Faculty of Engineering, Department of

— Electrical and Electronic Engineering

This publication refers to the session 2009–10. The information given, including that relating to the availability of courses, is current at the time of publication; 5 October 2009; and is subject to alteration.

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For details of postgraduate opportunities go to www.imperial.ac.uk/pgprospectus.
Electrical and Electronic Engineering

Imperial College provides undergraduate courses leading to the BEng degree after three years of study, the MEng degree after four years of study, and postgraduate courses leading to the Diploma of the Imperial College (DIC) and the MSc degree. Graduates are also accepted for research leading to the higher degrees MPhil and PhD. Some 170 students are admitted annually on to the undergraduate courses in the Department. There are also 260 or so postgraduate students, of whom approx 70 are studying on one-year courses leading to the MSc and DIC, whilst approx 190 are working towards MPhil or PhD degrees.

There is a wide range of research activities in Electrical and Electronic Engineering at Imperial, many in collaboration with high technology industries, mainly in the following fields: communications and signal processing; intelligent and interactive systems; optics, semiconductors and micromechanical systems; digital and analogue circuits and systems; control engineering, electrical machines and power systems. The range of expertise is utilised extensively in the planning and presentation of the undergraduate and postgraduate courses, especially in the third and fourth years of the undergraduate courses and project work.

Details of postgraduate opportunities can be found in the online Postgraduate Prospectus at www.imperial.ac.uk/pgprospectus.

Undergraduate courses

The Department runs three and four-year courses leading to a BEng or an MEng degree. All courses give a firm foundation in the first two years combined with an unrivalled degree of specialisation in the third and fourth years. There are seven degree courses to choose from but the initial choice is between Electrical and Electronic Engineering (EEE) and Information Systems Engineering (ISE).

Electrical and Electronic Engineering (EEE courses)

A unified undergraduate course offers the choice of:

- **BEng in Electrical and Electronic Engineering** (three years)
- **MEng in Electrical and Electronic Engineering (T stream)**
  (four years, with a focus on technological subjects in the final two years)
- **MEng in Electrical and Electronic Engineering with Management (EM stream)**
  (four years, with a focus on business studies, alongside technical studies in the final two years)
- **MEng in Electrical and Electronic Engineering with a Year Abroad (EY stream)**
  (four years, in which the final year will be spent at a Higher Education Institution abroad)

The first two years of the course are common to all students taking EEE courses, and binding decisions about later patterns of study are not made until the end of the second year. Advice on choice is given at the end of the second year. Entry to the third year of any four-year stream is restricted to students with good academic records.

Information Systems Engineering (ISE courses)

This course offers the choice of:

- **BEng in Information Systems Engineering** (three years)
- **MEng in Information Systems Engineering** (four years)
- **MEng in Information Systems Engineering with a Year Abroad** (four years, of which the final year will be spent at a Higher Education Institution abroad)

The ISE course is for those who want a balance of electronics and computing. This combination has become of greater significance as computers have become components of many fields in the electrical and computing industries, requiring engineers to be able to cope with both software and hardware design. It combines the more practical half of the computing course as taught in the Department of Computing with electronics and communications drawn from the Electrical and Electronic Engineering course.
The first two years of the course are common to all students on the ISE pathway and binding decisions about later patterns of study are not made until the end of the second year. Advice on choice is given at the end of the second year. Entry to year three of any four-year stream is restricted to students with good academic records.

All courses are accredited by the Institution of Engineering and Technology.

Students entering the first year must satisfy the general University entrance requirements and the course requirements, normally through recognised GCE A-level examinations A-grades attained in at least three subjects. Here, A-grades in Mathematics and Physics are mandatory for all our degree programmes, and a third A-grade from one of the following subjects: Accounting, Applied ICT, Biology, Business Studies, Chemistry, Computer Science, D&T, Economics, Electronics, Further Mathematics, ICT, Music Technology, Statistics or Technology. By far, the most useful third subject in Further Mathematics. Applicants also require a qualification in English, e.g. minimum of a C-grade in GCSE or its equivalent

The course consists of lectures with supporting study groups, practical work involving set laboratory exercises and project tasks. A personal tutorial scheme is organised. Students are encouraged and assisted to obtain industrial experience during the vacations.
Syllabuses

Electrical and Electronic Engineering

**FIRST YEAR**

Electrical engineering
Computing
Mathematics
Technical communication
Business studies
Practical work

**E1.1 Analysis of circuits (EEE, ISE)**

MR D M BROOKES


**E1.2 Digital electronics I (EEE, ISE)**

DR Z. DURRANI

Basic logic theory; Boolean algebra; simple combinational circuits; logic minimisation; data representation and number systems; binary addition and adders, simple multiplies; digital building blocks as functional blocks, sequential circuits; flip-flops; finite-state machines, state diagrams; machine identification and control; counters and shift registers.

**E1.3 Devices and fields (EEE only)**

DR K. FOBELETS, PROFESSOR E.M. YEATMAN

Semiconductor devices: electrons and holes used for conduction in semiconductors. Drift and diffusion as current carrying mechanisms. Energy band diagrams help with the prediction of allowed conduction or not. MOS capacitor, a capacitor for integrated circuits. Metal-oxide-semiconductor field effect transistor for high speed, low power digital applications. pn-diodes as rectifiers: minority carriers are important. Schottky diodes are fast, majority carrier rectifiers. Bipolar junction transistors: towards high gain amplifiers. Fields: importance and classification. Steady electric fields (electrostatics): electric charge, Gauss's law, electric potential, equipotentials and field lines, capacitors and capacitance, conductors. Steady magnetic fields (magnetostatics): magnetic force, magnetic flux density, magnetic field intensity, Biot-Savart law, Ampere's law, magnetic materials, inductor and inductance, magnetic analysis. Electromagnetic induction: Faraday's law, mutual inductance, force calculations; basics of transformers, basic DC motor analysis.

**E1.4 Analogue electronics I (EEE, ISE)**

PROFESSOR A.S. HOLMES

The bipolar junction transistor (BJT): physical structure and modes of operation; common-emitter amplifier; bias stabilisation; use as a switch. Small-signal analysis: basic principles; small signal models for two-terminal devices; BJT small-signal model and Early effect; macromodels; frequency response of AC-coupled circuits. The MOSFET: physical structure and modes of operation; small-signal models; common-source amplifier; active loads; the body effect. Analogue building blocks: current mirror; differential amplifier; emitter follower. Transients and oscillators: transient behaviour of LR, LC and LRC networks; transients in switched transistor circuits, switching oscillators, sinusoidal oscillators (RC and LDC).
E1.5 Electronic materials (EEE only)
DR W.T. PIKE

E1.6 Communications I (EEE, ISE)
DR P.L. DRAGOTTI

E1.7 Introduction to computing (EEE, ISE)
DR J.V. PITT
Procedural computing: variables, constants and types, conditionals and loops, data structures, procedures and functions, file I/O.
Software design: algorithm design (pseudo code), dataflow, data design, testing and specification. Modular programming: units, abstract data types, objects (an overview). Introduction to pointers.

E1.8 Algorithms and data structures (ISE only)
DR C. BOUGANIS
A review of C++ language; Software engineering principles; Data structures; Lists; ordered lists; Trees Ordered trees; Hash tables; Parsing. Algorithms for sorting and searching.

E1.9 Principles of computers and software engineering (ISE only)
DR Y. DEMIRIS, DR T.J.W. CLARKE
Architecture:
The kernel of computer architecture: the instruction set architecture. Trends in technology and the basics of a computer system architecture.

Operating systems
Fundamentals: what is an operating system and what services does it provide to users? Examples of operating systems (including desktop, server and embedded OS). Evolution of operating systems; batch systems, multiprogramming, timesharing. Multiprocessor and distributed system, real time OS. Criteria for OS design.
Operating system structures: operating system services and components; system calls; hardware support for OS (memory protection, timers, privileged and user modes of operation); organisation of OS: monolithic and layered systems; virtual machines; client-server models and microkernels.

Process management
Fundamentals: processes, process states, process control blocks, process tables; two-, five- and seven-state models of process management; scheduling queues and queuing diagrams; process creation, termination and switch; introduction to threads: advantages, user and kernel level threads.
Process scheduling: schedulers and interrupts, pre-emptive and non-pre-emptive scheduling; priority and non-priority based schedulers; short-term scheduling criteria; scheduling algorithm: first-come-first-served, shortest remaining job first, round robin, priority scheduling, multilevel queue scheduling with/without feedback.

Interprocess communication and synchronisation
Fundamentals: independent and cooperating processes; shared memory and message passing, race conditions, critical regions, mutual exclusion; locks, turn variables, Peterson's solution to mutual exclusion; hardware assisted mutual exclusion; semaphores: basics, associated data structures, implementation; use of semaphores for process coordination and mutual exclusion.

Memory management
From program to running process: tools and address binding; compilers, assemblers, linkers and loaders.
Logical vs physical address space. Memory protection, base/relocation and limit registers; memory allocation: fixed versus dynamic partitioning, memory allocation algorithms. Internal and external fragmentation, compaction, paging, segmentation and virtual memory.

E1.10 Mathematics (EEE only)
DR R. BEARDMORE, PROFESSOR P. HALL (DEPARTMENT OF MATHEMATICS)
Revision: limits, differentiation, integration, Taylor series, complex numbers, Gaussian elimination.
Complex numbers and functions: polar form, de Moivre's theorem, roots of polynomial equations, definition of basic complex functions, roots of transcendental equation, branch cuts.
Ordinary differential equations: first order, separable equations, equations reducible to separable form, integrating factors. Second order, constant coefficients—complementary and particular solutions, numerical integration.
Linear algebra: vectors, equations of lines and planes, Gaussian elimination, matrices—inverse and transpose, LU factorisation, determinants, eigenvalues and eigenvectors, diagonalisation.
Functions of several variables: partial differentiation; contours; total differentials; change of variables; PDEs.
Convergence of infinite series; geometric progression; ratio and comparison tests; alternating series; radius of convergence.
Fourier series: full range Fourier series; exponential form of Fourier series, half range sine and cosine series; convergence; differentiation and integration of Fourier series; Parseval's identity; applications.
Laplace transforms: basic definition, inverse form tables, shift theorem; application to differential equations.

