.5

### M.Eng. Electrical and Computer Engineering with Collaborative Specialization in Data Science (4.5 credits)

**Requirements - by Coursework (4.5 credits)**

1. **0.5 credit in**: 0.5
   - DATA 5000 [0.5] Data Science Seminar

2. **1.5 credits from** data science elective courses: 1.5
   - SYSC 5001 [0.5] Simulation and Modeling
   - SYSC 5004 [0.5] Optimization for Engineering Applications
   - SYSC 5101 [0.5] Design of High Performance Software
   - SYSC 5103 [0.5] Software Agents
   - SYSC 5104 [0.5] Methodologies For Discrete-Event Modeling And Simulation
   - SYSC 5201 [0.5] Computer Communication
   - SYSC 5207 [0.5] Distributed Systems Engineering
   - SYSC 5303 [0.5] Interactive Networked Systems and Telemedicine
   - SYSC 5306 [0.5] Mobile Computing Systems
   - SYSC 5401 [0.5] Adaptive and Learning Systems
   - SYSC 5405 [0.5] Pattern Classification and Experiment Design
   - SYSC 5407 [0.5] Planning and Design of Computer Networks
   - SYSC 5500 [0.5] Designing Secure Networking and Computer Systems
   - SYSC 5703 [0.5] Integrated Database and Cloud Systems

3. **0.5 credit in**: 0.5
   - SYSC 5902 [0.5] Research Methods for Engineers in the area of data science

4. **2.0 credits in** courses 2.0

**Total Credits**: 4.5

### Cooperative Master’s Degree (5.0 credits)

Participation in the Cooperative Master’s program is subject to acceptance by a suitable sponsoring organization.

**Requirements - by thesis**

1. **3.0 credits in** courses 3.0
2. **2.0 credits in** Thesis 2.0

**Total Credits**: 5.0
Requirements - by project

1. 4.0 credits in courses  
2. 1.0 credit in two 0.5-credit projects (Each project conducted in one of two work terms)

Total Credits 5.0

Ph.D. Electrical and Computer Engineering (1.5 credits)
Subject to the approval of the advisory committee, a student may take up to half of the course credits in the program in other disciplines (e.g., Mathematics, Computer Science, Physics).

Requirements:
1. 1.5 credits in courses 1.5
2. A comprehensive examination involving written and oral examinations and a written thesis proposal, to take place before the end of the fourth term of registration
3. 0.0 credits in a thesis which must be defended at an oral examination 0.0

Total Credits 1.5

Ph.D. Electrical and Computer Engineering with Concentration in Software Engineering (1.5 credits)

Requirements:
1. 1.0 credit from software engineering core courses: 1.0
   - SYSC 5001 [0.5] Simulation and Modeling
   - SYSC 5004 [0.5] Optimization for Engineering Applications
   - SYSC 5101 [0.5] Design of High Performance Software
   - SYSC 5103 [0.5] Software Agents
   - SYSC 5104 [0.5] Methodologies For Discrete-Event Modeling And Simulation
   - SYSC 5105 [0.5] Software Quality Engineering and Management
   - SYSC 5206 [0.5] Resource Management on Distributed Systems
   - SYSC 5207 [0.5] Distributed Systems Engineering
   - SYSC 5500 [0.5] Designing Secure Networking and Computer Systems
   - SYSC 5701 [0.5] Operating System Methods for Real-Time Applications
   - SYSC 5703 [0.5] Integrated Database and Cloud Systems
   - SYSC 5708 [0.5] Model-Driven Development of Real-Time and Distributed Software Engineering
   - SYSC 5709 [0.5] Advanced Topics in Software Engineering
   - SYSC 5805 [0.5] Model-Driven Security Engineering
   - SYSC 5807 [0.5] Advanced Topics in Computer Systems
   - SYSC 5809 [0.5] The Internet of Things
2. 0.5 credit in courses 0.5
3. 0.0 credit in comprehensive examination (one topic of which must be in the area of software engineering) 0.0
4. 0.0 credits in: 0.0

Total Credits 1.5

Graduate Courses
In all programs, the student may choose graduate courses from either university with the approval of the adviser or advisory committee. Course descriptions may be found in the departmental section of the calendar. All courses are of one term duration. Only a selection of courses listed is given in a particular academic year. The following codes identify the department offering the course.

Carleton University
- ELEC Department of Electronics
- SYSC Department of Systems and Computer Engineering

University of Ottawa
- EACJ School of Electrical Engineering and Computer Science

Course List by Research Area
BIOMEDICAL ENGINEERING

Systems and Computer Engineering (Carleton)
- SYSC 5302 (ELG 6321) Biomedical Instrumentation
- SYSC 5303 (ELG 6133) Interactive Networked Systems and Telemedicine
- SYSC 5304 (ELG 5127) Medical Imaging Modalities
- SYSC 5307 (ELG 6307) Biological Signals

COMPUTER AIDED DESIGN FOR ELECTRONIC CIRCUITS

Department of Electronics (Carleton)
- ELEC 5401 (ELG 6341) Signal Integrity in High-Speed Designs: Modeling and Analysis
- ELEC 5402 (ELG 6342) Introduction to Electronic Design Automation Algorithms and Techniques
- ELEC 5404 (ELG 6344) Neural Networks for High-Speed/High-Frequency Circuit Design
- ELEC 5405 (ELG 6340) Advanced Linear and Nonlinear Circuit Theory and Applications
- ELEC 5504 (ELG 6354) Analysis of High-Speed Electronic Packages and Interconnects
- ELEC 5506 (ELG 6356) Simulation and Optimization of Electronic Circuits
- ELEC 5508 (ELG 6358) Advanced Methods for Simulation of Large-Scale Circuits and Systems
- ELEC 5704 (ELG 6374) Advanced Topics in CAD
- ELEC 5803 (ELG 6383) Behavioural Synthesis of ICs

