Civil and Environmental Engineering

Teaching and research in civil and environmental engineering are concentrated in the Skempton Building on the South Kensington campus, which contains all the facilities necessary to support undergraduate and postgraduate courses, as well as research work, both for higher degrees and in support of industry. In addition to lecture theatres and study rooms, there are five large, well-equipped laboratories supporting research work and a number of smaller laboratories specifically for undergraduate instruction. There is a dedicated subject library holding 19,000 books, 4,500 periodical volumes and report literature. The library also provides access to electronic information services, as well as facilities for private study. Computing facilities include pc and network points, connected to a high-speed backbone, throughout the building. A programme to install wireless networking is underway throughout the college. These facilities are available to students and staff. For student project work, there is a range of supporting software.
Undergraduate students now number approximately 350, with about 90 new admissions each year. the 25 specialised one-year MSc courses covering a wide range of civil engineering activities attracted up to 220 postgraduate students in 2004-05, many applicants having several years of practical experience. About 110 research students are currently working for PhD degrees. Additionally, some 50 research assistants, many also registered for the PhD degree, are working on research projects funded by industry. The variety of interests and expertise in civil and environmental engineering at Imperial College, and the strong industrial contact maintained through our postgraduate courses, together with research and consultancy, give both breadth and interest to the undergraduate courses.

Undergraduate courses

MEng in Civil Engineering

MEng in Civil and Environmental Engineering

MEng in Civil Engineering with a Year Abroad

MEng in Civil and Environmental Engineering with a Year Abroad

Four-year courses in civil engineering have been offered since 1992 when the previous three-year programme was phased out. The courses lead to the award of the MEng degree of the University of London and the Associateship of the City and Guilds of London Institute (ACGI).
Students entering the first year of undergraduate studies must normally have satisfied the general university entrance requirements and the individual course requirements, as indicated in the section on conditions of admission in the Imperial college calendar 2005-6.
Our courses aim to provide a stimulating and challenging education programme, befitting graduates for influential service in civil engineering or any other related professional discipline. Furthermore, they are constructed to harmonise with the pattern of civil engineering education currently to be found in many of the elite educational institutions of continental Europe.
The first two years of the programme, which are common to all four courses, provide the main compulsory or core studies. However, the programme for the last two years embodies a free choice of modules from a menu of elective subjects so as to encourage students to study in depth one or two civil engineering disciplines which suit their own particular interests or talents. Students enrolled in the civil and environmental engineering degree courses will be expected to make a choice of elective subjects predominantly from the field of environmental engineering.
Undergraduate teaching involves lectures, tutorials, projects, laboratory and field work. Student assessment is based on performance in coursework and in written examinations. Coursework comprises design projects, computer work, laboratory reports, model building, Drawing, surveying and geology fieldwork and other practical and professional skills.
Students are strongly encouraged to undertake relevant industrial training during the summer vacations. This complements academic studies by aiding the development of an appropriate professional attitude, allowing insight into the practical use of scientific methods in engineering, and by helping students to

sustain the motivation necessary for achieving their full potential in the degree course.
In keeping with its policy of openness to the international dimension of civil and environmental engineering, the two MEng courses with a year abroad. the students going to Europe continue their language training throughout the first three years of the courses; for all students on the year abroad programme, there is a requirement that the overall results be at a 2.1 level throughout years 2 and 3 (and preferably year 1 also).
Those who satisfy these conditions then take their final year studies at a host institution in continental Europe, Australia or Hong Kong. Currently, there are student exchange agreements with the following prestigious educational institutions: Ecole Nationale des Ponts et Chaussées, Paris, the Escuela Tecnica Superior de Ingenieros de Caminos, Canales y Puertos, Madrid, the Rheinisch-Westfälische Technische Hochschule, Aachen, the Technical University of Delft, the Politecnico di Torino in Turin, the Eidgenossische Technische Hochschule in Zurich, the University of Melbourne, Australia and the Hong Kong Polytechnic University.

CE.101 Engineering Knowledge

MS A.L. AHEARN, DR N. MCINTYRE WITH OTHER LECTURERS AND GUEST SPEAKERS
Objective: to assist new students in taking up their roles as university students and as student members of the engineering profession.
Structure: the module provides learning support for freshers as they make the transition to their role as university students. It provides professional support to students as they take up their role as 'student engineers'. The module involves talks, workshops, site visits and a buddy scheme. It is not formally assessed but participation and submission of a site visit report assists the examination board in understanding a student's engagement with their engineering studies.
General: students are given induction activities in week 1. Throughout autumn term and summer term, students are introduced to the learning to learn booklet, the college's "ICE Employability" website which promotes personal development planning (PDP), the Year Abroad Scheme; the institution of civil engineers; CivSoc; the Buddy Scheme; the Careers Service and CV writing; construction site visits and other incidental events that promote an understanding of the engineering profession and an understanding of academic work.

CE.102 Mathematics

PROFESSORS J.R. CASH, J. BARRETT
49 lectures and 50 tutorials.
Functions, limits, differentiation, series expansions. vectors, matrices, solution of linear algebraic equations. Partial differentiation, contours. Complex numbers, hyperbolic functions. Integration. Ordinary differential equations. Newton-Raphson and fixed-point iteration, numerical integration.

CE.103 Mechanics

DR M.A. WADEE, DR G.R. HUNT
24 hours lectures and tutorials.
Statics: scalar and vector quantities and dimensions; Newton's laws of motion: free body diagrams; static equilibrium in space; forces, moments and couples; friction, distributed forces and centre of mass.
Deformable bodies: elasticity and plasticity. Mechanical energy concepts and stability of equilibrium.
Kinematics: coordinate systems; displacement, velocity and acceleration.
Dynamics: integration of Newton's second law. Spring-mass damper systems: free forced vibrations.