E1.11 Mathematics (ISE only)
DR J. GIBBONS, PROFESSOR M. LIEBECK (DEPARTMENT OF MATHEMATICS)
Analysis: functions of one variable: odd, even, inverse functions. Limits: continuous and discontinuous functions. Differentiation: continuity and differentiability; implicit and logarithmic differentiation; Leibniz's formula; stationary points and points of inflection; polar coordinates. Rolle's and mean value theorems; Taylor's and Maclaurin's series; l'Hôpital's rule. Convergence of power series; ratio and comparison test; alternating series; radius of convergence. Complex numbers and functions: the complex plane; polar
representation; de Moivre's theorem; ln z and exp (z). Integration: definite and indefinite integrals; the fundamental theorem; improper integrals; integration by substitution and by parts; partial fractions. Functions of more than one variable: partial differentiation; total differentials; change of variable; Taylor's theorem for a function of two variables; stationary values; contours. PDEs.

Linear algebra: vector algebra: basic rules; cartesian coordinates; scalar and vector products; applications to geometry; equations of lines and planes; triple products; linear dependence. Matrix algebra: double suffix notation; basic rules; transpose, symmetric, diagonal, unit, triangular, inverse and orthogonal matrices. Determinants: basic properties; Cramer's rule. Linear algebraic equations: consistency; elementary row operations; linear dependence; Gauss-Jordan method; Gaussian elimination; LU factorisation. Eigenvalues and eigenvectors; diagonalisation.

Ordinary differential equations: first order equations: separable, homogeneous, exact, linear. Second order linear equations with constant coefficients. Laplace transforms; basic definition; inversion from table; shift theorem; application to ODEs. Fourier series: standard formulae; even and odd functions; half-range sine and cosine series; complex form; convergence, differentiation and integration of Fourier series; Parseval's identity; applications.

E1.15 Technical communication (EEE, ISE)

DR S. BAINS
1. Two 5-minute talks (one practice and one assessed) on technical topics of the student's choice.
2. One technical essay that makes an argument.
3. One laboratory report, written both to convey technical information and demonstrate the ability to explain and provide context.
In addition, there will be two optional editing exercises.

E1.16 Introduction to management and organisations (EEE, ISE)

DR A. EISINGERICH, DR B. JONES, DR H. SCHILDT (BUSINESS SCHOOL)
The primary aim of this course is to equip students, who are not business specialists, with a set of working tools that are relevant to their future careers in a range of sectors. During the course of the term they will develop a working familiarity with key concepts in Organisational Behaviour, Strategy, and Marketing that will enable them to understand how managers analyse and react to business situations. The course will teach some basic business terminology and managerial frameworks, and develop their skills in framing and responding to a range of managerial situations.
The following subject fields will be covered: Introduction to management; individuals at work; power and politics in organisations; organisational culture; marketing concept and consumer behaviour; pricing and distribution; marketing communication and relationship marketing; vision and positioning; firm boundaries and core competences, strategy process.

Practical work (core to all courses)

Electrical laboratory

DR T. TATE
About 120 hours.
A course complementary to all lecture courses.
The oscilloscope—basic measurements
Digital logic—build your own arithmetic logic unit!
PIC Microprocessor—an introduction to a powerful microcontroller, from machine code up
Passive networks—introduction to ac and real components
Transistor switching and timing—a basic transistor experiment
OPAMP Applications—introduction to OPAMPS
OPAMP Design—build your own OPAMP from BJTs!
Power experiments—PSUs, motors, transformers
Radio design project—design and build your own radio to take home and keep!
Computing laboratory
DR J.V. PITT, DR C. BOUGANIS, MR L.G. MADDEN
About 40 hours.
The first year Computing laboratories support Dr Pitt’s lecture course, E1.7 Software Engineering 1: Introduction to Computing. The laboratories consolidate understanding of the course concepts to produce console applications in Pascal. A virtual learning environment (VLE) is used to deliver the laboratory instructions that are the same for both the EEE and ISE courses. However, those studying EEE courses use the Delphi integrated development environment (IDE) running under MS-Windows and those on the ISE pathway use a command-line Pascal compiler running under Linux. In the Spring term students enrolled on EEE course streams will follow VLE-based instruction to consolidate their understanding of Pascal and extend their knowledge of Delphi in order to produce visual applications.
In the first half of the Spring term ISE students will follow VLE-based instruction to learn how to apply the concepts of E1.7 in the C language. In the second half of the Spring term the ISE stream will follow VLE-based instruction to learn how to program in procedural C++ which supports Dr Bouganis’s lecture course, E1.8 Software Engineering 1: Algorithms and data structures. The ISE stream use command-line C and C++ compilers running under Linux.

SECOND YEAR
Electrical engineering
Computing
Mathematics
Humanities course
Technical communication
Practical work

E2.1 Digital electronics II (EEE, ISE)
MR D.M. BROOKES

E2.2 Analogue electronics II (EEE only)
DR C. PAPAVASSILIOU
The main content of the course is: analogue circuit techniques: cascading, bootstrapping, high frequency BJT and FET amplifier techniques, Miller’s theorem; building blocks: single-stage BJT and FET amplifiers, current mirrors, differential pairs, power outage stages, PTAT current sources, operational amplifier.

E2.3A Fields and devices (EEE only)
PROFESSOR R.R.A. SYMS, DR K. FOBELETS
Electromagnetic fields: The Electromagnetic spectrum; Maxwell's Equations; Waves on transmission lines; Transmission line devices; Electromagnetic waves; Reflection and refraction; Imaging; Radio and radar; Microwaves; Optical fibre.
Semiconductor devices: Short review of the DC behaviour of semiconductor devices with a focus on uni- versus bi-polar device behaviour. A more realistic view on MOSFETs: sub-threshold conduction. Minority carrier charge storage effects are responsible for the delay in bipolar devices. Some clever methods to trick the bipolar devices in switching faster. AC behaviour of FETs for analogue applications, introduction
of cut-off frequency. Downscaling of the MOSFET for improved speed. Switching of MOSFETs. Gate delays and power consumption.

**E2.3B Electrical power engineering (EEE only)**

PROFESSOR T.C. GREEN


**E2.4 Communications II (EEE, ISE)**

PROFESSOR KIN LEUNG


**E2.5 Signals and linear systems (EEE, ISE)**

PROFESSOR P.Y.K. CHEUNG

We draw a distinction between the fundamentals of signal modelling in the time and frequency domains, and indicate the significance of alternative descriptions. The basic concepts of Fourier series, Fourier transforms, Laplace transforms and related areas are developed. The idea of convolution for linear time variant systems is introduced and expanded on from a range of perspectives. The transfer function for continuous and discrete time systems is used in this context. Stability is discussed with respect to the pole locations. Some elements of statistical signal description are introduced as signal comparison methods. The discrete Fourier transform is discussed as a Z-transform evaluation and its consequences examined. Some basic filtering operations for both continuous and discrete signals are developed. Where appropriate use of MATLAB is made for demonstration purposes.

**E2.6 Control engineering (EEE, ISE)**

DR I.M. JAIMOUKHA


**E2.8 Mathematics (EEE only)**

PROFESSOR J.D. GIBBON, DR A. GANDY (DEPARTMENT OF MATHEMATICS)

The main topics covered are: Vector calculus; Transforms; Complex variable; Linear algebra; Probability and Statistics.

**E2.11 Mathematics (ISE only)**

DR A. WALTON, DR E. MCCOY (DEPARTMENT OF MATHEMATICS)

Fourier transforms: basic definitions and properties; the complex integral method; the convolution theorem, Parseval's theorem; the delta function; the uncertainty principle. Laplace transforms: revision of definition and shift theorems; the inverse transform; transforms of derivatives and integrals; the convolution theorem. Line integrals; parametric representation of curves in a plane. Path independence in
simply connected domains; finding a potential. Double in integrals: double and iterated integrals in simple and general domains; applications to computing volumes in three dimensions. Green’s theorem in simply-connected domains; applications to computing line and double integrals. Functions of a complex variable; revision of complex numbers; analytic functions; Cauchy’s theorem; residue theorem. Probability and statistics: Probability: axioms of probability; elementary probability results; conditional probability; the law of total probability; Bayes theorem. Systems reliability. Discrete random variables: binomial distribution; Poisson distribution. Continuous random variables: exponential distribution; normal distribution; uniform distribution. Reliability; hazard rates.

**E2.12 Software engineering II: object-oriented software engineering (ISE only)**
MR L.G. Madden


**C210 Computer architecture (ISE only)**
Professor W. Luk (Department of Computing)

To build on the foundation laid by courses on Computer Systems and Hardware; to show the relationship between hardware and software; to focus on the concepts that provide the basis for current computers.

Introduction: overview; performance. Instructions: formats, representations, interface with software. Arithmetic: number representation; hardware for arithmetic operations; Arithmetic Logic Unit. Datapath and control unit: single-clock and multiple-clock implementations; microprogramming; exception handling. Memory hierarchy: caches, virtual memory. Pipelining: pipelined datapaths, data and branch hazards, exceptions. Advanced topics: hardware compilation, parallel architectures, special-purpose processors.

**E2.15 Language processors (ISE only)**
Dr Y. Demiris

**Fundamentals**: introduction to language processors; types of language processing; assemblers, compilers, preprocessors, interpreters and disassemblers; T-diagram representations of compilers; examples of language processors (GCC, Tex/Latex, Matlab, SysTran, Postscript, XML): compiling and running a compiler, cross-compilation and bootstrapping; semantics, conceptual structure of language processors; front and back-ends; passes; compiler width; criteria for design and evaluation of language processors; history and evolution of language processors; a complete example of a language processor (an infix to postfix expression converter) in full detail; syntax-directed translation; attributes and annotated parse trees; tree-traversal methods.

**Theoretical underpinnings of language processors**: introduction to grammars; basics; production rules and derivation of strings; formal definitions; Chomsky’s hierarchy; context-sensitive and context-free grammars; Turing machines; linearly-bound automata; push-down automata; regular grammars; finite state automata; BNF/EBNF syntax; regular expressions and their limitations.

**Lexical analysis**: introduction to lexical analysis; tokens and attributes; deterministic and non-deterministic finite state automata; epsilon-transition; equivalency of NFA and DFA; elimination of e-transitions and non-deterministic transitions; epsilon closures; subset construction; Thompson’s algorithm for converting a regular expression to NFA; automatic construction of DFAs; DFA minimisation; automatic generation of lexical analysers using Lex/Flex.