School of Electrical Engineering and Computer Science (Ottawa)
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
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</thead>
<tbody>
<tr>
<td>EACJ 5705 (ELG 5195)</td>
<td>Digital Logic Design</td>
</tr>
<tr>
<td>SYSC 5101 (ELG 6111)</td>
<td>Design of High Performance Software</td>
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<tr>
<td>SYSC 5103 (ELG 6113)</td>
<td>Software Agents</td>
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<tr>
<td>SYSC 5104 (ELG 6114)</td>
<td>Methodologies For Discrete-Event Modeling And Simulation</td>
</tr>
<tr>
<td>SYSC 5105 (ELG 6115)</td>
<td>Software Quality Engineering and Management</td>
</tr>
<tr>
<td>SYSC 5108 (ELG 6118)</td>
<td>Topics in Information Systems</td>
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<tr>
<td>SYSC 5701 (CSI 5117)</td>
<td>Operating System Methods for Real-Time Applications</td>
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<tr>
<td>SYSC 5703 (ELG 6173)</td>
<td>Integrated Database and Cloud Systems</td>
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<tr>
<td>SYSC 5704 (ELG 6174)</td>
<td>Elements of Computer Systems</td>
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<td>SYSC 5708 (ELG 6178)</td>
<td>Model-Driven Development of Real-Time and Distributed Software</td>
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<td>SYSC 5709 (ELG 6179)</td>
<td>Advanced Topics in Software Engineering</td>
</tr>
<tr>
<td>SYSC 5807 (ELG 6187)</td>
<td>Advanced Topics in Computer Systems</td>
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<td>EACJ 5100 (ELG 5200)</td>
<td>Machine Vision</td>
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<td>EACJ 5203 (ELG 5191)</td>
<td>Distributed System Software</td>
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<tr>
<td>EACJ 5204 (ELG 5124)</td>
<td>Virtual Environments</td>
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<td>EACJ 5205 (ELG 5125)</td>
<td>Quality Service Mgmt/Multimed</td>
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<td>EACJ 5703 (ELG 5194)</td>
<td>Reliable Digital Systems</td>
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<td>EACJ 5705 (ELG 5195)</td>
<td>Digital Logic Design</td>
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<td>EACJ 5807 (ELG 7186)</td>
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<td>EACJ 5808 (ELG 7187)</td>
<td>Topics in Computers II</td>
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<td>Sujets choisis sur les ordinateur</td>
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<td>SYSC 5207 (ELG 6127)</td>
<td>Distributed Systems Engineering</td>
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<td>SYSC 5306 (ELG 6136)</td>
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<td>Network Access Techniques</td>
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<td>SYSC 5407 (ELG 5137)</td>
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<td>SYSC 5408</td>
<td>Cross Layer Design for Wireless Networks</td>
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<td>SYSC 5500 (ELG 6189)</td>
<td>Designing Secure Networking and Computer Systems</td>
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<td>SYSC 5502 (ELG 6152)</td>
<td>Advanced Linear Systems</td>
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<td>SYSC 5801 (ELG 6181)</td>
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<td>EACJ 5009 (ELG 5383)</td>
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<td>EACJ 5104 (ELG 5199)</td>
<td>Distributed Database Systems</td>
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<td>EACJ 5108 (ELG 5382)</td>
<td>Switching and Traffic Theory</td>
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<td>EACJ 5200 (ELG 5120)</td>
<td>Queuing Systems</td>
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<tr>
<td>EACJ 5202 (ELG 5122)</td>
<td>Analysis/Perf Eval: Comp Comm</td>
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<tr>
<td>EACJ 5206 (ELG 5126)</td>
<td>Source Coding and Data Compress.</td>
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<tr>
<td>EACJ 5208 (ELG 7185)</td>
<td>Wireless Ad Hoc Networking</td>
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<td>EACJ 5500 (ELG 5371)</td>
<td>Digital Comm by Satellite</td>
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<tr>
<td>EACJ 5605 (ELG 7177)</td>
<td>Topics in Communications I</td>
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<tr>
<td>EACJ 5606 (ELG 7178)</td>
<td>Topics in Communications II</td>
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<tr>
<td>EACJ 5607 (ELG 5374)</td>
<td>Computer-Communication Network</td>
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<tr>
<td>EACJ 5609 (ELG 5396)</td>
<td>Internetworking Technologies</td>
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<td>EACJ 5384/COMP 5406 [0.5] (ELG 5384,CSI 5105,LEG 5384)</td>
<td>Network Security and Cryptography</td>
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<td>SYSC 5200 (ELG 6120)</td>
<td>Algebraic Coding Theory</td>
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<td>SYSC 5503 (ELG 6153)</td>
<td>Stochastic Processes</td>
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<tr>
<td>SYSC 5504 (ELG 6154)</td>
<td>Principles of Digital Communication</td>
</tr>
<tr>
<td>SYSC 5506 (ELG 5170)</td>
<td>Information Theory</td>
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<td>SYSC 5605 (ELG 6165)</td>
<td>Advanced Digital Communication</td>
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<tr>
<td>SYSC 5606 (ELG 6166)</td>
<td>Introduction to Mobile Communications</td>
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<tr>
<td>SYSC 5607 (ELG 6167)</td>
<td>Source Coding and Data Compression</td>
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<tr>
<td>SYSC 5608 (ELG 6168)</td>
<td>Wireless Communications Systems</td>
</tr>
<tr>
<td>SYSC 5804 (ELG 6184)</td>
<td>Advanced Topics in Communications Systems</td>
</tr>
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DIGITAL AND OPTICAL COMMUNICATIONS

Department of Electronics (Carleton)

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<tr>
<td>ELEC 5605 (ELG 6365)</td>
<td>Optical Fibre Communications</td>
</tr>
<tr>
<td>ELEC 5606 (ELG 6366)</td>
<td>Phase-Locked Loops and Receiver Synchronizers</td>
</tr>
</tbody>
</table>

Systems and Computer Engineering (Carleton)

<table>
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<tbody>
<tr>
<td>SYSC 5200 (ELG 6120)</td>
<td>Algebraic Coding Theory</td>
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<tr>
<td>SYSC 5503 (ELG 6153)</td>
<td>Stochastic Processes</td>
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<td>SYSC 5504 (ELG 6154)</td>
<td>Principles of Digital Communication</td>
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<td>SYSC 5506 (ELG 5170)</td>
<td>Information Theory</td>
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<td>SYSC 5606 (ELG 6166)</td>
<td>Introduction to Mobile Communications</td>
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<td>SYSC 5607 (ELG 6167)</td>
<td>Source Coding and Data Compression</td>
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| ELEC 5804 (ELG 6384) | VLSI Design |
| ELEC 5805 (ELG 6385) | VLSI Design Project |
| ELEC 5808 (ELG 6388) | Signal Processing Electronics |
| ELEC 5809 (ELG 6389) | Nonlinear Electronic Circuits |

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**Admission**

The normal requirement for admission to a master’s program is a bachelor’s degree in electrical engineering or a related discipline with a CGPA of B+.