CE.104 Structural Mechanics

PROFESSOR M.N. PAVLOVIC, DR A. ABBAS
30 hours of lectures and tutorials supported by four hours of computer laboratory work.
Introduction to structural systems; free body diagrams, statistical determinacy, mechanisms; trusses (simple, compound, complex), reactions and member forces; beams (bending moments and shear forces); frames (bending moments, shear forces and axial thrust); torsion and bending; elastic beam

theory, first and second moments of area, curvature, deflection, shear stress distribution; effects of yielding and plasticity; plastic moment capacity, simple mechanism calculations. Design of beams for strength and stiffness.

CE.105 Fluid mechanics

DR G.R. HUNT, DR R. MACIVER
30 hours lectures and 22 laboratory hours.
This module provides an introduction to the field of fluid mechanics. To begin, stationary fluids are considered and, subsequently, the fundamental relationships that govern the motion of fluids are developed. Further insight into the behaviour of fluids is gained through laboratory demonstrations and exercises in which real flows are measured and visualised, and subsequently modelled using the theoretical relationships developed in lectures. The principles of fluid flow are applied to solve a range of general problems in fluid mechanics before attention focuses on a classical problem in engineering hydraulics, namely, flow in open channels.

CE.106 Geotechnics

DR M. COOP, MR M.C. CALLOW
16 lectures, four tutorials and a one-day field course.
A short introduction to soil mechanics and geology. Soil description; index properties; Compaction in field and laboratory. Seepage in the laboratory; Darcy's Law; principle of effective stress. Outlines of geological materials, stratigraphy and geological structures. The field course demonstrates landslides, the interaction between engineering geology and soil mechanics through detailed study of a large landslide.

CE.107 Materials

PROFESSOR N.R. BUENFELD, DR B.A. SHOLLOCK, DR R. MURPHY
40 lectures and six laboratory hours.
Steels (16 lectures): structure of metals, phase equilibria, iron-carbon phase diagram, equilibrium microstructures of steels, non-equilibrium microstructures of steels, mechanical testing (tensile, fracture, fatigue), plastic deformation, dislocations, strengthening mechanisms, fracture mechanics, s-n curves, impact testing, ductile to brittle transition, corrosion of steels, forms of corrosion, corrosion prevention and protection, welding techniques, effect of welding of microstructure and properties, steels for civil engineering applications.
Concrete (16 lectures): introduction. History of cement and concrete. cement manufacture and characteristics. Hydration processes and products. setting and hardening. Curing. Aggregate production and characteristics. Properties of fresh concrete. Placing and compaction. properties of hardened concrete.
Timber (four lectures): production and structure. Response to stress, volume changes, durability.
Plastics and composites (four lectures): reasons for selection. Properties of matrix. Types of composites. Properties. Methods of production. Applications. Design methods.

CE.108 Engineering in context I

MS A.L. AHEARN AND OTHERS
36 hours teaching including workshops, lectures, computer-based learning.
Engineering in Context I is about the breadth of issues and concerns in civil and environmental engineering (beyond maths and physics) and aims to develop generic skills needed by students in their academic work and as professional engineers. To do this, students will use a case study approach in order to compare engineering in a developed country and a developing country, to identify how the "context" affects the engineering problem. Classroom and computer-lab based teaching supports the students in acquiring the skills needed in order to find out the information for their case study: the information literacy elements are taught by chartered librarians using the OLIVIA software (online virtual information assistant). Short briefings are given on topics such as construction law, governance,

engineering as a business, engineering as a social intervention, stakeholders in engineering and the roles and responsibilities of engineers. Students undertake a series of tasks involving library research, academic writing, oral presentations, team organisation, time management, and self-reflective learning. The module is intended to help develop students Personal Development Planning by providing them with material to put in a professional development portfolio. Assessment is wholly by coursework but includes as information literacy test administered via an online module.

CE.109 Computer applications for engineering

DR K. RAMACHANDRAN
18 contact hours.
This module teaches how computers may be used to solve civil and environmental problems. It commences with workshop sessions on spreadsheets. Subsequently Fortran 95 programming is introduced with a series of formal lectures followed by interactive tutorials and laboratory sessions. Assessment is undertaken through supervised assignments in the computer laboratory. These assignments help students to appreciate the use of computers in structural, fluid and soil mechanics applications, as well as mathematics.

CE.110 Drawing

DR N.R. McINTYRE, DR S. POPO-OLA, MS L. LE FEUVRE
14 hour of engineering drawing, six hours of CAD, nine hours of freehand sketching.
This module is split into three sections: a) manual drawing, b) computer-aided drawing (CAD) and c) freehand drawing. The course is designed to provide the student with an understanding of engineering drawing conventions in civil engineering, and in particular, how engineering drawing can be both a design tool and a means of communicating precise instructions to engineers and crafts people. The CAD element introduces students to how computer software can be employed to replace the manual drawing procedure. The freehand drawing course develops the ability to convey objects effectively and attractively with freehand line, marks and tone.