**Parsing**: introduction to parsing; leftmost and rightmost derivations; parsing ambiguities; top-down vs bottom-up parsing; \(L(L/R)\{k\}\) notation, recursive descent parsing; lookahead and predictive parsing; FIRST and FOLLOW sets and their computation; left-recursion and its elimination; left-factoring; transition diagrams and tables and their construction; bottom-up parsing; shift reduction parsing; stack
implementation; LR(k) parsing; LR/SLR/Canonical LR/LALR; construction of parsing tables; automatic construction of parsers using YACC/Bison.

**Context-handling:** introduction to context-handling; attributes and attribute grammars; dependency graphs; S- and L-attributed grammars; S-attributed and bottom-up parsing; inherited attributes; type checking; symbol tables.

**Code generation and optimisation:** introduction to code generation; intermediate code generation; types of intermediate code (Pascal P-code, Java byte-code; three-address code); translation of intermediate code to target code; instruction selection issues; storage management; memory, heap, garbage collection; register allocation; flow graphs and basic blocks; converting three-address statement sequences into basic blocks; local and global transformations; dead-code elimination; common subexpression elimination; algebraic transformations; computation of next use information; register and address descriptors; register allocation in detail; interference graphs; register allocation through graph colouring; optimisation: peephole optimisation; flow of control optimisations; removal of redundancy; loads and stores; removal of unreachable code; copy propagation; code motion; constant folding; dataflow analysis; code profiling.

**Case studies:** GCC and internals; front and back ends; register transfer language; construction of a PASCAL to ARM assembly language processor (assessed laboratory coursework).

**E2.17 Discrete mathematics and computational complexity (ISE only)**
DR G.A. CONSTANTINIDES
Functions, relations and sets. Logic: forms of logic, logical connectives, normal forms, universal and existential quantification. Recurrence relations: definitions, the master theorem. Algorithmic analysis: upper and average case complexity, big O/omega/theta, recurrence relations for recursive algorithms. Computability: tractability, intertractability and uncomputability.

**E2.18 Algorithms and data structures (EEE only)**
DR C. BOUGANIS
A review of C++ language; Software engineering principles; Data structures; Lists; ordered lists; Trees Ordered trees; Hash tables; Parsing. Algorithms for sorting and searching.

**E2.19 Introduction to Computer architecture (EEE only)**
DR T.J.W. CLARKE
The kernel of computer architecture: the instruction set architecture. Trends in technology and the basics of a computer system architecture.

**Humanities**
Students take one of the following courses, the syllabuses of which are in the Humanities section: Arabic, French, German, Italian, Japanese, Mandarin (with option for Cantonese speakers), Mandarin Language and Literacy for Heritage Speakers, Russian, Spanish, Art of the twentieth century, Communicating science: the public and the media, Controversies and ethical dilemmas in science and technology, Creative writing, European history 1870-1989, Global history of twentieth century things, History of medicine,
Modern Literature and Drama, Music and western civilisation, Music technology, Philosophies of Science: Theory, Society and Communication, Philosophy, Politics, the Roman Empire.

**Optional courses (EEE only)**

An additional Humanities course, selected from the list above, may be taken by students of sufficient academic standing.

**E2.20 Technical communication (EEE, ISE)**

DR S. BAINS

1. One e-mail message explaining the status of the second year project.
2. One executive summary that outlines the contents of a larger document and provides informed recommendations/analysis.
3. Second year project report and presentation.

In addition there will be two optional editing exercises.

**Practical work (core to all courses)**

*Electrical laboratory*

DR T.J.W. CLARKE

About 100 hours.

Students perform a course of experiments and projects complementary to all lecture courses. Hardware experiments in Control, Power Electronics, Electromagnetic fields, A/D and D/A converters, Active Filters, Semiconductor devices, Signal Processing and Digital Logic. Software experiments in communications and signal processing.

*Computing laboratory*

DR. T.J.W. CLARKE, DR C. BOUGANIS, DR. Y. DEMIRIS, MR L.G. MADDEN

40 hours' computing laboratory activity.

The second year Computing laboratories in the Autumn term for EEE courses involves ARM assembly language programming and supports Dr Clarke’s lecture course, E2.19 Introduction to Computer Architecture. The Spring term involves procedural C++ programming and supports Dr Bouganis’s lecture course, E2.18 Software Engineering 1: Algorithms and data structures. MS-Windows program development environments are used in both terms.

The second year Computing laboratories in the Autumn term for ISE courses involves object oriented C++ programming and supports Mr Madden’s lecture course, E2.12 Software Engineering II: Object oriented Software Engineering. The Spring term involves object oriented C++ programming in conjunction with compiler writing software tools and supports Dr Demiris’s lecture course, E2.15 Language Processors. Linux program development environments are used in both terms.

**Other activities**

Students participate in group projects in which they investigate technological, economic and social aspects of a complex engineering problem, reporting by means of an oral presentation, a written report, and a web page.

**THIRD YEAR (EEE ONLY)**

Students are required to take the following:

- **BEng course**: six technical and one non-technical module. One additional module may be taken.
- **T and EY streams**: seven technical and one non-technical module. One additional module may be taken.
- **EM stream**: three technical modules, three business modules, and two other technical or non-technical modules.

One additional course may be taken. A minimum of seven technical modules must be taken across the third and fourth years.
Students spend approximately 20 hours on coursework associated with each of their chosen options. MEng students undertake a group project throughout the year. BEng students undertake an individual project from November through to the end of the summer term.

Technical modules

**E3.01 Analogue integrated circuits and systems**
PROFESSOR C. TOUMAZOU

**E3.02 Instrumentation**
DR C. PAPAVASSILIOU

**E3.03 Communication systems**
PROFESSOR A. MANIKAS
Communication sources and channels: modelling of communication sources and communication channels, measures of information, Gaussian sources and channels, etc. Performance criteria and limits of communication systems: introductory concepts, energy utilisation efficiency (EUE), bandwidth utilisation efficiency (BUE), bandwidth expansion factor, signal-to-noise power ratio (SNR), probability of error. Shannon's threshold capacity curve, theoretical limits on performance of digital communication systems and the concept of an ideal communication system. The (Pe/SNR, EUE, BUE) parameter planes. Representation of the major communication systems on the parameter planes. Comments, comparisons and discussions. Digital transmission of analogue signals: a brief review of sampling theory and quantisation (uniform, ideal and natural sampling, practical problems, uniform quantisers), maximum-SNR-non-uniform quantisers, A-law and M-law comparers, differential quantisers, basic concepts of differential PCM. Principles of source and channel coding: source encoder-decoder (the prefix of a binary sequence, prefix code, Kraft inequality, defining an optimum code, Shannon's first coding theorem, etc.). Channel capacity. Error control coding (Shannon's second coding theorem, linear block codes, convolutional codes). Interleaving-deinterleaving. Line codes and digital modems. Principles of multiplexing and public switched telephone networks: using concepts and analytical tools presented in the previous topics, the examination of multiplexing and PSTN will be presented, based on the CCITT recommendations for PCM and the associated digital hierarchy. Principles of ADSL/VDSL. Mobile communication systems: a compact review of a mobile radio network and a detailed description/analysis of the pan-European cellular communication system. The analysis will be based on European telecommunication standards.

**E3.05 Digital system design**
DR C. BOUGANIS
Case study: definition of the digital system to be used as demonstrator; linked finite state machines; FSM implementation issues; race, hazards and metastability; dynamic memory interface; special memory
devices; multiplier circuits; bit-serial arithmetic circuits; data coding circuits; design for testability; programmable logic, FPGAs and CPLDs; system level interfacing.

**E3.06 VHDL and logic synthesis**

DR T.J.W. CLARKE

VHDL—modelling of hardware: model of behaviour, time and structure. Major VHDL constructs: entity declarations; architecture bodies; subprograms; packages and ‘use’ clauses. Basic VHDL data types: literals; scalars; vectors. Behavioural description: processes; activation and suspension of processes; sequential assignments; signal assignments; variable assignments; sequential control; procedure and function calls; concurrent statements. Structural description: parts; component instantiation; configuration specifications; busses. Access types: files, file I/O.


**E3.07 Digital signal processing**

DR P.A. NAYLOR


**E3.08 Advanced signal processing**

DR D.P. MANDIC


**E3.09 Control engineering**

PROFESSOR A. ASTOLFI

Abstract dynamical systems; differential and difference equations; state space models; Lyapunov stability; structural properties (controllability and observability); Kalman decomposition; pole placement via state feedback and dynamic output feedback; observer design.

**E3.10 Mathematics for Signals and Systems**

DR M. DRAIEF

functions, polynomial interpolation Applications: Matrices in engineering, Graphs and Networks, Fourier series.

**E3.11 Advanced electronic devices**

DR K. FOBELETS

Energy band diagrams as a route to understand semiconductor devices

Processing: how is it done? What are the consequences of aggressive downscaling of FETs?

Discussion and comparison of different Field Effect Transistors: JFET, GaAs MESFET, Si:SiGe MODFET and GaAs/InGaAs HEMT. Strain as an extra parameter to engineer devices. Optimising the "classical BJT" using a combination of different materials: HBT. Quantum mechanics and how is it used in semiconductor devices. An example: the resonant tunnelling diode. SOI, SGOI, sSOI, novel substrates for better device performance. Double/triple gating option to keep control on nano-scale FETs. Carbon nanotubes, Si nanowires: devices for the future?

**E3.12 Optoelectronics**

PROFESSOR R.R.A. SYMS

Maxwell’s equations; the wave equation for electromagnetic waves; evanescent waves; power flow.

Waveguide structures: boundary matching, slab dielectric waveguide; guided and radiation modes; cut-off conditions; free carrier contribution to the dielectric constant; waveguides in semiconductors—homostructure and heterostructure guides; epitaxy and lattice matching; channel waveguides. Channel waveguide devices: power splitters, filters. Diode-based waveguide structures: homojunctions and heterojunctions; carrier injection phase modulators; electro-optic phase modulators; switches and intensity modulators. Photodetectors: absorption of light by semiconductors; quantum efficiency; photoconductive detectors; p-i-n photodiodes; heterojunction photodiodes. LEDs: spontaneous and stimulated emission; electroluminescence in p-n junctions; simple LED structures; emission spectrum of LED; DC efficiency and frequency response of LED; ELEDs.

Semiconductor lasers: conditions for laser oscillation; inversion and optical gain; emission spectrum of laser; the double heterostructure; threshold condition and power-current characteristics.