**Accelerated Pathway**

The accelerated pathway in the M.A.Sc. and M.Eng. Electrical and Computer Engineering program is a flexible and individualized plan of graduate study for students in their final year of a Carleton B.Eng degree. Students with demonstrated academic excellence and aptitude for research may qualify for this option.

Students in their third-year of study in the B.Eng. degree should consult with both the Undergraduate Chair and the Graduate Chair to determine if the accelerated pathway is appropriate for them and to confirm their selection of courses for their final year of undergraduate studies.

**Accelerated Pathway Requirements**

1. At least 0.5 credit in ELEC or SYSC courses, or other approved courses, at the 5000-level with a grade of B+ or higher.
2. Minimum overall CGPA of A-.

Students may receive advanced standing with transfer of credit of up to 1.0 credit which can reduce their time to completion.

**Admission**

The normal requirement for admission into the Ph.D. program is a master’s degree with thesis in electrical engineering or a related discipline.

**Regulations**

See the General Regulations section of this Calendar.

**Regularly Scheduled Break**

For immigration purposes, the summer term (May to August) for the M.Eng. Electrical and Computer Engineering (coursework and research project pathways only), including all concentrations and specializations, is considered a regularly scheduled break approved by the University. Students should resume full-time studies in September.

**Note:** a Regularly Scheduled Break as described for immigration purposes does not supersede the requirement for continuous registration in Thesis, Research Essay, or Independent Research Project as described in Section 8.2 of the Graduate General Regulations.
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EACJ 7116 [0.5 credit]
Signal Proc: Intr Convex Optim

Electronics (ELEC) Courses
Note: The Departments of Electronics and Systems and Computer Engineering offer courses in: Biomedical and Electrical Engineering, Communications Engineering, Computer Systems Engineering, Electrical Engineering, Software Engineering and Engineering Physics.

ELEC 5200 [0.5 credit] (ELG 6320)
Advanced Topics in Integrated Circuits and Devices
Topics vary from year to year.

ELEC 5301 [0.5 credit]
Silicon Photonics
Fundamentals of silicon photonics, advanced electromagnetic theory, guided wave optics, interferometry, silicon-on-insulator (SOI) photonics, silicon based waveguide devices (planar, rib, strip), fabrication of photonic devices, passive and active silicon photonic devices such as modulators, lasers, detectors, silicon opto-electronic integration.

ELEC 5302 [0.5 credit]
Renewable and Distributed Energy Resource Technologies
Topics covered include renewable energy resources, photovoltaic systems, wind generation systems, energy storage units, electric vehicles, grid integration, distributed generation, microgrid, active distribution network, modeling and analysis of power system components, state-of-the-art power system simulation tools.

ELEC 5303 [0.5 credit] (ELG 6320 100)
Advanced Power Systems Analysis
Power system sustainability and control, transmission lines, transformers, synchronous generators, induction motor, power flow, small-signal stability, transient stability, voltage stability, state of the art power system simulation tools.
Precludes additional credit for ELEC 5200.

ELEC 5304 [0.5 credit] (ELG 6397)
Solar Cells - Principles, Materials, Systems and Operation
Precludes additional credit for ELEC 5703.

ELEC 5305 [0.5 credit] (ELG 7113)
Electric Motor Drives
DC and AC motors, speed and torque control, efficiency, maximum torque per ampere, power converters, rectifiers, inverters, field-oriented vector control, direct torque control, and sensorless control.
Precludes additional credit for EACJ 5209.

ELEC 5401 [0.5 credit] (ELG 6341)
Signal Integrity in High-Speed Designs: Modeling and Analysis
Crosstalk, distortion, ground bounce, skin effect. Interconnect modeling/simulation, packages, ground/power planes, Elmore delay, lossy-coupled, frequency-dependent transmission lines, telegraphers equations, extraction, measured parameters, macromodeling: passivity/icausalit, MoC/MRA, vector fit, model reduction, electromagnetic compatibility/interference, mixed-domain systems, concurrent analysis.
Precludes additional credit for ELEC 5704 (ELG 6374). Prerequisite(s): permission of the Department.

ELEC 5402 [0.5 credit] (ELG 6342)
Introduction to Electronic Design Automation Algorithms and Techniques
Digital design process; overview of design automation tools/methodologies; theory of computational complexity; layout compaction; placement and partitioning; floorplanning; routing; digital simulation; switch-level simulation; logic synthesis; verification; analog and RF simulation.
Precludes additional credit for ELEC 5704 Section "Y" (ELG 6374 Section "Y").

ELEC 5404 [0.5 credit] (ELG 6344)
Neural Networks for High-Speed/High-Frequency Circuit Design
Introduction to neural network methodologies for computer-aided design of high-speed/high-frequency circuits, including modeling of passive and active devices/circuits, and their applications in high-level design and optimization in wired and wireless electronic systems.

ELEC 5405 [0.5 credit] (ELG 6340)
Advanced Linear and Nonlinear Circuit Theory and Applications
Graph theory, incidence matrices, cutset matrices, generalized KCL, topological formulation, state-space equations, Tellegen's theorem, state-transition matrix, multi-port representation, stability, passivity, causality, synthesis of passive circuits, active networks, nonlinear dynamic circuits.
ELEC 5408 [0.5 credit] (ELG 7100 100)
Wireless Power Transfer and Energy Harvesting
Principles and design guidelines for efficient wireless power transfer and harvesting, short and long range power transfer, RF energy scavenging, and contactless communication. System and subsystem circuit design and analysis is expected and commercial software will be used for all course deliverables. Precludes additional credit for EACJ 5131.