CE.111 Engineering risk analysis

PROFESSOR A. EVANS
8 hours' lectures or tutorials.
The module is intended to introduce the basic concepts related to risk and a lexicon of terminology related to risk analysis and risk management. the concepts and of terminology lay the basis for addressing risk and risk management in subsequent modules throughout the degree course, including in the major design project in the third year. The module does not aim to equip the student with the mathematical tools required to undertake a probabilistic risk assessment, but rather to enable the student to appreciate how formal risk assessments can fit in to the general practice of risk management.
Objective: to demonstrate how risk management is an integral part of civil and environmental engineering projects and that risk management should be treated as simply one component of successful engineering. The module begins with an introduction to basic concepts of risk in general and an overview of risk in civil engineering, including issues related to health and safety. Subsequent lectures illustrate risk analysis in specific areas of civil and environmental engineering. The introductory lecture and subsequent case histories are each followed by interactive tutorials in which the students explore and discuss risk analysis and risk management.
Aim: to enable the student to employ a vocabulary to refer to risk-related issues and to identify the different kinds of risk in engineering projects. The student should also acquire an appreciation of how risk management can be incorporated into the general practice and management of civil and environmental engineering.

CE.112 Surveying

DR W.Y. OCHIENG
14 hours of lectures, tutorials and practicals with associated coursework, plus a six-day residential field course.

Introduction to surveying, geodesy and geospatial/geomatic engineering. Covering in particular: civil engineering surveying and setting out; plane coordinate calculations; the level and levelling; the theodolite and angle measurements; the tape, and edm (electromagnetic distance measurement) and distance measurement; the total station; the role of satellite positioning systems, geographical information systems (gis), remote sensing and photogrammetry in civil engineering. The related practical work forms a preparation for the field course which normally takes place in the last week of spring term at the Imperial College field station, Silwood Park, near ascot. The six-day project concerns the design and setting out of a new road. it integrates practical exercises, carried out in small teams including, traversing, levelling, detail mapping, plan compilation (Drawing), road planning, environmental appraisal, design, determination of quantity of earthworks and setting out. The submissions resulting from this work contribute to the coursework assessment. The cost of accommodation and subsistence, which students are expected to bear, is £200, payable prior to departure to Silwood Park.

CE.113 Creative design I

PROFESSOR D. LLOYD SMITH AND OTHERS
40 contact hours.
Creative design and engineering theory are inextricably linked. Creative design i is the first part of a two year design foundation course with creative design learning at its heart. The course is practical, and workshop based. Students learn by doing, armed with a soft pencil, butter paper and sketch-book, pinup space, and their voices. The aim is for students to design something at every session. Three key learning outcomes are creativity, clarity and confidence. Frequent practice, feedback and constructive criticism are the means. Skills learnt during the course provide a thread of creative design relevant to all four years of the degree course. This will also help to provide a frame of reference for existing theoretical teaching, by allowing students to understand its relevance to engineering in practice.

CE.114 Humanities or language studies

Humanities: 30 hours (20 lectures and 10 fortnightly seminars). Although the contact hours are less for the non-language options, the overall number of hours spent (including seminar preparation, background reading, essay writing), should be the same for humanities as it is for Languages.
Languages: 63 hours (75 for those studying for the year abroad degree).
Students are required to choose one of the following electives:
H.1 Philosophy I
H.4 Controversies and Ethical Dilemmas in Science and Technology
H.5 European History: 1870–1989
H.6 Politics
H.7 Science and Technology in Western Civilisation
H.8 Global History of Twentieth-Century Things
H.9 History of Medicine
H.10 Modern Literature and Drama
H.11 Art of the Twentieth Century
H.12 Music and Western Civilisation
H.13 Communicating Science, the Public and the Media
H.15 Humanities Essay
H.17 The Roman Empire
H.19 Creative Writing
H.21 Music Technology
H.22 Saying True Things: How Science Invents and Persuades
Languages (one of the following): French, German, Italian, Mandarin, Spanish, Russian, Japanese.
H.23 Film Studies
Students Studying for the Year Abroad Degree are required to take the relevant language course.

SECOND YEAR

CE.201 Mathematics

DR A. WALTON, PROFESSORS A. YOUNG, A. GOGOLIN
54 lectures
Aims: The aim is to ensure that all students acquire the mathematical knowledge and skills required for their second year civil engineering course.
The Syllabus includes: ordinary Differential equations; numerical methods; fourier series; pactial differential equations; vector calculus; complex variables; integration; linear algebra; probability and statistics; matrix differential equations.

CE.202 Fluid Mechanics

PROFESSOR C. SWAN AND PROFESSOR R. SOBEY
22 lectures, 22 tutorials and 16 laboratory hours
Free surface and closed conduit flows with the introduction of unsteadiness, two-dimentionality and frictional effects. Mathematical description of gravity waves and how wave-loads on offshore and coastal structures can be predicted. Stream function and velocity potentials, the unsteady bernoulli equation, linear wave theory, steady and unsteady flow around cylinders and the related forces.
Description of a real fluid, steady flow in pipes, pipe systems and open channels. Real fluids (Newton's law of viscosity); laminar and turbulent flow; steady pipeflow; pipe systems; gradually varied flow in open channels; local conservation equations.

CE.203 Geotechnics

DR J.R. STANDING, DR L. ZDRAVKOVIC, MR M.C. CALLOW
Soil mechanics: 30 lectures and tutorials, four laboratory hours, fieldwork, six hours' mini-project.
Geology: 12 lectures, 21 laboratory hours.
Continues the study of geotechnical engineering methods that commenced in first year. The geology course aims to introduce civil engineering students to those aspects of geology which they will most need in practice.
Soil mechanics: seepage and effective stress; one-dimensional consolidation; shear strength of soil. General requirements for geotechnical analysis; plasticity bound theorems; closed form solutions; limit equilibrium and stress fields.
Geology: geological materials: character and origin of sedimentary, igneous and metamorphic rocks. Surface erosion and depositional processes: fluvial, desert, glacial and periglacial features. Plate tectonics and rock deformation: volcanoes and earthquakes. Stratigraphy. Geological maps.
There will also be a one-week geology field course. The total cost of travelling and subsistence, which the student will be expected to bear, is approximately £400.