**E3.13 Electrical energy systems**

PROFESSOR G. STRBAC, DR B. CHAUDHURI


**E3.14 Power electronics and machines**

PROFESSOR T.C. GREEN, DR P.D. MITCHESON

Improvements to basic switch-mode power supply circuits to provide isolation, negative polarity and low ripple; inversion of DC to AC and rectification with sinusoidal current; principles of power (c.f. signal) semiconductors; analysis of power losses and loss reduction techniques; control of induction machines with an inverter; use of inverters as grid interfaces for real and reactive power control.

**E3.16 Artificial intelligence**

DR J.V. PITT

Search: search space, problem formulation, generic graph search algorithm; graph theory; uninformed search strategies—depth first, breadth first, uniform cost, iterative deepening; informed search strategies—best first, A*, interactive deepening A*; analysis of algorithms—completeness, complexity, optimality; minimax, alpha-beta search; reinforcement learning and potential fields for path planning.

Knowledge representation and reasoning: knowledge acquisition, knowledge engineering; propositional logic—semantic proof, syntactic proof, soundness and completeness of proof systems; automated
reasoning with KE; predicate calculus and expert systems; modal logic and practical reasoning. Distributed
AI: agents, agency and multi-agent systems; BDI agents.

E3.17 Communication networks
DR J.A. BARRIA
Introduction to layered approach to the analysis of communication networks. Study and analysis of
different communication networks, their architectures and associated protocols: local area network (LAN),
metropolitan area network (MAN), wide area networks (WAN) and internet. Design of data and packet
switched networks, topological issues, routing strategies and congestion control. TCP/IP internet
Optimal routing problem.

E3.18 Microwave technology
DR S. LUCYSZYN
Review of the electromagnetic spectrum. Review of Maxwell’s equations. Electromagnetic numerical
Thermionic devices. Solid state active devices; two-terminal and three-terminal. Integrated circuit
technologies. HMICs and MMICs
S-parameters: general and signal flow graph techniques. Measurement techniques: general and laboratory
sessions. Applications of microwave technology.

E3.19 Real-time digital signal processing
DR P.D. MITCHESON
DSP architecture – the internals of a Texas Instruments DSP chip, its advancement over a simple processor
design and how it compares to a general purpose microprocessor, such as a Pentium 4.
How to use Texas Instruments’ Code Composer Studio (CCS)—to help you get started on the labs
and coursework.
Interrupt handling—real time systems make heavy use of interrupts when dealing with input/output.
Data conversion—we need to interface our DSP with the real analogue world.
Data representation—precision, number formats, etc. How is the data represented and what limits does
this place on the system?
Digital filters and design using practical tools—how would you design a digital filter in industry?
Filter implementation—how to efficiently write code for a digital filter implementation on a DSP.
Frame processing – use a technique to perform frequency domain processing on an audio signal
in real time.

E3.20 Discrete mathematics and computational complexity
DR G.A. CONSTANTINIDES
Functions, relations and sets. Logic: forms of logic, logical connectives, normal forms, universal and
existential quantification. Recurrence relations: definitions, the master theorem. Algorithmic analysis:
upper and average case complexity, big O/omega/theta, recurrence relations for recursive algorithms.
Computability: tractability, intertractability and uncomputability.
Non-technical modules

Business studies modules for the MEng in Electronic and Electrical Engineering with Management (EM stream)

Core modules (must be covered across years 3 and 4)
- BS0822 Accounting
- BS0821 Project management
- BS0815 Managerial economics OR BS0602 Business Economics
- BS0809 Finance and financial management
- BS0806 Entrepreneurship
- BS0826 Innovation management

Optional modules
- BS0612 Organisational behaviour and human resource management
- BS0817 Marketing
- BS0803 Business strategy
- BS0826 International business

See Business School section for details.

Business studies options (not EM stream)
- BS0822 Accounting
- BS0821 Project management
- BS0815 Managerial economics
- BS0808 Finance and financial management
- BS0806 Entrepreneurship
- BS0820 Innovation management

See Business School section for details.

Humanities and language options

Students take one of the following modules, the syllabuses of which are shown in the Humanities section: Arabic, French, German, Italian, Japanese, Mandarin (with option for Cantonese speakers), Mandarin Language and Literacy for Heritage Speakers, Russian, Spanish, Art of the twentieth century, Communicating science: the public and the media, Controversies and ethical dilemmas in science and technology, Creative writing, European history 1870-1989, Global history of twentieth century things, History of medicine, Modern Literature and Drama, Music and western civilisation, Music technology, Philosophies of Science: Theory, Society and Communication, Philosophy, Politics, the Roman Empire. See the Department of Humanities section for further details.
THIRD YEAR (ISE ONLY)
Students are required to take the following:

- **BEng course:** C526 Databases module, plus five or six technical modules and one or two business, humanities or language modules (a total of seven or eight modules—i.e. including ISE3.2). At least one technical module must be taken from each department (EEE and Computing).

- **MEng courses:** C526 Databases module, plus six or seven technical modules and one or two non-technical modules (a total of eight or nine modules). At least one technical module must be taken from each department (EEE and Computing).

Students spend approximately 20 hours on coursework associated with each module. MEng students undertake a group project in summer term. BEng students undertake an individual project from November through to the end of the summer term.

Technical modules

**ISE3.1 Human-computer interaction**
PROFESSOR R. SPENCE
Overview of HCI, with examples illustrating the issues posed by human perceptual and cognitive processes. Within the very broad field of HCI, a useful focus is provided by information visualization, comprising representation, presentation and interaction. Norman's Stages of action, its properties and its value to interaction design and evaluation. The representation of values and relations. Presentation in space and time: focus+context and Rapid serial visual Presentation are examples. Classes of interaction, including sensory interaction. Concepts of sensitivity, residue and scent. Navigation of information spaces. Design methods, including sketching: dynamic sketches as prototypes. Approaches to system design. Selected specialist topics presented by visiting professional designers

**C526 Databases**
MR J. JACOBSON. MR N. RIZOPOULOS (DEPARTMENT OF COMPUTING)
Introduction to databases, including data modelling, database management, data dictionary, query formulation and evaluation.
Relational databases: design, functional dependencies, normalisation up to and including the fourth normal form, losslessness, dependency preservation.
Relational database languages, including relational algebra and relational tuple calculus.
Views and database integrity.
Transaction management and recovery: transaction atomicity, database log, commit and rollback, recovery from system and media failure, deferred and immediate database modifications, checkpoints.
Concurrency: including conflict serialisability, conflict equivalence, precedence graphs, serialisability, locking, two phase locking protocol, deadlock.
Entity-relationship modelling and translation to the relational model.
The course will be supported by laboratory sessions using the relational database system, Ingres, and the language SQL.

**ISE3.3 Communication systems**
PROFESSOR A. MANIKAS
Communication sources and channels: modelling of communication sources and communication channels, measures of information, Gaussian sources and channels, etc.
Performance criteria and limits of communication systems: introductory concepts, energy utilisation efficiency (EUE), bandwidth utilisation efficiency (BUE), bandwidth expansion factor, signal-to-noise power ratio (SNR), probability of error. Shannon's threshold capacity curve, theoretical limits on performance of digital communication systems and the concept of an ideal communication system. The (Pe/SNR, EUE,
BUE) parameter planes. Representations of the major communication systems on the parameter planes. Comments, comparisons and discussions.

Digital transmission of analogue signals: a brief review of sampling theory and quantisation (uniform, ideal and natural sampling, practical problems, uniform quantisers), maximum-SNR-non-uniform quantisers. A-law and M-law companders, differential quantisers, basic concepts of differential PCM.

Principles of source and channel coding: source encoder-decoder (the prefix of a binary sequence, prefix code, kraft inequality, defining an optimum code, Shannon's first coding theorem, etc.) Channel capacity. Error control coding (Shannon's second coding theorem, linear block codes, convolutional codes).

Interleaving-deinterleaving. Line codes and digital modems.

Principles of multiplexing and public switched telephone networks: using concepts and analytical tools presented in the previous topics, the examination of multiplexing and PSTN will be presented, based on the CCITT recommendations for PCM and the associated digital hierarchy.

Principles of ADSL/VDSL.

Mobile communication systems: a compact review of a mobile radio network and a detailed description/analysis of the pan-European cellular communication system. The analysis will be based on European telecommunication standards.

**C318 Custom computing**

PROFESSOR W. LUK, (DEPARTMENT OF COMPUTING)

Overview: motivations; features and examples of custom computers, summary of development methods and tools. Design: parameterised description of leaf components and composite structures; resource and performance characterisation; high-level design tools. Optimisation: techniques for improving design efficiency such as pipelining, serialisation, transposition and their combinations. Realisation: bit-level designs, data refinement, FPGA-based implementations. System-on-chip architectures, technology trade-offs, design and optimization methods. Examples will be selected from a number of application areas including digital signal processing, computer architecture and non-numerical operations.

**ISE3.5 VHDL and logic synthesis**

DR T.J.W. CLARKE


High level synthesis: state minimisation in FSM.

Technology mapping: gate arrays, FPGA, PLDs.

**ISE3.7 Mathematics for signals and systems**

DR M. DRAIEF


**C302 Software engineering—methods**

DR A. ARGENT-KATWALA, PROFESSOR J. MAGEE, MR A. MCVEIGH (DEPARTMENT OF COMPUTING)

This course features state-of-the-art methods in software engineering practices from a managerial, technical, and ethical perspective. First we present prominent and well proven agile and iterative development techniques, focusing on management and some programming aspects: we discuss the methods Scrum, Extreme Programming, the Unified Process, and Evolutionary Project Management and explore the history and utility of these methods. On the more technical side as explore what solutions are currently available that aid implementors in achieving quality assurance of their code. We mostly study an approach of annotating source code with integrity constraints (object invariance, pre- and post-conditions etc) and survey some of the freeware tool support that is available at present. If time permits, we will give a brief introduction to the CASE tool Rational Rose.

On the purely professional side, we identify some professional issues that may not have managerial or technical solutions. Notably we ask which problems have an ethical dimension and try to identify what an ‘ethical dimension’ is. We offer some exploration tools that help in recognising and assessing ethical dilemmas and we apply these tools to some case studies.

**ISE3.9 Control engineering**

PROFESSOR A. ASTOLFI

Abstract dynamical systems; differential and difference equations; state space models; Lyapunov stability; structural properties (controllability and observability); Kalman decomposition; pole placement via state feedback and dynamic output feedback; observer design.