Lecture

ELEC 5409 [0.5 credit] (ELG 6349)
Microwave and Millimeterwave Integrated Circuits

ELEC 5501 [0.5 credit] (ELG 6351)
Passive Microwave Circuits

ELEC 5502 [0.5 credit] (ELG 6352)
Analog Integrated Filters
The fundamentals and details of analog continuous-time and SAW filters. Comparison to switched-capacitor filters. Review of filter concepts, types of filters, approximations, transformations. Building blocks such as op amps, transconductance amplifiers, and gyrators. Design using cascaded second-order sections, multiple loop feedback and LC ladder simulations.

ELEC 5503 [0.5 credit] (ELG 6353)
Radio Frequency Integrated Circuit Design

ELEC 5504 [0.5 credit] (ELG 6354)
Analysis of High-Speed Electronic Packages and Interconnects
Introduction to modeling, simulation and optimization of high-speed VLSI packages; models for packages, interconnects and ground/power planes; lumped, distributed and EM models for interconnects; delay, crosstalk and switching noise; moment matching techniques; concurrent thermal/electrical analysis of IC packages and boards.

ELEC 5506 [0.5 credit] (ELG 6356)
Simulation and Optimization of Electronic Circuits
Introduction to computer simulation and optimization of electrical circuits. Time- and frequency-domain formulations for sensitivity analysis and optimization. Optimization techniques for performance-, cost- and yield-driven design of electronic circuits. Optimization approaches to modeling and parameter extraction of active and passive elements.

ELEC 5508 [0.5 credit] (ELG 6358)
Advanced Methods for Simulation of Large-Scale Circuits and Systems

ELEC 5509 [0.5 credit] (ELG 6359)
Integrated Circuit Technology
Survey of technology used in silicon VLSI integrated circuit fabrication. Crystal growth and crystal defects, oxidation, diffusion, ion implantation and annealing, gettering, CVD, etching, materials for metallization and contacting, and photolithography. Structures and fabrication techniques required for submicron MOSFETs. Applications in advanced CMOS processes.

ELEC 5600 [0.5 credit] (ELG 6360)
Digital Integrated Circuit Testing
Production testing of digital integrated circuits. Outline of methods of testing used in production. Testing schemes and design for testability. Faults and fault models, yield estimates, testability measures, fault simulation, test generation methods, sequential testing, scan design, boundary scan, built-in self test, CMOS testing.
ELEC 5602 [0.5 credit] (ELG 6362)
Microwave Semiconductor Devices and Applications
Theory of operation for microwave diodes (varactor, p-i-n, Gunn, IMPATT) and transistors (BJT, MESFET, HBT, HEMT). Small-signal, large-signal, and noise models for CAD. Diode oscillators and reflection amplifiers. Design of transistor oscillators and amplifiers. Discussion of technology/fabrication issues and MMIC applications.

ELEC 5604 [0.5 credit] (ELG 6364)
Radar Systems
Fundamentals; range equation, minimum detectable signal, radar cross-section, pulse repetition frequency, range ambiguities. Radar classes: CW, FM-CW, MTI, tracking, air surveillance, SSR, PAR, MLS, SAR, SLAR, OTH, 3D and bistatic radars. Radar subsystems; transmitters, antennas, receivers, processors, displays, detection criteria; CFAR receivers, noise, clutter precipitation.

ELEC 5605 [0.5 credit] (ELG 6365)
Optical Fibre Communications
Transmission characteristics of and design considerations for multi-mode and single-mode optical fibre waveguides; materials, structures, and device properties of laser light sources; properties and performance of p-i-n and avalanche photodiodes; types of optical fibre signal formats, preamplifier topologies, noise, receiver sensitivity, transmitter design, link design.

ELEC 5606 [0.5 credit] (ELG 6366)
Phase-Locked Loops and Receiver Synchronizers
Phase-locked loops; components, fundamentals, stability, transient response, sinusoidal operation, noise performance, tracking, acquisition and optimization. Receiver synchronizers: carrier synchronizers including squaring loop, Costas loop, and remodulator for BPSK, QPSK BER performance; clock synchronizers including early-late gate, in-phase/midphase, and delay line multiplier.

ELEC 5607 [0.5 credit] (ELG 6367)
Fundamentals of Antenna Engineering
Basic properties of antennas (gain, radiation patterns, polarization, antenna temperature). Analysis of common antennas (dipoles, loops, helices, aperture antennas, microstrip, dielectric resonator antennas, reflectors). Analysis and design of linear and planar arrays (array factors, beam scanning, amplitude weighting, feed networks).

ELEC 5608 [0.5 credit] (ELG 6368)
Fourier Optics
The theory and applications of diffractive and nondiffractive coherent optics, with emphasis on holograms, tomography and high-speed optical computing. Mathematical basis: generalized 2-D Fourier transforms, transfer function of an optical system, 2-D sampling theory, Helmholtz equation, Green's theorem, and the classical diffraction theories.

ELEC 5609 [0.5 credit] (ELG 6369)
Nonlinear Microwave Devices and Effects
The physical basis and mathematical modeling of a variety of microwave/millimeter-wave devices, (some of which exhibit the most extreme nonlinear behaviour known), how they can be exploited in practical circuits and systems, and how the resulting device/circuit interactions can be analyzed.

ELEC 5701 [0.5 credit] (ELG 6371)
Fibre and Waveguide Components for Communications and Sensors
Optical wave propagation in dielectric waveguides. Theory and practice for passive photonic devices used for routing, filtering, and signal processing, including structural and biochemical sensors. Directional couplers and splitters, filters (gratings and etalons), Mach-Zehnder interferometers, Arrayed waveguide gratings, and dispersion compensators.

ELEC 5702 [0.5 credit] (ELG 6372)
Principles of Photonics
Electromagnetic wave propagation in crystals; review of geometric optics; Gaussian beam propagation; optical fibres; dielectric waveguides for optical integrated circuits; optical resonators; optical properties of materials; theory of laser oscillation; specific laser systems; electro-optic modulators; photorefractive materials and applications; holography; optical interconnects.