CE.204 Environmental engineering

PROFESSORS H.S. WHEATER, N.J.D. GRAHAM AND DR. C.R. CHEESEMAN
20 lectures and 10 tutorials.
Hydrology and environmental management; hydrological cycle, management of floods and water resources; environmental impacts of land-use change; pollutant pathways; climate change.
Floods and flood management: rainfall-runoff modelling; the unit hydrograph, rainfall and flood frequency; flood routing; flood management.
Water and wastewater treatment: solid-liquid separation methods such as sedimentation and filtration; biological oxidation, including kinetics, activated-sludge, trickling filters; reactor design. Water quality.
Waste management: solid wastes and their disposal; hazardous waste management; recycling and resource recovery; landfill engineering and waste incineration.

CE.205 Creative design II

PROFESSOR D. LLOYD SMITH AND OTHERS

This is the second part of the two-year design foundation course with creative design learning at its heart. Students have already completed creative design i as part of their first year studies. The course is practical, and workshop based, using short versions of real design projects. Students learn by doing, armed with a soft pencil, butter paper and sketch-book, pin-up space, and their voices. The aim is for students to design something at every session. Three key learning outcomes are creativity, clarity and confidence. Frequent practice, feedback and constructive criticism are the means. Skills learnt during the course continue the thread of creative design through all four years of the degree course.

CE.206 Structural mechanics

PROFESSOR D. LLOYD-SMITH, DR K. RAMACHANDRAN, DR C.M. TSANG
41 lectures and 19 tutorials.
This module is split into two separate sections: mechanics of materials and structural mechanics.
Mechanics of materials: displacement and strain fields, compatibility, Mohr's circle and analysis of strain gauge data. Stress and stress-function fields, equilibrium, Mohr's circle for stress and transformation. Solutions of equilibrium equations for assumed elastic strain field, asymmetric bending shear stresses due to flexure and shear connections, torsion of thin-walled sections and twisting moment distributions.
Structural mechanics: introduction to virtual work for trusses, beams, and frames, application to equilibrium and displacement calculations. Introduction to influence line concept. Static indeterminacy. Flexibility (compatibility) method for linearly elastic continuous beams and frames. Kinematic Indeterminacy. Stiffness (equilibrium) method for linearly elastic continuous beams and frames. Introduction to moment distribution method as a stiffness method for hand calculations of beams and frames.

CE.207 Structural design

DR L. GARDNER, PROFESSOR N.R. BUENFELD
28 hours
This module is split into two parts: a) structural steel design and b) structural concrete design.
Basic design of structural steelwork. Tension members, columns, beams. connection design by bolting and welding. Reinforced concrete design, including behaviour and analysis of structural elements.

CE.208 Advanced computer applications in engineering

PROFESSOR R. SOBEY
20 contact hours.
This course provides a coursework-focussed introduction to MATLAB and its application to problem solving in civil and environmental engineering. Topics will include syntax, arrays, file operations, functions, graphics and animation, linear equations, programming, data analysis, numerical calculus.

CE.209 Design projects

PROFESSOR C. SWAN, PROFESSOR N.R. BUENFELD, DR L. GARDNER
42 hours.
This module is split into the following parts: fluid mechanics design, structural steel design, and structural concrete design.
Fluid mechanics design: a two-day project concerning the design wave forces acting on a floating deep water structure.
Structural steel design: a two-day project on design of an industrial building including drawing and fabrication details.
Reinforced concrete design: a two-day project on the design of a simple RC structure.

CE.210 Humanities or language studies

Humanities: 30 hours (20 lectures and 10 fortnightly seminars). Although the contact hours are less for the non-language options, the overall number of hours spent (including seminar preparation, background

reading, essay writing), should be the same for humanities as it is for languages.
Languages: 63 hours (75 hours for those studying for the year abroad degree).
Students are required to choose one of the following electives:
H.1 Philosophy I
H.4 Controversies and Ethical Dilemmas in Science and Technology
H.5 European History: 1870–1989
H.6 Politics
H.7 Science and Technology in Western Civilisation
H.8 Global History of Twentieth-Century Things
H.9 History of Medicine
H.10 Modern Literature and Drama
H.11 Art of the Twentieth Century
H.12 Music and Western Civilisation
H.13 Communicating Science, the Public and the Media
H.15 Humanities Essay
H.17 The Roman Empire
H.19 Creative Writing
H.21 Music Technology
H.22 Saying True Things: How Science Invents and Persuades
Languages (one of the following): French, German, Italian, Mandarin, Spanish, Russian, Japanese.
H.23 Film Studies
Students Studying for the Year Abroad Degree are required to take the relevant language course.

CE.211 Engineering in context II

PROFESSOR M.G.H. BELL
5 hours lectures, eight hours tutorials.
The module is structured around four major civil engineering case histories, covering projects such as major tunnels and dams, reconstruction following natural disasters and environmentally sensitive developments. The case histories are presented in lectures given by members of the Department of Civil and Environmental Engineering or distinguished visitors who have been involved with the projects. The case histories are complemented by a lecture on leadership in engineering, usually presented by the Rector. The design and execution of the projects is then debated in sessions in which the students assume roles, such as the consultant engineers, the owner, environmental groups and affected residents, amongst Others.
The module serves two purposes, the first being to provide an opportunity to practice the team-working and oral communication skills developed in the first year course. The second is to raise awareness of the broader issues associated with major civil engineering projects and their political, social, economic and environmental contexts. The students are encouraged to appreciate the importance of clear, rational and technically sound presentation of their case in a persuasive and constructive manner.
At the end of the module, each student is required to produce a short essay on their perception of the civil engineering profession and their role within it. The module is assessed on the basis of this essay and the oral presentations made during the debates.