**ISE3.11 Digital signal processing**

DR P.A. NAYLOR

Sampling theory, Z-transforms, system functions. Digital filter structures, signal flow graphs, elementary FIR/IIR filter design techniques, windows, bilinear and band transformations. Discrete Fourier transform, relationship between DFT and DTFT, simple and short-time spectral estimation, fast computation of DFT as decimation-in-time. Linear convolution, cyclic convolution, sectioned convolution (overlap-add and overlap-save), application to fast filtering algorithms, windowing. Basic multirate elements and identities, design of sample rate changing systems, polyphase representation of filters, maximally decimated filter banks, polyphase representation of maximally decimated filter banks, typical applications. Overview of microprocessor architectures for DSP, implementational aspects of simple DSP algorithms.

**C317 Graphics**

DR D.F. GILLIES, DR D. RUECKERT (DEPARTMENT OF COMPUTING)

**ISE3.17 Advanced signal processing**  
DR D.P. MANDIC  

**C337 Simulation and modelling**  
DR A.J. FIELD, DR J. BRADLEY (DEPARTMENT OF COMPUTING)  
Introduction and basic simulation procedures.  
Model classification (with worked examples for each): Monte Carlo simulation, discrete-event simulation, continuous system simulation, mixed continuous/discrete-event simulation.  
Quantitative modelling paradigms: queueing networks, stochastic process algebras and stochastic Petri nets.  
Input and output analysis: random numbers, generating and analysing random numbers, sample generation, trace- and execution-driven simulation, point and interval estimation.  
Process-oriented and parallel and component simulation and modelling

**ISE3.19 Digital system design**  
DR C. BOUGANIS  
Case study: definition of the digital system to be used as demonstrator; linked finite state machines; FSM implementation issues; race, hazards and metastability; dynamic memory interface; special memory devices; multiplier circuits; bit-serial arithmetic circuits; data coding circuits; design for testability; programmable logic, FPGAs and CPLDs; system level interfacing.

**C343 Operations research**  
PROFESSOR B. RUSTEM, DR D. KUHN (DEPARTMENT OF COMPUTING)  
To introduce optimal decision-making processes in design and management. To give the necessary mathematical background and its application to solving a selection of constrained optimisation problems with special reference to computation.  
Preview: optimal policy in design and management: mathematical models.  
Linear programming: the Simplex method, two-phase Simplex method, duality, shadow prices.  
Linear integer programming: Gomory's cutting plane methods for pure and mixed linear integer programming.  
Search methods; branch and bound algorithms.  
Game theory; two-person non-cooperative games. Saddle points. Matrix games.

**ISE3.23 Artificial intelligence**  
DR J.V. PITT  
Search: search space, problem formulation, generic graph search algorithm; graph theory; uninformed search strategies—depth first, breadth first, uniform cost, iterative deepening; informed search strategies—best first, A*, iterative deepending A*; analysis of algorithms—completeness, complexity, optimality, minimax, alpha-beta search; reinforcement learning and potential fields for path planning.  
Knowledge representation and reasoning: knowledge acquisition, knowledge engineering; propositional logic—semantic proof, syntactic proof, soundness and completeness of proof systems; automated reasoning with KE; predicatate calculus and expert systems; modal logic and practical reasoning.  
Distributed AI: agents, agency and multi-agent systems; BDI agents.
**C223 Concurrency**

PROFESSOR J. KRAMER. DR S. UCHITEL (DEPARTMENT OF COMPUTING)

To study the concepts, formal models and implementation techniques appropriate for design, analysis and construction of concurrent programs.

Students will perform a laboratory exercise involving concurrent programming using Java.

Introduction to concurrent programming: key ideas, interleaved actions, synchronisation, interference, deadlock, starvation, fairness, safety and liveness.

Monitors: entry queues, condition variables, wait and notify, reasoning about monitors.

Message passing: processes, synchronous and asynchronous communication, ports, send and receive, request-reply communication, non-deterministic choice, configuration programming.

Specification: introduction to formalisms for the specification and verification of concurrent systems; labelled transition systems, process calculi CCS, CSP.

Software structure: structuring applications into modular, distributable software components; component types and instances; nesting and dynamic structures; component interfaces; connection patterns and naming.

**ISE3.31 Communication networks**

DR J.A. BARRIA


**ISE3.33 Real-time digital signal processing**

DR P.D. MITCHESON

DSP architecture – the internals of a Texas Instruments DSP chip, its advancement over a simple processor design and how it compares to a general purpose microprocessor, such as a Pentium 4.

How to use Texas Instruments Code Composer Studio (CCS) – to help you get started on the labs and coursework.

Interrupt handling—real time systems make heavy use of interrupts when dealing with input and output.

Data conversion—we need to interface our DSP with the real analogue world.

Data representation – precision, number formats, etc. How is the data represented and what limits does this place on the system?

Digital filters and design using practical tools—how would you design a digital filter in industry?

Filter implementation—how to efficiently write code for a digital filter implementation on a DSP.

Frame processing—use a technique to perform frequency domain processing on an audio signal in real time.

**ISE3.35 Real-time operating systems**

DR T.J.W. CLARKE

Real-time system design; task control in FreeRTOS; mutexes, interrupt and pre-emption locks; semaphores, messages queue, event registers; synchronisation; scheduling: priority and EDF; RMA; deadlocks; starvation; livelocks priority inversion and priority inheritance: PCP and CPP protocols; interrupt and foreground/background system design; interrupt latency calculations; pollings vs interrupt vs timer-polled service routines; implementation of FreeRTOS: context-switch, tasks lists and ready list, tick interrupt, message queues.
**C341 Introduction to bioinformatics**  
PROFESSOR Y. GUO, DR M. VIGLIOTTI (DEPARTMENT OF COMPUTING)  
Broadly speaking, bioinformatics is the application of computational techniques to the discovery of knowledge from biological data.  

**CC527 Computer networks and distributed systems**  
DR P.R. PIETZUCH, PROFESSOR M. SLOMAN (DEPARTMENT OF COMPUTING)  
Network overview: interfaces, protocols and services, connection-oriented and connectionless services, OSI and TCP/IP reference models.  
Data link protocols: framing and data transparency, error detection and correction, flow control.  
Internet protocols: IP addressing, APR and RARP, IP and ICMP, UDP and TCP.  
Overview of distributed system architecture: motivation, system structures, OPD reference model and distribution transparencies, design issues.  
Interaction primitives: message passing, remote procedure call, remote object invocation.  
Interaction implementation message passing, RPC, concurrency and threads.  
Security threat analysis: security policies – military (Bell Lapadula) versus commercial models; access control concepts – identification, authentication, authorisation and delegation; authorisation policy: access matrix, access rules and domains; access control lists, capabilities, secret and public key encryption, digital signatures, authentication, Kerberos.

**Non-technical modules**

**Business studies options**  
For all ISE streams:  
BS0822 Accounting  
BS0821 Project management  
BS0815 Managerial economics  
BS0808 Finance and financial management  
BS0806 Entrepreneurship  
BS0820 Innovation management  
See Business School section for details.

**Humanities and language options**  
Students take one of the following modules, the syllabuses of which are shown in the Humanities section: Arabic, French, German, Italian, Japanese, Mandarin (with option for Cantonese speakers), Mandarin Language and Literacy for Heritage Speakers, Russian, Spanish, Art of the twentieth century, Communicating science: the public and the media, Controversies and ethical dilemmas in science and technology, Creative writing, European history 1870-1989, Global history of twentieth century things, History of medicine, Modern Literature and Drama, Music and western civilisation, Music technology, Philosophies of Science: Theory, Society and Communication, Philosophy, Politics, the Roman Empire.  
See the Department of Humanities section for further details.
FOURTH YEAR (EEE ONLY)

Students are required to take the following:

- **T stream**: six technical and one non-technical module. One additional module may be taken.
- **EY stream**: a full year in a Higher Education Institution abroad. Studies include an individual project, dissertation and technical modules.
- **EM stream**: three technical modules, three business modules, and one other technical or non-technical module. One additional module may be taken. A minimum of seven technical modules must be taken across the third and fourth years.

EM and T stream students spend about 10 hours per week in the autumn and spring terms and work full-time (after final examinations) on individual projects in the summer term. In addition, each student gives an oral presentation on his/her individual project during the summer term.

Technical modules

**E4.01 Advanced communication theory**
PROFESSOR A. MANIKAS
Introductory concepts: modelling of information sources, communication channels and sinks. Definitions of priori and posterior probabilities in relation to the model of a communication channel. MAP criterion, likelihood functions and likelihood ratio. An initial study on the performance of a digital communication system and expansion to a spread spectrum system.


PN-sequences: Galois field GF(2) basic theory, shift registers, basic properties of m-sequences, statistical properties of m-sequences, Gold sequences.

PN-signals: modelling, cross/auto correlation functions and power spectral density, partial correlation properties.

Spread spectrum systems (SSS): basic concepts and parameters. Classification and modelling of jammers. Modelling of BPSK and QPSK direct sequence SSS in a jamming environment, estimation of SNIR and bit-error-probability. Direct sequence SSS on the (SNR/pe, EUE, BUE) parameter plane. Frequency hopping SSS.

Principles of CDMA system: investigation of important system components with special attention given to RAKE receiver. Modelling and analysis with emphasis given on capacity issues. An overview of the TIA/ISA IS-95 CDMA standards. Wideband CDMA (3G).


**E4.03 Mobile radio communication**
DR M.K. GURCAN
Transmission path: VHF and UHF propagation; propagation losses; inverse fourth power propagation; Rayleigh fading, shadowing losses. Coverage probability; outage and coverage probabilities, error performance analysis for transmission systems; quality factor and re-use distance calculations.

Transmission schemes: wideband channels and wideband transmission; equalisation and multiplexing; multiple access schemes. Area coverage, analogue and digital transmission systems.
**E4.04 Advanced data communication**
DR M.K. GURCAN
Data transmission systems: elements of the system, the source, shaping filters and modulation systems and demodulation techniques. Maximum Likelihood detection and and MAP algorithm. Equalization: Linear Equalisers, Decision Feedback Equalisers. Multi tone modulation (ADSL and OFDM) and rate adaptive and margin adaptive discrete bit loading algorithms.

**E4.05 Traffic theory and queuing systems**
DR J.A. BARRIA
Introduction to teletraffic analysis. Mathematical basis of traffic theory: Markov processes. Loss-system analysis: route congestion in circuit-switched systems; models for overflow traffic; restricted availability; congestion in circuit switches. Delay-system analysis: introduction to queueing theory; congestion in message-switched systems and packet-switched systems; queueing network models. Analysis of random-access protocols; traffic characterisation of broadband services; admission and access control in broadband networks; routing in ATM networks. Performance/reliability (performability) models.