ELEC 5703 [0.5 credit] (ELG 6373)
Advanced Topics in Solid State Devices and IC Technology
Recent and advanced topics in semiconductor device physics, modeling, and integrated circuit fabrication technology. Topic varies from year to year according to departmental research interests. Students may be expected to contribute lectures or seminars on selected topics.
ELEC 5704 [0.5 credit] (ELG 6374)
Advanced Topics in CAD
Recent and advanced topics in computer-aided techniques for the design of VLSI and telecommunications circuits. Topics will vary from year to year according to the departmental research interests. Students may be expected to contribute lectures or seminars on selected topics.

ELEC 5705 [0.5 credit] (ELG 6375)
Advanced Topics in VLSI
Recent and advanced topics in the design of very large scale integrated circuits, with emphasis on mixed analog/digital circuits for telecommunications applications. Topic varies from year to year according to departmental research interests. Students may be expected to contribute lectures or seminars on selected topics.

ELEC 5706 [0.5 credit] (ELG 6376)
Submicron CMOS and BiCMOS Circuits for Sampled Data Applications
The analog aspects of digital CMOS and BiCMOS circuit design in submicron technologies including reliability; sampled analog circuits, including amplifier non-ideal characteristics and switch charge injection; CMOS/BiCMOS amplifier design considerations, leading up to standard folded-cascode and two-stage circuits.

ELEC 5707 [0.5 credit] (ELG 6377)
Microsensors and MEMS
Physical design of microelectromechanical systems (MEMS) and microfabricated sensors and actuators. An overview of thin and thick film processes and micromachining techniques will provide fabrication background. Device design including piezoresistive, piezoelectric, electromagnetic, thermal, optical, and chemical sensors and actuators.

ELEC 5708 [0.5 credit] (ELG 6378)
ASICs in Telecommunications
Introduction to modern ASIC technologies for Telecom. Review of circuit-level building blocks for typical wireline and wireless applications, including power/performance tradeoffs. Corresponding FPGA analog and digital IO circuits are discussed. A topical literature study and circuit level design exercises.

ELEC 5709 [0.5 credit] (ELG 6379)
Advanced Topics in Electromagnetics
Recent and advanced topics in electro-magnetics, antennas, radar systems, microwave devices and circuits, or optoelectronics. The subject material will vary from year to year according to research interests in the department and/or expertise provided by visiting scholars or sessional lecturers.

ELEC 5800 [0.5 credit] (ELG 6380)
Theory of Semiconductor Devices

ELEC 5801 [0.5 credit] (ELG 6381)
High-Speed and Low-Power VLSI
High-Speed and Low-Power CMOS VLSI circuit techniques. Low and high levels of abstraction; transistor, switch, logic-gate, module, system levels. State-of-the-art techniques to optimize the performance and energy consumption of a circuit. One or more of these techniques are used in a design project.
Prerequisite(s): ELEC 4708 or ELEC 5804 or the equivalent or permission of the instructor.

ELEC 5802 [0.5 credit] (ELG 6382)
Surface-Controlled Semiconductor Devices
Fundamentals of the MOS system; MOS capacitors. Long channel behaviour: theory, limitations and performance of the SPICE level 1 and 2 models. Small geometry effects. Subthreshold operation and modeling. Hot electron effects and reliability.

ELEC 5803 [0.5 credit] (ELG 6383)
Behavioural Synthesis of ICs
Various topics related to computer analysis and synthesis of VLSI circuits including: logic synthesis, finite state machine synthesis, design methodologies, design for reuse, testing, common VLSI functions, a review of Verilog.
Prerequisite(s): Some IC design knowledge such as given in ELEC 4708.

ELEC 5804 [0.5 credit] (ELG 6384)
VLSI Design
IC design course with strong emphasis on design methodology, to be followed by ELEC 5805 (ELG 6385) in the second term. Design philosophies considered will include Full Custom design, standard cells, gate-arrays and sea-of-gates using CMOS and BiCMOS technology. State-of-the-art computer-aided design tools are used.

ELEC 5805 [0.5 credit] (ELG 6385)
VLSI Design Project
Using state-of-the-art CMOS and BiCMOS technologies, students will initiate their own design of an integrated circuit using tools in the CAD lab and submit it for fabrication where the design warrants.
ELEC 5807 [0.5 credit] (ELG 6375)
RF System Design
System level design of a typical integrated radio. System architectures for radio front ends. Detailed design procedures going from a radio specification to determine block level specifications: determining NF, EVM, phase noise, linearity from BER and radio range requirements. Precludes additional credit for ELEC 5705.
Prerequisite(s): None.
Seminar

ELEC 5808 [0.5 credit] (ELG 6388)
Signal Processing Electronics
CCDs, transversal filters, recursive filters, switched capacitor filters, with particular emphasis on integration of analog signal processing techniques in monolithic MOS ICs. Detailed op amp design in CMOS technology. Implications of nonideal op amp behaviour in filter performance. Basic sampled data concepts.

ELEC 5809 [0.5 credit] (ELG 6389)
Nonlinear Electronic Circuits
Introduction to non-linear circuits used in today’s telecommunications ICs; CMOS non-linear circuits such as direct-RF-sampling mixers, phase-detectors; digital loop-filters, DCOs, frequency synthesizers and clock-and-data-recovery are introduced. Modeling of these non-linear circuits and existing options for simulations and closed form circuit analysis is presented.
Precludes additional credit for ELEC 5705 (ELG 6375).
Prerequisite(s): permission of the Department.

ELEC 5900 [0.5 credit] (ELG 6389)
Engineering Project I
A one-term course, carrying 0.5 credit, for students pursuing the course work M.Eng. program. An engineering study, analysis and/or design project under the supervision of a faculty member. Written and oral reports are required. This course may be repeated for credit.
Includes: Experiential Learning Activity

ELEC 5901 [1.0 credit] (ELG 6389)
Engineering Project II
A one-term course, carrying full-course credit, for students pursuing the course work or co-op M.Eng. program. An engineering study, analysis and/or design project under the supervision of a faculty member. Written and oral reports are required.
Includes: Experiential Learning Activity

ELEC 5906 [0.5 credit] (ELG 6389)
Directed Studies
Various possibilities exist for pursuing directed studies on topics approved by a course supervisor, including the above listed course topics where they are not offered on a formal basis.