THIRD YEAR

Core subjects

CE.301 Structural mechanics

DR M.A. WADEE, DR A. ABBAS, DR K. RAMACHANDRAN
25 lectures, 10 tutorials and 15 project hours.
Stability: energy methods for single degree-of-freedom systems; buckling; limit points; bifurcations; imperfection-sensitivity.
Instabilities in struts and columns: idealised and real behaviour; Rayleigh and Timoshenko methods.
Instabilities in beams: lateral-torsional buckling. Introduction to plate buckling.
Plasticity: moment capacity of composite sections; moment capacity reduction due to shear and axial force, plastic collapse of beams and frames; upper and lower bound theorems. Combination of mechanisms for frame analysis.
Dynamics: dynamic loads, structural modelling: degrees of freedom, lumped mass;
Free, damped and undamped vibrations of single degree-of-freedom elastic structures: viscous damping; logarithmic decrement. Forced vibrations: harmonically forced with and without damping: resonance; support motion and earthquake excitation. Concepts of generalised mass, stiffness, damping and force.
Project: design, construction and testing of aluminium plate or box girder beams.

CE.302 Hydraulic engineering

DR G.R. HUNT, DR A.P. BUTLER, DR R. MACIVER
32 lectures, 12 tutorials and six laboratory hours.
Review of open channel flow: sediment transport in unidirectional flows. Pollutant transport, dispersion, mixing, jets and plumes. Groundwater: energy, momentum and mass balance, steady-state flow, aquifiers, well hydraulics.

CE.303 Soil mechanics

PROFESSOR R.J. JARDINE, PROFESSOR D.M. POTTS, DR J.R. STANDING, DR M.R. COOP
32 lectures, 11 tutorials, one laboratory experiment, fourteen hours mini-projects.
The course covers the applied aspects of soil mechanics. Foundations: bearing capacity, settlement, pile foundations. Earth-retaining structures: earth pressures, retaining structures, ground anchors, deep excavations. Slopes: slope stability, planar and non-planar movements, landslide investigation and instrumentation, slope stabilisation.
The course includes three design projects: one on soil properties, another designing an earth retaining structure and a third designing foundations. The laboratory session involves testing model foundations.

CE.304 Systems engineering (half module)

DR C. ONOF, PROFESSOR D. LLOYD-SMITH
13 lecture hours and 12 tutorial hours.
An introduction to the use of decision sciences and mathematical programming in the solution of civil and environmental engineering problems. Systems approach to decision-making: objectives, constraints and decision variables. Linear programming: geometric and simplex algorithms, sensitivity analysis, duality. Networks: network flows, minimum cost path algorithm. Non-linear optimisation: lagrange multipliers, numerical search and gradient methods. Applications to planning, design, construction and operation of projects: construction project management, resource allocation and levelling, river basin planning, optimal structural design, traffic control.

CE.305 Engineering economics and management (half module)

PROFESSOR S. GLAISTER, MS A.L. AHEARN
21 lectures, five tutorials and five hours' case study.

An introduction to the principles and tools of business planning and project management, corporate plans. Management and financial accounts. Profits and loss statements and balance sheets. Discounting and net present values. Projects and role of project managers. project financing. Construction planning. Contracts. Conditions of contract, torts.

Elective subjects

Students are required to choose any three elective subjects.

CE.306 Concrete structures and design

DR R.L. VOLLUM, DR C.M. TSANG
50 contact hours.
Construction methods.
Reinforced concrete: Design and analysis of sections for axial load, flexure, shear, torsion and combinations thereof at the ultimate limit state. Detailing of reinforcement. Design for the serviceability limit states of deflection and cracking. Design of continuous beams and slabs.
Prestressed concrete: mechanics of the prestressed section. Pre-and post-tensioning. Design and analysis of a beam section for given moment; definition of central and limit kerns; derivation and use of Magnel diagrams for critical sections. Determination of steel envelope throughout beam. Introduction to statically indeterminate beam structures; concept of concordancy for tendon profile. Derivation of concordant tendon profile, leading to non-concordant profiles and their properties. Introduction to load balancing method.

CE.308 Computational engineering analysis

PROFESSOR R.J. SOBEY, DR B.A. IZZUDDIN, PROFESSOR D.M. POTTS
50 hours comprising lectures, tutorials and computing labs.
Numerical Fluid Mechanics: Implicit Algebraic Equations: applications such as Colebrook-White, normal depth, pipe systems.
Ordinary Differential Equations: applications such as pipe networks and gradually-varied channel flow.
Initial value problems in partial differential equations: alternatives (finite difference, finite volume, finite element, method of lines) presented in context of unsteady contaminant transport.
Finite element analysis: problem discretisation using finite elements. Assembly and solution of discrete model equations. Two-dimensional finite elements, with emphasis on plane stress/plane strain and axisymmetric solid elements. Error estimation for linear analysis. Application to structural engineering problems.
Finite element analysis in geotechnical engineering: non-linear solution strategies-tangent stiffness. Visco-plastic and Newton-Raphson approaches. Implicit and explicit stress point schemes. Coupled analysis: mechanical and pore flow. Boundary conditions: construction, excavation, tied freedoms, infiltration, precipitation, etc. Application to geotechnical problems.

CE.309 Engineering geology (half module: to be taken with CE.310)

MR M.C. CALLOW
25 hours of lectures and coursework.
Influence of geology on engineering works and the professional relationships between geology and engineering. Control on geotechnical properties by geological materials and processes. Design and analysis of ground investigations. Environmental and engineering geological controls on design, construction and performance of engineering works, including slopes, foundations, groundwater and waste disposal. Influence of geology on methods of material supply, construction and excavation and methods of ground improvement.