**E4.06 Optical communication**
PROFESSOR E.M. YEATMAN

**E4.07 Coding theory**
PROFESSOR A.A. IVANOV (DEPARTMENT OF MATHEMATICS)

**E4.10 Probability and stochastic processes**
DR M. DRAIEF

**E4.13 Spectral estimation and adaptive signal processing**
DR D.P. MANDIC

**E4.14 Speech processing**
DR P.A. NAYLOR
The human vocal and auditory systems. Characteristics of speech signals: phonemes, prosody, IPA notation. Lossless tube model of speech production. Time and frequency domain representations of speech; window characteristics and time/frequency resolution tradeoffs. Properties of digital filters: mean log response, resonance gain and bandwidth relations, bandwidth expansion transformation, all-pass filter

**E4.16 Current-mode analogue signal processing**

DR C. PAPAVASSILIOU


**E4.17 High performance analogue electronics**

DR E. RODRIGUEZ-VILLEGAS


**E4.18 Radio frequency electronics**

DR S. LUCYSZYN


**E4.20 Introduction to digital integrated circuit design**

PROFESSOR P.Y.K. CHEUNG


**E4.23 Stability and control of non-linear systems**

DR D. ANGELI

For non-linear systems, methods for determining stability and for designing stabilising controllers are studied using state-space (Lyapunov and Lasalle theory, variable structure analysis), function space (small gain theorem, passivity) and frequency-domain (Popov and circle criteria, describing function) methods. Model reference adaptive control is treated using the passivity concept.

**E4.25 Design of linear multivariable control systems**

DR I.M. JAIMOUKHA

E4.26 Estimation and fault detection
PROFESSOR R.B. VINTER
This course is concerned with the recursive estimation of signals from sensor measurements, and the detection and isolation of faults and changes in stochastic systems. Topics covered include: Stochastic models: stochastic differential equations, ARMAX models, state-space representations, covariance equations. Kalman filtering: the Kalman filter, steady-state filters, continuous-time filters, Bayes confidence intervals. Nonlinear filters: the extended Kalman filter. Fault detection and estimation: Bayes and Neyman-Pearson hypothesis tests, joint estimation and model testing.

E4.27 Identification and adaptive control
PROFESSOR R.B. VINTER
Stochastic dynamical systems and their description in terms of standard discrete time models; these include linear state-space models and linear difference equation models known as ARMAX (Autoregressive Moving Average models with Exogenous input) models. Least-squares parameter estimation. The statistical properties of parameter estimates. Recursive algorithms for parameter identification. Sources of parameter bias. Techniques for eliminating bias, including the Generalized Least Squares algorithm. The effects of over-parameterisation. Techniques for selecting model order.

E4.29 Optimisation
PROFESSOR A. ASTOLFI
Topics covered include unconstrained optimisation and the associated algorithms of steepest descent and conjugate gradient, Newton methods, rates of convergence, constrained optimisation and the method of Lagrange multipliers, quadratic programming, penalty methods. A brief introduction to global optimization and integer programming will be also given.

C332 Advanced computer architecture
PROFESSOR P.H.J. KELLY (DEPARTMENT OF COMPUTING)
Performance: measuring and reporting computer systems performance. Amdahl's law.
Pipelined CPU architecture: instruction set design and pipeline structure.
Dynamic scheduling using scoreboard and Tomasulo’s algorithm. Software instruction scheduling and software piping. Superscalar and long-instruction-word architectures. Branch prediction and speculative execution.
Uniprocessor cache coherency issues: self-modifying code, peripherals, address translation.
Vectorising compilers and their capabilities; applications to parallelisation and memory hierarchy optimisation.
Interconnection networks: topology, routing, flow control, deadlock avoidance. The k-ary n-cube family of topologies. Virtual channels, wormhole routing and virtual cut-through.
C317 Graphics
PROFESSOR D.F. GILLIES, PROFESSOR D. RUECKERT (DEPARTMENT OF COMPUTING)

E4.40 Information theory
DR C. LING
Elements of information theory of discrete systems; information measures, memoryless and memory sources, the noiseless coding theorem. Methods of source coding. Information theory of continuous systems. Shannon's capacity theorem and its interpretation. Lossy source coding and rate-distortion theory. Network information theory.

C493 Intelligent data and probabilistic inference
PROFESSOR D.F. GILLIES (DEPARTMENT OF COMPUTING)
The course is concerned with probabilistic methods for modelling data and making inferences from it. The first part of the course introduces Bayesian Inference and Networks and includes probability propagation and inference in singly connected networks, generation networks from data, and calculating the network accuracy. The course then goes on to consider highly dependent data and special techniques for exact and approximate inference in these networks. The next topic to be covered is data modelling using distributions and mixture models. The topic of sampling and re-sampling is covered along with data reduction by principal component analysis and special problems that occur with small sample sizes. The last part of the course is concerned with classification using linear discriminant analysis and support vectors.
The emphasis of the course is algorithmic rather than mathematical, and the coursework is a practical programming exercise in analysing data from a study into the prognosis of hepatitis C.
Note that the course does not include non-probabilistic methods of data analysis such as neural networks, fuzzy logic or expert systems.

E4.43 Synthesis of digital architectures
DR G.A. CONSTANTINIDES
Introduction to the fundamental architectural synthesis problems: scheduling, allocation, binding, estimation and control unit synthesis. Introduction to graph theory and combinatorial optimisation. Scheduling algorithms: as-soon-as-possible and as-late-as-possible, list scheduling, integer linear programming. Resource sharing algorithms: interval graphs, graph colouring, integer linear program models; register sharing.

E4.45 Wavelets and applications
DR P.L. DRAGOTTI


**E4.46 Distributed computation and networks: a performance perspective**
PROFESSOR E. GELENBE

Description of distributed system architectures and their components; digital sensors and actuators, processing units, local area networks, packet networks and the IP protocol, wireless ad-hoc networks. The role of protocols.


**E4.47 Modelling and control of multi-body mechanical systems**
DR S. EVANGELOU, PROFESSOR A. ASTOLFI

Basic vector calculus; Newtonian mechanics; Holonomic and nonholonomic systems; Control of nonholonomic systems; Kinematics of rigid body motion; Dynamics of rigid body motion; Variational principles and analytical mechanics: Calculus of variations and Lagrange multipliers, Euler-Lagrange differential equations, Virtual work, D'Alembert's principle.; Hamilton's principle and Lagrangian equations of motion; Control by energy shaping and damping injection; Multibody building software.

**E4.48 Power system control, measurement and protection**
DR B. PAL

The course will cover modelling of machines, excitation, prime-movers, governors, network and loads; transient stability; small-signal stability, Eigenvalue analysis, power system stabilisers, wide area measurement; protection philosophy; digital protection; distance and over-current protection.

**E4.49 FACTS and power electronics**
PROFESSOR T.C. GREEN, DR P.D. MITCHESON, DR B. PAL

The lecture topics will include: principles of Flexible AC Transmission Systems (FACTS); operation of inverters in series and shunt connection; modelling of inverters in electirfcal networks; voltage control with FACTS devices; flow control with FACTS devices; power electornic techniques specific to high power ratings (series valves, multi-level and multi-pulse systems); devices for power quality improvement (dynamic voltage restorers, DVR and active power filters, APF); modelling of power converters using state-space averaging, stability analysis of power converters and design of stabilising controllers.
E4.50 Sustainable electrical systems
PROFESSOR T.C. GREEN, PROFESSOR G. STRBAC
Context, Drivers and Policy The world of energy and the panorama for the UK Government and international objectives and policies. The status of the present system.

E4.51 Power system economics
PROFESSOR G. STRBAC

E4.52 Real-time operating systems
DR T.J.W. CLARKE
Real-time system design; task control in FreeRTOS; mutexes, interrupt and pre-emption locks; semaphores, messages queue, event registers; synchronisation; scheduling; priority and EDF; RMA; deadlocks; starvation; livelocks; priority inversion and priority inheritance; PCP and CPP protocols; interrupt and foreground/background system design; interrupt latency calculations; pollings vs interrupt vs timer-poll service routines; implementation of FreeRTOS; context-switch, tasks lists and ready list, tick interrupt, message queues.

E4.53 High voltage technology and HVDC transmission
DR B. CHAUDHURI
High Voltage Technology: Introductions, HV Insulators, HV Cables, Corona, HV Bushings, Over voltage phenomena, Surge Arresters and Insulation Coordination.
HVDC Transmission: Introduction - AC vs DC, HVDC schemes, Converter Operation, Converter Control, Harmonics, Interaction with AC systems, Voltage Source Converter (VSC) based HVDC systems.

E4.54 Predictive control
DR E. KERRIGAN

E4.55 MEMS and nanotechnology
DR Z. DURRANI, PROFESSOR A.S. HOLMES
Introduction Micro- and nano-scale size domains; scaling of physical laws MEMS materials and processes; MEMS devices and applications. Nanostructures in semiconductors and metals; introduction to quantum effects in nanostructures; nanostructure applications. Fabrication Technologies. Semiconductor materials; photolithography; doping; thin film growth and deposition; metallisation; wet and dry etching. Silicon micromachining; metal MEMS processes. Nanofabrication methods – submicron optical lithography; electron beam lithography. MEMS Sensors and Actuators. Mechanics – elasticity; beam bending theory; membranes/plates. Microactuators based on various principles e.g. electrothermal, electrostatic,
electromagnetic, piezoelectric and SMA Actuator applications e.g. inkjet, electrical and optical switching
Physical sensors, e.g. acceleration, strain, flow Chemical sensors Microfluidics Scaling laws for
microfluidics; transport in micro-channels Microfluidic components – filters; mixers/reactors;
valves/controllers; pumps Grown Nanostructures Si nanowires and nanocrystals, Carbon nanotubes,
nanostructures in III-V materials, metal nanostructures, devices using grown nanostructures
Nano-electronic Semiconductor Devices The nano-scale MOSFET, short channel effects in a nano-MOSFET,
‘scaling’ of MOSFETs, scaling of semiconductor memory (FLASH and Random Access memory), bio-sensors
Quantum devices in nanostructures Electron tunnelling, quantum confinement effects, single-electron
effects, ballistic transport, optical properties of nanostructures, quantum dots, quantum point contacts,
single-electron transistor, single-electron memory and logic.