ELEC 5909 [2.5 credits]
M.A.Sc. Thesis
Includes: Experiential Learning Activity

ELEC 6909 [0.0 credit]
Ph.D. Thesis
Includes: Experiential Learning Activity

Systems and Computer Engineering (SYSC) Courses
SYSC 5001 [0.5 credit] (ELG 6101)
Simulation and Modeling
Simulation as a problem solving tool. Random variable generation, general discrete simulation procedure: event table and statistical gathering. Analyses of simulation data: point and interval estimation. Confidence intervals. Overview of modeling, simulation and problem solving using SIMSCRIPT, MODSIM and other languages. Also offered at the undergraduate level, with different requirements, as SYSC 4005, for which additional credit is precluded.

SYSC 5004 [0.5 credit] (ELG 6104)
Optimization for Engineering Applications
Introduction to algorithms and computer methods for optimizing complex engineering systems. Includes linear programming, networks, nonlinear programming, integer and mixed-integer programming, genetic algorithms and search methods, and dynamic programming. Emphasizes practical algorithms and computer methods for engineering applications.

SYSC 5101 [0.5 credit] (ELG 6111)
Design of High Performance Software
Designing software to demanding performance specifications. Design analysis using models of computation, workload, and performance. Principles to govern design improvement for sequential, concurrent and parallel execution, based on resource architecture and quantitative analysis.
Prerequisite(s): SYSC 5704 (ELG 6174) and a course in software engineering, or equivalent.
Also offered at the undergraduate level, with different requirements, as SYSC 4102, for which additional credit is precluded.
SYSC 5103 [0.5 credit] (ELG 6113)  
**Software Agents**  
Agent-based programming; elements of Distributed Artificial Intelligence; beliefs, desires and intentions; component-based technology; languages for agent implementations; interface agents; information sharing and coordination; KIF; collaboration; communication; ontologies; KQML; autonomy; adaptability; security issues; mobility; standards; agent design issues and frameworks, applications in telecommunications.  
Prerequisite(s): Knowledge of Java, C/C++ or Smalltalk.

SYSC 5104 [0.5 credit] (ELG 6114)  
**Methodologies For Discrete-Event Modeling And Simulation**  
Prerequisite(s): knowledge of C++ and of basic concepts of concurrency and distributed systems.

SYSC 5105 [0.5 credit] (ELG 6115)  
**Software Quality Engineering and Management**  
All aspects of software quality engineering. Software testing, at all stages of the software development and maintenance life cycle. Software reviews and inspections. Use of software measurement and quantitative modeling for the purpose of software quality control and improvement.  
Precludes additional credit for CSI 5111 (COMP 5501).  
Prerequisite(s): an undergraduate course in software engineering such as SYSC 4800 or SEG 3300, or equivalent, and basic statistics.

SYSC 5108 [0.5 credit] (ELG 6118)  
**Topics in Information Systems**  
Recent and advanced topics in the field of Information Systems and its related areas.

SYSC 5200 [0.5 credit] (ELG 6120)  
**Algebraic Coding Theory**  
Review of Algebra, Finite Fields, Linear Block Codes and their Properties, Hamming Codes, Cyclic Codes, Hadamard Matrices and Hadamard Codes, Golay Codes, Reed-Muller Codes, BCH and Reed-Solomon Codes, Decoding Algorithms, Coding Bounds.

SYSC 5201 [0.5 credit] (ELG 6121)  
**Computer Communication**  
Computer network types, introductory queuing theory and performance analysis. OSI layering and BISDN layering modifications. Data link layer. Local area networks and random access (CSMA, CD, switched ethernet, token ring, wireless LAN). Public Networks. IP networks, addressing, routing. Transport layer, flow control. Introduction to ISDN. Precludes additional credit for EACJ 5607 (ELG 5374) or SYSC 4602 (ELG 4181).  
Prerequisite(s): Undergraduate preparation in probability theory equivalent to STAT 3502.

SYSC 5202 [0.5 credit] (BMG 5107)  
**Applications in Biomedical Image Processing**  
Includes: Experiential Learning Activity  
Also listed as BIOM 5202.

SYSC 5206 [0.5 credit]  
**Resource Management on Distributed Systems**  
Principles and techniques for resource management on distributed systems including clouds, grids and data analytics platforms; management of computing and storage resources; service level agreements; performance and energy aware techniques for scheduling, allocation, dynamic resource provisioning; cyber-physical systems and BigData; resource management for BigData analytics.  
Includes: Experiential Learning Activity

SYSC 5207 [0.5 credit] (ELG 6127)  
**Distributed Systems Engineering**  
Prerequisite(s): permission of the Department.

SYSC 5302 [0.5 credit] (ELG 6321)  
**Biomedical Instrumentation**  
Instrumentation designed to measure physiological variables related to the function of the heart, lungs, kidney, nervous and musculo-skeletal system; emergency, critical care, surgery and anaesthesia equipment.  
Also listed as EACJ 5302 (ELG 6321).  
Precludes additional credit for BIOM 5100 (BMG 5103).  
Prerequisite(s): permission of the instructor.
SYSC 5303 [0.5 credit] (ELG 6133)
Interactive Networked Systems and Telemedicine
Telemanipulator; human motoring and sensory capabilities; typical interface devices; mathematical model of haptic interfaces; haptic rendering; stability and transparency; remote control schemes; time delay compensation; networking and realtime protocols, history and challenges of telemedicine; telemedicine applications: telesurgery, telemonitoring, telediagnosis and telehomecare.
Also listed as BIOM 5402 (BMG 5304).
Prerequisite(s): permission of the Department.

SYSC 5304 [0.5 credit] (ELG 5127)
Medical Imaging Modalities
Mathematical models of image formation based on the image modality and tissue properties. Linear models of image degradation and reconstruction. Inverse problems and regularization for image reconstruction. Image formation in radiology, computed tomography, magnetic resonance imaging, nuclear medicine, ultrasound, positron emission tomography.
Also listed as BIOM 5200 (BMG 5105).