CE.310 Rock mechanics (half module to be taken with CE.309)

DR J.P. HARRISON
25 contact hours; lectures, tutorials and project work.
Stress: two-dimensional stress, stress transformation, constitutive relations. Strain: two-dimensional strain, strain transformation, compatibility equations. In situ rock stress. Measurement techniques and results, kirsch equations. engineering ramifications. elementary hemispherical projection. Discontinuities: geometrical characteristics, RQD, mean spacing and frequency, hemisperical projection techniques. Intact rock: mechanical properties of intact rock, complete stress-strain curve, stiff and servo-controlled testing machines, simple failure criteria. Rock masses: properties of rock masses, deformability, single plane of weakness theory, failure criteria. CHILE vs DIANE: inhomogeneity, anisotropy, index tests, scale effects. Rock mass classification schemes: Q and RMR, practical implementation, relations with rock mass properties. The complete rock mechanics problem: interactions and coupled mechanisms. Rock reinforcement and rock support: underlying principles, similarities and differences, particular methods and materials. Foundations and slope stability: foundations on discontinuous rock, slope instability, basic mechanisms and static equilibrium Solutions. Design of surface excavations: kinematic methods, hemisperical projection, overlay methods. Underground excavations in discontinuous and stratified rock: stability of tetrahedral blocks, kinematic methods. Underground excavations in continuous rock: approximate analytical methods. ground response curve and subsidence: rock support interaction, subsidence prediction methods. Mining applications: optimal orientation, pillar strength, mining methods. Environmental and petroleum applications: underground storage, radioactive waste isolation, contaminant transport in fractured rock masses. Computer methods in rock mechanics and rock engineering: principal stability methods.

CE.311 Introductory microbiology and chemistry for environmental engineering

DR C.R. CHEESEMAN, DR S.R. SMITH, DR G.D. FOWLER
50 contact hours of lectures, seminars and essays.
Introduction to inorganic chemistry: periodic table; ionic, covalent and hydrogen bonding; equilibrium reactions; oxidation/reduction reactions; solubility products; acids/bases/ph; determination of dissolved oxygen; COD, BOD, carbonate system.
Organic chemistry: aliphatic, aromatic and heterocyclic compounds; carbohydrates, amino acids, proteins and lipids. Introduction to analytical chemistry.
Environmental microbiology: introduction; structure, classification, metabolism, function and environmental significance of micro-organisms; role of micro-organisms in environmental engineering, industrial and wastewater treatment processes; waterborne disease transmission and control.

CE.312 Highway and traffic engineering

PROFESSORS M.G.H. BELL AND R.J. JARDINE
32 lectures, 16 tutorials.
This option divides into two parts, the first focusing on traffic (its properties, its measurement, its simulation and its control) and the second on highways (pavement design, materials, geometric alignment and geotechnical engineering). The first part starts with traffic flow variables and their measurement, then students are introduced to traffic flow theory and traffic queuing theory. The principles of traffic signal control are followed by motorway monitoring and control. Students are taught how to use traffic simulation software. Quantitative methods taught in the lectures are practised in tutorials. The second part covers the principles of route location, geometric design, the design of cycleways and busways, earthwork calculations and the optimisation of horizontal and vertical alignments. This is followed by geotechnical aspects, such as the design and construction of cuttings, embankments and foundations. Students are taught how to use highway design software.

CE.313 Engineering geomatics

DR W.Y. OCHIENG, DR J.J. BOMMER, DR C. ONOF
50 hours of lectures, tutorials and practicals with associated coursework.
This course is designed to enable students to acquire theoretical knowledge and practical skills required in the management of spatial information for civil and environmental engineering projects.

Specific topics covered include: introduction to geomatics; conventional data capture techniques and instrumentation; mathematical optimisation; survey adjustment and quality control; GPS surveying; setting-out; basic principles of geographical information systems, photogrammetry and remote sensing and their application in civil and environmental engineering; digital terrain modelling; example areas of application of GPS and GIS in civil and environmental engineering.
Tutorials and demonstrations are given in the use of gis software and hardware, GPS equipment and software, photogrammetric equipment for engineering applications and the process of acquiring positioning data from remotely sensed images. Coursework exercises are given on theoretical and practical aspects of the module. These include basic principles of engineering geomatics and spatial reference systems, mathematical optimisation and GPS surveying, and the use of GPS and GIS for navigation. A one-day field course is run where students design and execute a scheme to capture and process GPS and conventional survey data for engineering applications.

CE.314 Coastal engineering

PROFESSOR R. SOBEY, PROFESSOR C. SWAN
35 lecture hours and 15 tutorials/presentations.
Regular waves; irregular or random waves; wave statistics; wave transformations and wave breaking. Wind waves (physics, fetch graph, spectral models). Wave climate (observations, probability summaries, intensity-duration-frequency).
Tides (observations, harmonic analysis, propagation). Storm tides (historical storms, evolution, frequencies). Wave evolution (diffraction, combined refraction-diffraction). Nearshore circulation (surf zone, undertow, longshore current, edge waves).