C430 Network security
DR E. LUPU, DR H. WIKLICKY (DEPARTMENT OF COMPUTING)
Introduction: assets, threats, countermeasures; network security models, security functions:
confidentiality, authentication, integrity, nonrepudiation, access control, availability, passive and active
attacks, end-to-end vs link-to-link encryption.
Classical Cryptography: key ideas, steganography, codes, one-time pad, substitution and transposition
ciphers, cryptanalysis, cryptographic strength.
Symmetric-Key cryptography: Feistel cipher; DES: basics, rounds, e-box, s-box, p-box, key box; Modes of
Operation: ECB, CBC, CFB, OFB; Double DES, Triple DES, IDEA, RC5, AES, problems with symmetric
key cryptography.
Public-Key cryptography: requirements, confidentiality, authentication, modular arithmetic,
Diffie-Hellman key exchange, RSA, attacks against RSA, hybrid cryptosystems, Elliptical Curve, Quantum
Cryptography.
Digital Signatures: characteristics, MAC’s, one-way hash functions, signing and verification, birthday
attack, public-key certificates, disavowed signatures, arbitrated digital signatures, chaffing & winnowing.
Mutual Authentication: basics, replay attacks, man-in-the-middle, interlock protocol, Andrew Secure RPC,
Needham Schroeder, Wide-Mouth Frog, Neuman-Stubblebine, Woo-Lam.
BAN-Logic Key Management: distribution, KDC, announcements and directories, public key certificates,
X509 certification authorities, PGP web of trust, control vectors, key generation and destruction,
key backup.
Intruders and Programmed Threats: host access, password systems and attacks, one-time passwords,
token cards, biometrics, trapdoors, programmed threats: trapdoors, logic bombs, trojan horses, viruses,
worms, countermeasures, intrusion-direction.
Firewalls: internet security policies, firewall design goals, firewall controls, TCP/IP, packet filtering routers,
application-level gateways, circuit-level gateways, firewall architectures, VPNs.
Web Security: WWW, web servers, CGI, active content, Java applets, Java security model:
sandbox, class loaders, bytecode verification, security manager, Java attacks, bypassing Java, mobile
code cryptography.

E4.57 Discrete-event systems
DR D ANGELI
Fourth year students on the T stream MEng may also select ONE module offered under the ‘Envision’
programme. Those available in 09/10 are:
E4.81 Medical Imaging (Bioengineering Dept module)
E4.83 Computational finance (Computing Dept module)
E4.84 Performance Analysis (Computing Dept module)
E4.85 Environmental impact assessment 1 (ESE Dept module).
E4.86 Nanomaterials 1 (Materials Dept module)
E4.87 Operations research (Computing Dept module)
E4.88 Design-led innovation and new venture creation – (Mech Eng module)

Business studies modules (MEng in Electronic and Electrical Engineering with Management only)

Core modules (must be covered across years 3 and 4)
BS0822 Accounting
BS0602 Business economics
BS0821 Project management
BS0809 Finance and financial management
BS0806 Entrepreneurship
BS0820 Innovation management

Optional modules
BS0817 Marketing
BS0803 Business strategy
BS0826 International business
BS0612 Organisational behaviour and human resource management
See Business School section for details.

Non-technical modules

Business studies modules (T stream only)
BS0822 Accounting
BS0821 Project management
BS0808 Finance and financial management
BS0806 Entrepreneurship
BS0820 Innovation management
BS0815 Managerial Economics
See Business School section for details.

Humanities and language options
Students take one of the following modules, the syllabuses of which are shown in the Humanities section:
Arabic, French, German, Italian, Japanese, Mandarin (with option for Cantonese speakers), Mandarin Language and Literacy for Heritage Speakers, Russian, Spanish, Art of the twentieth century,
Communicating science: the public and the media, Controversies and ethical dilemmas in science and technology, Creative writing, European history 1870-1989, Global history of twentieth century things, History of medicine, Modern Literature and Drama, Music and western civilisation, Music technology, Philosophies of Science: Theory, Society and Communication, Philosophy, Politics, the Roman Empire.
See the Department of Humanities section for further details.
FOURTH YEAR (ISE ONLY)

Students are required to take the following:

• **MEng in ISE**: Six or seven technical modules and one or two non-technical modules (a total of seven or eight modules). At least one technical module must be taken from each Department (EEE and Computing).

• **MEng in ISE with a Year Abroad**: a full year in a Higher Education Institution abroad. Studies include an individual project, dissertation and technical modules.

A number of courses have coursework associated with them. Students also undertake an individual project from November through to the end of the summer term.

Technical modules

**C418  Computer vision**

DR G-Z. YANG (DEPARTMENT OF COMPUTING)

Overview of early, intermediate and high level vision: first and second moments of illumination for recognition and classification of machine shop components in silhouette.

Segmentation: region splitting and merging; quadtree structures for segmentation; mean and variance pyramids; computing the first and second derivatives of images using the isotropic, Sobel and Laplacian operators; grouping edge points into straight lines by means of the Hough transform; limitations of the Hough transform; parameterisation of conic sections.

Perceptual grouping: failure of the Hough transform; perceptual criteria; improved Hough transform with perceptual features; grouping line segments into curves.

Overview of mammalian vision: experimental results of Hubel and Weisel; analogy to edge point detection and Hough transform; neural networks based on the mammalian vision system.

Relaxation labelling of images: detection of image features; simulated annealing.

Grouping of contours and straight lines into higher order features such as vertices and facets.

Depth measurement in images; triangulation; projected grid methods; shape from shading based on multi-source illumination.

Matching of images: the correspondence problem for stereo vision; two-camera and multiple-camera systems; shape from motion as a further stage of stereo vision; optical flow between adjacent video frames.

Expert system modelling in computer vision: model based vision using inference engines and rules.

**ISE4.3  Mobile radio communication**

DR M.K. GURCAN

Transmission path: VHF and UHF propagation; propagation losses; inverse fourth power propagation; Rayleigh fading, shadowing losses. Coverage probability; outage and coverage probabilities, error performance analysis for transmission systems; quality factor and re-use distance calculations.

Transmission schemes: wideband channels and wideband transmission; equalisation and multiplexing; multiple access scheme. Area coverage, analogue and digital transmission systems.

**C312  Advanced databases**

DR P. MCBRIEN, DR P. PIETZUCH (DEPARTMENT OF COMPUTING)

Database management system architecture: main components of a DBMS, buffers, caches, and optimisation high level query languages and low level primitive operations.

Concurrency control and recovery: ACID properties of transactions, recoverability, serialisability.

Transaction histories as a method for analysing database execution. Two-phase locking (2PL) ANSI SQL concurrency control levels.

Query optimisation.

**C474 Multi-agent systems**

DR F. TONI (DEPARTMENT OF COMPUTING)

General introduction to the concept of a software agent and a computation embedded in an environment, achieving one or more goals, taking into account changes in the environment. Introduction to a multi-threaded logic programming language to be used on the course (Qu-Prolog). Three forms of inter-thread communication in QuP. Reactive agents. Finite state machine behaviours. Co-ordination of reactive agents with and without communication. Reactive agents in Qu-Prolog. Distributed problem solving and the contract net protocol. Implementation of the contract net. Agents with mental state: Agent0; implementing and generalising Agent0. Agent communication languages: KQML and FIPA ACL and matchmakers. Issues concerning the semantics of ACLs. Communication policies and protocols, dialogues, various notions of conformance (of policies to protocols, of dialogues to policies and protocols). Resource allocation, negotiation, various notions of social welfare (utilitarian, egalitarian), various notions of negotiation deals. BDI agents. Multi-threaded BDI agents. Mobile agents – agent stations as places for agents to visit and security issues. Implementation of a mobile agent. Infrastructure and a mobile information gathering point.

**ISE4.9 Advanced data communications**

DR M.K. GURCAN

Data transmission systems; elements of the system, the source, shaping filters and modulation systems and demodulation techniques. Maximum Likelihood detection and and MAP algorithm. Equalization: Linear Equalisers, Decision Feedback Equalisers. Multi-tone modulation (ADSL and OFDM) and rate adaptive and margin adaptive discrete bit loading algorithms.

**C429 Parallel algorithms**

PROFESSOR P.G. HARRISON, DR W. KNOTTENBELT (DEPARTMENT OF COMPUTING)

**ISE4.11 Advanced communication theory**

**PROFESSOR A. MANIKAS**


**C430 Network security**

**DR E. LUPU, DR H. WIKLICKY (DEPARTMENT OF COMPUTING)**

**ISE4.15 Coding theory**  
PROFESSOR A.A. IVANOV (DEPARTMENT OF MATHEMATICS)  

**C475 Advanced topics in software engineering**  
MR A. ARGENT-KATWALA, DR R. CHATLEY, PROFESSOR S. EISENBACH, DR N. PRYCE (DEPARTMENT OF COMPUTING)  
Maintenance and evolution: software maintenance/evolution is the modification of a software product after delivery to correct faults, to improve performance or other attributes, or to adapt the product to a changed environment. We look at a collection of software evolution problems associated with modern code and at reverse engineering techniques for code improvement. Test driven development (which is more than test first), mock objects, acceptance testing, continuous integration, coverage etc. Intentional programming: programs that are designed to be read, expressing why as well as what, embedded DSLs, domain driven design, building a bridge to the customer/tester/analyst. Model checking: model checking is a technique for verifying complex concurrent software. It has a number of advantages over traditional approaches that are based on simulation, testing and proving. Model checking is automatic and usually quite fast. If the design contains an error, model checking will produce a counter example that can be used to pinpoint the source of the error. It has been used to verify real industrial designs, and companies are beginning to market commercial model checkers.

**ISE4.17 Speech processing**  
DR P.A. NAYLOR  

**ISE4.19 Introduction to digital integrated circuit design**  
PROFESSOR P.Y.K. CHEUNG  

**C477 Computing for optimal decisions**  
PROFESSOR B. RUSTEM (DEPARTMENT OF COMPUTING)  
To provide mathematical concepts and advanced computational methods for quantitative problems in management decision making. To introduce unconstrained and constrained optimal decision formulations and associated optimality conditions. To discuss quadratic and general non-linear programming formulations and algorithms. Introduction to optimisation and optimal decisions. Unconstrained optimisation. Constrained optimisation.