SYSC 5306 [0.5 credit] (ELG 6136)
Mobile Computing Systems
Systems to build mobile applications. Covers data link layer to application layer. Emphasis on existing wireless infrastructure and IETF protocols. Focuses on view of mobile application developer; communication systems, middleware and application frameworks, de facto standards proposed/developed by industry consortia.
Precludes additional credit for COMP 5402 (CSI 5142).
Prerequisite(s): EACJ 5607 (ELG 5374) or SYSC 5201 (ELG 6121) or permission of the Department.

SYSC 5307 [0.5 credit] (ELG 6307)
Biological Signals
Modeling of neuromuscular biological signals, including subthreshold phenomena, active behaviour of cell membranes, and innervation processes. Measurement of biological signals, including electrode effects. Time domain, frequency domain, and adaptive filtering techniques for noise reduction.
Precludes additional credit for BIOM 5101 (BMG 5104).

SYSC 53070 [0.5 credit] (ELG 5370)
Wavelets and Multiresolution Signal Analysis

SYSC 5401 [0.5 credit] (ELG 6141)
Adaptive and Learning Systems
Prerequisite(s): SYSC 5502 (ELG 6152) or equivalent.

SYSC 5403 [0.5 credit] (ELG 6143)
Network Access Techniques
A range of access technologies with emphasis on broadband access. Physical channels and the state-of-the-art of coding, modulation, multiplexing strategies to overcome physical impairments. Including high-speed transmission over twisted pair, wireless, fibre and co-axial media.
Prerequisite(s): SYSC 5503 (ELG 6153), and SYSC 5504 (ELG 6154) or ELG 5375 (EACJ 5506).

SYSC 5405 [0.5 credit] (ELG 6102)
Pattern Classification and Experiment Design
Introduction to a variety of supervised and unsupervised pattern classification techniques with emphasis on correct application. Statistically rigorous experimental design and reporting of performance results. Case studies will be drawn from various fields including biomedical informatics.
Includes: Experiential Learning Activity
Also listed as BIOM 5405.
Prerequisite(s): undergraduate introductory probability and statistics.

SYSC 5407 [0.5 credit] (ELG 5137)
Planning and Design of Computer Networks
Planning process of computer networks; needs and technical requirements; modeling of different network planning problems; exact and approximate algorithms; topological planning and expansion problems; equipment (switch, router) location problem; approximate and optimal routing algorithms; presentation of various case studies.
Includes: Experiential Learning Activity
SYSC 5408 [0.5 credit]  
**Cross Layer Design for Wireless Networks**  
Quality of service measures at different layers. Parameter adaptation, tradeoffs, and optimization at physical, data-link, network, transport, and application layers. Examples of cross-layer design in cellular, ad hoc, sensor, local area, green, and cognitive radio networks.

SYSC 5500 [0.5 credit] (ELG 6189)  
**Designing Secure Networking and Computer Systems**  
Network security with coverage of computer security in support of networking concepts. Covers various security issues in data networks at different protocol layers. Routing security, worm attacks, and botnets. Security of new mobile networks and emerging networked paradigms such as social networks and cloud computing. Precludes additional credit for SYSC 5801 Section "X" (ELG 6181).

SYSC 5502 [0.5 credit] (ELG 6152)  
**Advanced Linear Systems**  

SYSC 5503 [0.5 credit] (ELG 6153)  
**Stochastic Processes**  
Basic concepts of randomness, as applied to communications, signal processing, and queuing systems; probability theory, random variables, stochastic processes; random signals in linear systems; introduction to decision and estimation; Markov chains and elements of queuing theory. Precludes additional credit for EACJ 5109 (ELG 5119).

SYSC 5504 [0.5 credit] (ELG 6154)  
**Principles of Digital Communication**  
Elements of communication theory and information theory applied to digital communications systems. Characterization of noise and channel models. Optimum Receiver theory. Modulation and coding for reliable transmission: MPSK, MQAM, M-ary orthogonal modulation. Channel coding, trellis coded modulation. Spread spectrum and CDMA communications. Precludes additional credit for EACJ 5506 (ELG 5375). Prerequisite(s): SYSC 5503 (ELG 5503) or ELG 5119 (EACJ 5109) or equivalent (may be taken concurrently).

SYSC 5506 [0.5 credit] (ELG 5170)  
**Information Theory**  
Measure of information: entropy, relative entropy, mutual information, asymptotic equipartition property, entropy rates for stochastic processes; data compression: Huffman code, arithmetic coding; channel capacity; random coding bound, reliability function, Blahut-Arimoto algorithm, Gaussian channels, coloured Gaussian noise and 'water-filling'; rate distortion theory; network information theory. Precludes additional credit for EACJ 5501 (ELG 5170). Prerequisite(s): SYSC 5503 (ELG 6153) or EACJ 5109 (ELG 5119) or equivalent.

SYSC 5506 [0.5 credit] (ELG 6160)  
**Adaptive Signal Processing**  
Theory and techniques of adaptive filtering, including Wiener filters, gradient and LMS methods; adaptive transversal and lattice filters; recursive and fast recursive least squares; convergence and tracking performance; implementation. Applications, such as adaptive prediction, channel equalization, echo cancellation, source coding, antenna beamforming, spectral estimation. Precludes additional credit for EACJ 5800 (ELG 5377). Prerequisite(s): SYSC 5503 (ELG 5503) or ELG 5119 (EACJ 5109) or equivalent; SYSC 5602 (ELG 6162) or ELG 5376 (EACJ 5507) or equivalent.

SYSC 5602 [0.5 credit] (ELG 6162)  
**Digital Signal Processing**  

SYSC 5605 [0.5 credit] (ELG 6165)  
**Advanced Digital Communication**  
Techniques and performance of digital signalling and equalization over linear bandlimited channels with additive Gaussian noise. Fading multipath channels: diversity concepts, modeling and error probability performance evaluation. Synchronization in digital communications. Spread spectrum in digital transmission over multipath fading channels. Precludes additional credit for EACJ 5704 (ELG 5780). Prerequisite(s): SYSC 5504 (ELG 6154) or equivalent.
SYSC 5606 [0.5 credit] (ELG 6166)  
Introduction to Mobile Communications  
Mobile radio channel characterization: signal strength prediction techniques and statistical coverage; fading; delay spread; interference models and outage probabilities. Digital modulation and transmission system performance. Signal processing techniques: diversity and beamforming, adaptive equalization, coding. Applications to TDMA and CDMA cellular systems. Prerequisite(s): SYSC 5503 (ELG 5503) and SYSC 5504 (ELG 6154) (may be taken concurrently with SYSC 5606).