CE.315 Group design project

PROFESSOR D. LLOYD SMITH AND OTHERS
Five weeks full-time during summer term.
This course is a special one, because it is designed to generate an atmosphere that is as close as possible to the experience of working on the design of a real engineering project. The course is held after the summer examinations so that there are no other academic distractions. Most, or all, of the project work is carried out in college in studio groups. Students can choose their project from a list of 12 and work on it, full time, in a team of six to eight. During the course, students are given the chance to work on a challenging engineering design for a real site, using their own initiative and the engineering tools they have learned during the first three years of the MEng course. the emphasis is on creativity, design and understanding, teamworking and communication skills, as well as engineering judgement and problem solving. All projects are interdisciplinary, with the involvement of experienced practising engineers in addition to the Imperial college supervisors and tutors. At the end of the each week the design teams will make a milestone presentation of their work for discussion with a critical panel of the academic project supervisors and invited industry critics. At the end of the project, students will be expected to present their work as a team during a final crit, in the form of sketches, Drawings, sketch models, or through other appropriate media such as computer graphics, video, overheads or slides. Importantly, the design groups are rewarded as much for the way in which they have tackled their project as its final form.

FOURTH YEAR

Elective

Students are required to choose any six elective subjects.

CE.401 Steel structures and design

DR L.A. LOUCA, PROFESSOR T.A. WYATT
53 hours' lectures, tutorial and associated coursework, seven hours' project work.
Behaviour of elements: beams and lateral torsional buckling; beam-columns, composite slabs and beams, plate girders.

Conceptual design: lattice towers, trusses, tied arches, tension supported structures, portal frames, multi-storey buildings, long span bridges and tall buildings.
Project work: three projects typically based on grandstand spine trusses, plastically designed portal frames (to BS5950) and six-storey simply framed buildings.

CE.402 Structural dynamics

DR K. RAMACHANDRAN, PROFESSOR D. LLOYD-SMITH
38 lecture hours, 10 tutorial hours and 12 project hours.
Single-degree-of-freedom elastic structures (SDOF): response due to harmonic loads, pulse loads and impulse. Resonance. Evaluation of damping. Duhamel or convolution integral. Blast loading. Response spectrum method. Motion of supports and response due to earthquakes. Earthquake response spectra in seismic analysis and design. Multi-degree-of-freedom elastic structures (MDOF): stiffness and flexibility matrices. Undamped, free vibrations. Natural frequencies and natural modes. Orthogonality conditions. Stodola method of evaluating natural modes and frequencies. Generalised mass, stiffness matrices and force vector. Damped, forced vibrations. Response by modal superposition method. Root-sumsquare estimates of maximum response—displacements and internal forces. Earthquake resistant design. Direct integration of equations of motion. Newmark's and related finite-difference schemes. Implicit and explicit schemes. Flexural vibration of beams with continuous mass distribution: partial differential equation of motion. Free, undamped vibration of uniform beams. Frequency equation and natural modes. Approximate solutions: energy methods. Rayleigh's principle for fundamental mode approximation. Extension to Rayleigh-Ritz method. Random vibrations: introduction to random processes. Stochastic response of linear, SDOF systems. Wind loading and gust effects. Vibration of elastic structures in a fluid stream: vortex shedding. Crosswind excitation of structures. Galloping oscillations. Aerodynamic flutter and the vibration of suspension bridges.

CE.403 Non-linear structural mechanics

PROFESSOR D. LLOYD-SMITH, DR B.A. IZZUDDIN
36 lectures, 14 tutorial hours, 10 project hours.
The course builds on the elements of plasticity and stability of the third year structural mechanics core course, emphasising the importance of material and geometric non-linearities. Systematic plastic limit analysis of framed structures. mesh and nodal forms of static and kinematic laws, static-kinematic duality. Plastic collapse, the structural matrix relations, complementarity. Plastic limit analysis, the upper and lower bound theorems, representation as dual linear programs. Systematic use of spreadsheets containing an optimisation tool, such as Microsoft Excel, Corel Quattro Pro, Lotus 1-2-3. Application to steel, reinforced concrete and masonry construction. Estimation of displacements and plastic hinge rotations at collapse. Modelling and assessment of non-linear structural behaviour: fundamentals of geometric non-linearity for discrete structural systems. principles of stability and buckling analysis. Non-linear solution procedures for tracing equilibrium paths. Geometrically non-linear finite elements for one-dimensional structural systems. Materially non-linear finite elements for one-dimensional structural systems. Nonlinear dynamic analysis. Use of adaptic for non-linear structural analysis, with application to static and dynamic problems.

CE.405 Advanced soil mechanics

DR M.R. COOP
60 contact hours of lectures, tutorials and mini-projects and lab classes.
Provides a detailed background to more advanced aspects of soil mechanics for students wishing to specialise in geotechnics.
Effective stress: stress paths and stress parameters. Strain; Drained strength of granular and clay soils; undrained strength. Elastic-plastic stress-strain properties of clays.

CE.406 Applied hydrodynamics

PROFESSOR C. SWAN
22 lectures, 22 tutorials, 16 porject/laboratory hours

Fundamental properties governing the description of civil engineering fluid flows. The main course elements are: general description of fluid motion, flow regimes, slender body loads, large volume structures, extreme loading (impacts), dynamic response, boundary layers, turbulence modelling, sediment transport and marine energy (renewables).

CE.407 Water and wastewater engineering

PROFESSOR D. BUTLER, PROFESSOR N.J.D. GRAHAM, DR S.R. SMITH, PROFESSOR C. MAKSIMOVIC
41 lectures, 12 tutorials, seven project hours and a site visit.
Water supply: principles of design of works for the collection and distribution of water supplies, including abstraction, storage, pumping, distribution and network analysis.
Water treatment: definition of water quality; standards; scientific basis and design of unit processes in water treatment.
Urban Drainage: system definition, hydraulics, rainfall, stormwater and its collection, wastewater and its collection, combined sewers, stormwater management. Wastewater treatment: system definition, nature of sewage/wastewaters; and effluent quality requirements; treatment processes: primary sedimentation, activated sludge, biological filters, sludge treatment and disposal.