**ISE4.23 Design of linear multivariable control systems**  
**DR I.M. JAIMOUKHA**


**ISE4.27 Stability and control of non-linear systems**  
**DR D. ANGELI**

For non-linear systems, methods for determining stability and for designing stabilising controllers are studied using state-space (Lyapunov and Lasalle theory, variable structure analysis), function space (small gain theorem, passivity) and frequency-domain (Popov and circle criteria, describing function) methods. Model reference adaptive control is treated using the passivity concept.

**ISE4.31 Spectral estimation and adaptive signal processing**  
**DR D.P. MANDIC**


**ISE 4.36 Optical communication**  
**PROFESSOR E.M. YEATMAN**


**ISE4.41 Identification and adaptive control**  
**PROFESSOR R.B. VINTER**

Stochastic dynamical systems and their description in terms of standard discrete time models; these include linear state-space models and linear difference equation models known as ARMAX (Autoregressive Moving Average models with Exogenous input) models. Least-squares parameter estimation. The statistical properties of parameter estimates. Recursive algorithms for parameter identification. Sources of parameter bias. Techniques for eliminating bias, including the Generalized Least Squares algorithm. The effects of over-parameterisation. Techniques for selecting model order.

**CC480 Automated reasoning**  
**DR K. BRODA (DEPARTMENT OF COMPUTING)**

To describe the main techniques for automated reasoning in classical logic. Automated deduction: a brief history from 1960 to the present time. Propositional theorem proving; model generation and Davis Putnam Procedure. Resolution for the first order predicate calculus, completeness and soundness. Refinements of resolution, hyper-resolution, locking, connection graphs, advantages, disadvantages, use of the Otter

**ISE4.43 Synthesis of digital architectures**  
DR G.A. CONSTANTINIDES  
Introduction to the fundamental architectural synthesis problems: scheduling, allocation, binding, estimation and control unit synthesis. Introduction to graph theory and combinatorial optimisation. Scheduling algorithms: as-soon-as-possible and as-late-as-possible, list scheduling, integer linear programming. Resource sharing algorithms: interval graphs, graph colouring, integer linear program models; register sharing.

**C484 Quantum computing**  
PROFESSOR A. EDALAT (DEPARTMENT OF COMPUTING)  
Introduction to quantum mechanics, quantum bits and complex vector spaces, quantum evolution and quantum gates, quantum registers, universal gates, no-cloning theorem, quantum entanglement and teleportation, quantum algorithms and quantum search, quantum Fourier transform, phase estimation, quantum counting, order finding for periodic functions, quantum factoring of integers, physical realisation of quantum gates and quantum error correction.

**C417 Advanced graphics and visualisation**  
DR P. EDWARDS, PROFESSOR D. RUECKERT (DEPARTMENT OF COMPUTING)  
Principles of visualisation: fundamentals and concepts, scalar, vector and tensor data, applications such as flow visualisation. Volume rendering: image-order rendering; object-order rendering; scalar and ray transfer functions; isosurface generation; marching cubes algorithm. Surface reconstruction: surface decimation; surface normal generation; surface triangulation; Voronoi diagrams; Delaunay triangulation. Spline curves: parametric and non-parametric splines; cubic spline patches; Bezier curves; B-spline formulation. Surface modelling: coons patches; bi-cubic surfaces; B-spline surfaces; NURBS; rendering spline surfaces. Implicit surface models, soft objects. Image-based rendering and lightfields. Virtual reality: stereo perception; stereo display; head-mounted displays; autostereoscopic displays; holographic displays; haptic and tactile force feedback; virtual worlds; collision detection for VR. Augmented reality: definitions and examples, augmented real calibration and tracking. Simulation training in medicine.

**ISE4.47 Wavelets and applications**  
DR P.L. DRAGOTTI  


C493 Intelligent data and probabilistic inference
DR D.F. GILLIES (DEPARTMENT OF COMPUTING)
The course is concerned with probabilistic methods for modelling data and making inferences from it. The first part of the course introduces Bayesian inference and networks and includes probability propagation and inference in singly connected networks, generating networks from data, and calculating the network accuracy. The course then goes on to consider highly dependent data and special techniques for exact and approximate inference in these networks. The next topic to be covered is data modelling using distributions and mixture models. The topic of sampling and re-sampling is covered along with data reduction by principal component analysis and special problems that occur with small sample sizes. The last part of the course is concerned with classification using linear discriminant analysis and support vectors.
The emphasis of the course is algorithmic rather than mathematical, and the coursework is a practical programming exercise in analysing data from a study into the prognosis of hepatitis C.
Note that the course does not include non-probabilistic methods of data analysis such as neural networks, fuzzy logic or expert systems.

ISE4.49 Distributed computation and networks: a performance perspective
PROFESSOR E. GELENBE
Description of distributed system architectures and their components; digital sensors and actuators, processing units, local area networks, packet networks and the IP protocol, wireless ad-hoc networks. The role of protocols.

C436 Performance analysis
DR J. BRADLEY, PROFESSOR P. HARRISON (DEPARTMENT OF COMPUTING)
Motivation and survey; the need for performance prediction in optimisation and system design.
Basic probability theory: renewal processes; Markov processes; birth and death processes; the single server queue; Little’s law; embedded Markov chain; M/G/1 queue; queues with priorities; queueing networks — open, closed, multi-class; equilibrium state space probabilities, proof for single class; normalising constants; computation of performance measures; convolution algorithm; mean value analysis; application to multi-access systems with thrashing.
Decomposition and aggregation: Norton’s theorem; M/M/n queue; multiple independent parallel servers.
The course also offers an introduction to performance modelling using a stochastic process algebra, e.g. PEPA. To include: expansion law, apparent rate, steady-state analysis, transient state analysis through uniformisation and reward vectors.

ISE4.51 Information theory
DR C. LING
Elements of information theory of discrete systems; information measures, memoryless and memory sources, the noiseless coding theorem. Methods of source coding. Information theory of continuous systems. Shannon’s capacity theorem and its interpretation. Lossy source coding and rate-distortion theory. Network information theory.
C438 Complexity
DR I. PHILLIPS (DEPARTMENT OF COMPUTING)

ISE4.55 Optimisation
PROFESSOR A. ASTOLFI
Topics covered include unconstrained optimisation and the associated algorithms of steepest descent and conjugate gradient, Newton methods, rates of convergence, constrained optimisation and the method of Lagrange multipliers, quadratic programming, penalty methods. A brief introduction to global optimisation and integer programming will also be given.

C332 Advanced computer architecture
PROFESSOR P.H.J. KELLY (DEPARTMENT OF COMPUTING)

C395 Machine learning
PROFESSOR S. MUGGLETON, DR M. PANTIC (DEPARTMENT OF COMPUTING)

C420 Cognitive robotics
PROFESSOR M. SHANAHAN (DEPARTMENT OF COMPUTING)

ISE4.61 Predictive control
DR E. KERRIGAN
**C422 Computational finance**  
DR D. KUHN (DEPARTMENT OF COMPUTING)  
The course will discuss computational aspects of financial engineering. This includes computational models, algorithms and software design.  
Monte Carlo simulation. Interest rate derivatives.  

**ISE4.63 Discrete-event systems**  
DR D ANGELI  

**ISE4.64 Probability and stochastic processes**  
DR M. DRAIEF  

**Non-technical modules**  
A number of the modules have coursework associated with them. Students also undertake an individual project from November through to the end of the summer term.

**Business studies modules**  
BS0822 Accounting  
BS0821 Project management  
BS0808 Finance and financial management  
BS0806 Entrepreneurship  
BS0820 Innovation management  
BS0815 Managerial Economics  
See Business School section for details.

**Humanities and language options**  
Students take one of the following modules, the syllabuses of which are shown in the Humanities section:  
Arabic, French, German, Italian, Japanese, Mandarin (with option for Cantonese speakers), Mandarin Language and Literacy for Heritage Speakers, Russian, Spanish, Art of the twentieth century, Communicating science: the public and the media, Controversies and ethical dilemmas in science and technology, Creative writing, European history 1870-1989, Global history of twentieth century things, History of medicine, Modern Literature and Drama, Music and western civilisation, Music technology, Philosophies of Science: Theory, Society and Communication, Philosophy, Politics, the Roman Empire. See the Department of Humanities section for further details.
## EXAMINATIONS

### FIRST YEAR

**EEE courses**
- Mathematics (two papers)          June
- Analysis of circuits              June
- Digital electronics I             June
- Devices and fields               June
- Analogue electronics I            June
- Electronic materials             June
- Communications I                 June
- Management and organisations     April/May

**ISE courses**
- Analysis of circuits              June
- Digital electronics I             June
- Analogue electronics I            June
- Communications I                 June
- Software engineering             June
- Computer architecture and systems June
- Mathematics                      June
- Management and organisations     April/May

### SECOND YEAR

**EEE courses**
- Mathematics (two papers)          June
- Digital electronics II            June
- Analogue electronics II           June
- Fields and devices               June
- Electrical power engineering     June
- Communications II                June
- Signals and linear systems       June
- Control engineering              June
- Algorithms and data structures   June
- Introduction to computer architecture June
- Non-technical option(s)          March/April

**ISE courses**
- Digital electronics              June
- Communications II                June
- Signals and linear systems       June
- Control engineering              June
- Software engineering II          June
- Computer architecture           April/May
- Language processors              June
- Discrete mathematics and computational complexity June
- Mathematics                      June
- Non-technical option              April/May

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THIRD YEAR

**BEng in Electrical and Electronic Engineering**
Students are required to register for and be examined in at least six technical courses and at least one non-technical course.

**T stream**
Students are required to register for and be examined in at least seven technical courses and at least one non-technical course.

**EM stream**
At least three business courses, at least three technical courses and at least two other courses, which may be technical or non-technical.

**EY stream**
As T, but students may be required to study a language as one of their non-technical options.

**BEng in Information Systems Engineering**
Databases—one paper.
Six or seven additional papers, one for each chosen option.

**MEng in Information Systems Engineering**
Databases—one paper.
Seven or eight additional papers, one for each chosen option.

FOURTH YEAR

**T stream**
Students are required to register for and be examined in at least six technical courses and at least one non-technical course.

**EM stream**
Students are required to register for and be examined in at least three business courses, at least three technical courses and at least one other course which may be technical or non-technical.

**EY stream**
Students will be examined in an agreed number of technical courses in their host institution abroad.

**MEng in Information Systems Engineering**
Seven or eight papers, one for each chosen option.

**MEng in Information Systems Engineering with a Year Abroad**
Students will be examined in an agreed number of technical courses in their host institution abroad.