SYSC 5607 [0.5 credit] (ELG 6167)  
Source Coding and Data Compression  
Discrete and continuous sources. Discrete sources: Huffman coding & run length encoding. Continuous sources: waveform construction coding; PCM, DPCM, delta modulation; speech compression by parameter extraction; predictive encoding; image coding by transformation and block quantization. Fourier and Walsh transform coding. Applications to speech, television, facsimile. Prerequisite(s): SYSC 5503 (ELG 5503) or ELG 5119 (EACJ 5109) or equivalent.

SYSC 5608 [0.5 credit] (ELG 6168)  
Wireless Communications Systems  
Fundamentals of antenna systems and radio propagation, wireless channel characterization, link budget, spectrum, cellular and personal wireless communication systems, channel reuse, system capacity, mobility and location management, channel resource allocation, radio access network (RAN), multiple access principles, security and authentication, satellite networks, wireless LANs.

SYSC 5701 [0.5 credit] (CSI 5117)  
Operating System Methods for Real-Time Applications  
Principles and methods for operating system design with application to real-time, embedded systems. Concurrent programming: mechanisms and languages; design approaches and issues; run-time support (kernel). Methods for hard real-time applications. Methods for distributed systems. Programming assignments in a suitable programming language. Prerequisite(s): SYSC 3303 or SYSC 5704 (ELG 6174) or equivalent courses and/or experience. Programming experience in high level and assembly languages.

SYSC 5702 [0.5 credit]  
Sensor Fusion for Autonomous Systems  
Sensor fusion for autonomous navigation systems. Topics include reference frames, maps representation, state estimation, error modelling, localization and mapping, sensors for autonomous navigation, sensor fusion algorithms. The course is for students with background in signals/systems, linear-algebra, and probability. Programming in Matlab or Python is essential. Includes: Experiential Learning Activity

SYSC 5703 [0.5 credit] (ELG 6173)  
Integrated Database and Cloud Systems  
Review of database concepts: Conceptual database design, relational and object-oriented data models; application of SQL, recursive queries, relational algebra, and data integration; normalization theory, deductive approach to database, and query processing; object-oriented database; OLAP, data warehousing and data mining; Cloud computing, Hadoop, and MapReduce.

SYSC 5704 [0.5 credit] (ELG 6174)  
Elements of Computer Systems  
Concepts in basic computer architecture, assembly languages, high level languages including object orientation, compilers and operating system concepts (including concurrency mechanisms such as processes and threads and computer communication). Designed for graduate students without extensive undergraduate preparation in computer system engineering (or equivalent experience). Prerequisite(s): programming experience with at least one high level language and permission of the Department.

SYSC 5708 [0.5 credit] (ELG 6178)  
Model-Driven Development of Real-Time and Distributed Software  
Advanced development of real-time and distributed systems by model-driven development that shifts the focus from coding to modeling. Different types of models. Generating code by model transformations. Design patterns for distributed/concurrent systems with examples from communication applications. Design issues for reusable software. Prerequisite(s): knowledge of UML and operating systems concepts, and permission of the Department.

SYSC 5709 [0.5 credit] (ELG 6179)  
Advanced Topics in Software Engineering  
Recent and advanced topics in the field of software engineering and related areas. Primary references are recent publications in the field. Prerequisite(s): permission of the Department.
SYSC 5801 [0.5 credit] (ELG 6181)  
**Advanced Topics in Computer Communications**  
Recent and advanced topics in computer-communication networks intended as a preparation for research. Students are expected to contribute to seminars or present lectures on selected topics.  
Prerequisite(s): SYSC 5201 (ELG 6121) or ELG 5374 (EACJ 5607) or equivalent and permission of the Department.

SYSC 5804 [0.5 credit] (ELG 6184)  
**Advanced Topics in Communications Systems**  
Recent and advanced topics in communications systems.  
Prerequisite(s): permission of the Department.

SYSC 5805 [0.5 credit]  
**Model-Driven Security Engineering**  
Fundamentals of security engineering and its activities, with emphasis on model-driven approaches for asset identification, threat and risk assessment, security requirements elicitation, security controls selection, security evaluation, and security assurance for software intensive-systems. Examination of challenges for engineering secure software.  
Includes: Experiential Learning Activity

SYSC 5807 [0.5 credit] (ELG 6187)  
**Advanced Topics in Computer Systems**  
Recent and advanced topics in computer systems. The course will generally focus on one or more of the following areas: specification, design, implementation, and modeling/analysis. Students may be expected to contribute to lectures or seminars on selected topics.  
Prerequisite(s): permission of the Department.

SYSC 5809 [0.5 credit]  
**The Internet of Things**  
Main concepts of the Internet of Things (IoT) ranging from the physical devices and sensor networks to the applications and standards.  
Includes: Experiential Learning Activity

SYSC 5902 [0.5 credit]  
**Research Methods for Engineers**  
Topics required to perform engineering research including literature surveys, identifying issues, objectives, and methodology. Technical writing, documenting and presenting engineering ideas and a review of statistics, simulation, optimization and data analysis.  
Includes: Experiential Learning Activity

SYSC 5903 [0.5 credit]  
**Systems Engineering Project II**  
Students pursuing the non-thesis M.Eng. program conduct an engineering study, analysis, and/or design project under the supervision of a faculty member.  
Includes: Experiential Learning Activity  
Prerequisite(s): permission of the Department.

SYSC 5905 [2.0 credits] (ELG 6188)  
**M.C.S. Thesis**  
Also listed as MATH 5905, COMP 5905.

SYSC 5906 [0.5 credit]  
**Directed Studies**

SYSC 5909 [2.5 credits]  
**M.A.Sc. Thesis**  
Includes: Experiential Learning Activity

SYSC 6909 [0.0 credit]  
**Ph.D. Thesis**  
Includes: Experiential Learning Activity