CE.408 Water resource engineering

DR A.P. BUTLER, DR N.R. McINTYRE, DR C. ONOF
56 hours of lectures, tutorials, computer workshops and associated coursework.
Introduction to water resources: current issues in water resources engineering; hydrological processes; measuring fluxes; calculating catchment water balances.
Rainfall run-off modelling: the unit hydrograph model, general linear transfer functions, linear and nonlinear storage models, conceptual modelling, model calibration and uncertainty analysis. Surface water quality: introduction to surface water quality and relevant legislation. Organic pollution and dissolved oxygen, nutrients and eutrophication. Modelling fully and partially mixed systems, and nonconservative substances.
Groundwater resources management: introduction; resource exploration and evaluation; well pumping tests for yield assessment and hydrogeological parameter determination; use of modelling techniques for aquifer management; groundwater quality and contaminant transport; groundwater vulnerability and source protection.
Reservoir design: introduction; critical period design techniques; simulation and data generation.
Water resources systems analysis: introduction; water allocation; water supply capacity extension; reservoir design and operation.

CE.409 Transport engineering

PROFESSOR J.W. POLAK, DR R.B. NOLAND
38 lectures, 12 tutorials and four hours of computing.
Transportation in its social and economic context, the role of transport planning, understanding the demand for transport, transport networks, network performance and level of service, accessibility, congestion, generalised cost of travel, modelling travel choice (formulation and estimation of discrete choice models), applications and extension of the logit model, the four stage transport planning model (generation, distribution, mode choice, assignment), environmental impact of transport (safety, noise, emissions and land-use), travel demand management (regulation, pricing and design), economic evaluation.

CE.411 Systems analysis

DR C. ONOF
32 lecture hours and 20 tutorial hours.
An introduction to more advanced topics in systems analysis and the statistical evaluation of uncertainty for decision-making in civil and environmental engineering.
Dynamic programming: optimality principle, state transition equations, recursive solution procedure.

Game theory: zero-sum games, prisoner's dilemma. Decision-making under uncertainty: Bayes's rule, decision trees and Bayesian decision analysis. Stochastic dynamic programming. Markov chains. Queueing models, monte carlo simulation and dynamic system simulation.
Applications to schedule equipment maintenance and repair; production/inventory planning; contract bidding analysis: site survey information; optimal capacity expansion in water supply; reservoir operation; optimal design of structures; transport system operation; competitive market strategies.

CE.412 Management

DR R.B. NOLAND
Two one-term half-modules. 56 contact hours, including lectures, tutorials, and case studies.
This course is designed to provide students with the theoretical underpinnings of microeconomics. This is then followed by lectures on Innovation Management (Prof. David Gann) and issues relevant for project-based firms, typical of most civil engineering companies.
Lectures on microeconomics theory will provide a theoretical foundation in the principles of microeconomics. This includes theories of consumer behaviour, theories of the firm, market failures and public goods. Students will gain an understanding of basic microeconomic principles. They will be able to describe theories of consumer and industry behaviour, welfare economics, externalities, and public goods. They will be able to graphically and quantitatively describe these theories and communicate them to Others.
Lectures on Innovation Management aim to equip Civil Engineering students with an understanding of the main issues of project and Innovation Management, an awareness of the key features of success, and an appreciation of the relevant skills needed to manage innovation at both strategic and operational levels. It provides evidence of different approaches based on real-world examples and experiences of leading international firms.

CE.413 Earthquake engineering

DR J.J. BOMMER, DR A.Y. ELGHAZOULI, DR C.H. FENTON
40 lecture hours, 10 project/tutorial hours.
An introduction to the fundamentals of seismic hazard assessment and the earthquake-resistant design of steel structures. Concepts of seismic hazard and seismic risk. Earthquake processes; tectonics; faulting; seismic waves and seismograms; earthquake source parameters; seismicity. earthquake strong-motion: Accelerograms; attenuation relations; response spectra. Probabilistic seismic hazard assessment.
Dynamic soil properties; effects of soil layers on characteristics of ground motion.
Elements of seismic design: conceptual design and limit states; structural forms and load resisting systems; earthquake loading; analysis and seismic design of steel structures to eurocode 8.
Practial considerations for seismic design.

CE.416 Environmental fluid mechanics

PROFESSOR R.J. SOBEY, DR G. HUNT
55 hours of lectures, tutorials, coursework, and case studies.
Environmental fluid mechanics direct specific attention to flow and transport of water in rivers and estuaries and of air in buildings, the built environment.
The following topics are covered: unsteady flow in rivers and tidal channels, unsteady flow in stratified channels, longitudinal dispersion, ventilation of modern buildings, stratified flow in estuaries and ocean outfalls, case studies presented by practicing engineers.

Major project

CE.415 Investigative project

DR R.B. NOLAND

Unscheduled planning time of about three hours per week on average in the autumn and spring terms followed by a five weeks of full-time working in the summer term.

Examinations

	Degree exam for which recognised	Date
FIRST YEAR		
Mathematics (two papers)	Final, Part I	June
Structural mechanics	" "	"
Fluid mechanics	" "	"
Geotechnics	" "	"
Materials	" "	"
Mechanics	" "	"
SECOND YEAR		
Mathematics (two papers)	Final, Part II	June
Hydraulics	" "	"
Geotechnics	" "	"
Environmental engineering	" "	"
Structural mechanics	" "	"
THIRD YEAR		
Structural mechanics	Final, Part III	May
Hydraulic engineering	" "	"
Soil mechanics	" "	"
Systems engineering and Engineering economics/management	" "	"
Three elective subjects	" "	"
FOURTH YEAR		
Six elective subjects	Final, Part IV	May