Information and Application Guide

2009/2010

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The information in this guide is correct at the time of publication. However, SMA reserves the right to make changes when necessary and without prior notice.

1 SMA's Commitment

The Singapore-MIT Alliance (SMA) is a global partnership between Massachusetts Institute of Technology (MIT), National University of Singapore (NUS) and Nanyang Technological University (NTU).

Founded in November 1998 to promote global graduate science & engineering education and research, SMA is the world's largest interactive distance education initiative. The partnership taps world-class engineering expertise, ideas and technology required for cutting-edge research to fuel Singapore as well as the region's growth as an innovation and education hub.

Please visit the SMA website at: http://www.sma.nus.edu.sg for more details.

2 Key Contact Information

For more information, please visit the url at:
http://web.mit.edu/sma/about/directories/faculty_name_1.html.

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3 Programmes, Degree Tracks and Candidature

The Alliance offers dual degrees as well as direct PhD degrees. The dual degrees are awarded by MIT and either NUS or NTU. For the latter, the Master's degree is awarded by the Singapore university hosting the programme while the PhD degree is awarded by the university the thesis advisor is attached to.

SMA offers five programmes; four in the engineering disciplines and one in the life science discipline:
a. Advanced Materials for Micro- and Nano-Systems (AMM&NS)
b. Computational Engineering (CE)
c. Chemical and Pharmaceutical Engineering (CPE)
d. Manufacturing Systems and Technology (MST)
e. Computation and Systems Biology (CSB)

Four of these programmes (AMM&NS, CE, CPE and MST) offer the following degree tracks:
- An MIT Master's and an NUS/NTU Master's (Dual Masters)
- An MIT Master's and an NUS/NTU PhD (Master-PhD)
- An NUS/NTU PhD degree with SMA certificate (Direct-entry PhD)

The CSB Programme offers only the NUS/NTU PhD degree (Direct-entry PhD) track.

The AMM&NS, CE, CPE and CSB programmes are hosted by NUS while the MST programme is hosted by NTU.

The expected period of candidature is as follows:
- Dual Masters track - 1.5 years
- Master-PhD track - 5 years
- Direct PhD degree track - 4 years

3.1 By Coursework

AMM&NS

The AMM&NS Programme offers the Dual Masters track where the ***MIT Degree of Master of Engineering in Materials Science and Engineering*** and the ***NUS Degree of Master of Science in Advanced Materials for Micro- and Nano-Systems*** are awarded.

The AMM&NS Dual Masters track provides students with the background they need to become leaders in technology-based enterprises, especially those connected to advanced materials. The programme begins with graduate-level classes surveying the fundamentals of materials science and engineering with a focus on applying these fundamentals to real engineering problems and systems. This foundation is followed by subjects that build expertise in specific areas selected by the student and his or her advisor. Students are also encouraged to explore areas of interest outside the materials field, studying entrepreneurship or technology management for example. The programme's capstone experience involves student participation in engineering projects and technology assessment under the supervision of MIT faculty. Students spend the first Fall term in residence at MIT, taking courses and exploring research opportunities with faculty. Students spend the first and second Summer sessions as well as the first Spring and second Fall terms in Singapore, where they continue to take distance-enabled MIT courses along with other MIT students. Singapore-based students continue to collaborate with their MIT faculty supervisors and associated students and staff through regular video-conferencing as well as face-to-face meetings when MIT faculty members travel to Singapore.

The MIT Master of Engineering degree requires students to take 5 core modules, 3 restricted electives and complete a thesis. The NUS Master of Science degree requires students to read 1 core module and 4 electives. In addition, a total of 2.75 MIT modules are transferred as credits towards the NUS degree. In addition, students must complete a project, equivalent to credits earned for 3 modules, through a 6-month internship programme.

CE

The CE Programme offers the Dual Masters track where the ***MIT Degree of Master of Science in Computation for Design and Optimization*** and the ***NUS Degree of Master of Science in Computational Engineering*** are awarded.

The CE Dual Masters track is a programme aimed at the education of students in the formulation, analysis, implementation and critical application of computational approaches to understanding, predicting, optimising and designing engineered systems. The programme emphasises breadth through introductory courses in the areas of numerical simulation, optimisation, probability and statistics; depth in the areas of optimisation methods and numerical methods for partial differential equations; integration and multidisciplinary aspects; hands-on experience though numerous exercises, projects and assignments and the option of a significant thesis or two smaller separate thesis projects. A component of this degree is the 4-month internship. The degree programme will provide graduates with familiarity in using state-of-the-art numerical tools as well as specialisation in many of these tools.

The MIT Master of Science degree requires students to take 2 or 3 core modules from MIT, 1 NUS/MIT joint module, 1 or 2 restricted electives and 1 unrestricted elective from MIT and complete a thesis. The NUS Master of Science degree requires the student to read 2 core modules from NUS, 1 NUS/MIT joint module and 1 elective from NUS. In addition, a total of 3 MIT modules are transferred as credits towards the NUS degree. In addition, a student must complete a project, equivalent to credits earned for 3 modules, through a 4-month internship programme.

<u>CPE</u>

The CPE Programme offers the Dual Masters track where the ***MIT Degree of Master of Science in Chemical Engineering Practice*** and the ***NUS Degree of Master of Science in Chemical and Pharmaceutical Engineering*** are awarded.

The CPE Dual Masters track is a unique opportunity to get a Master's Degree in the MIT School of Chemical Engineering Practice. Established in 1916 to provide practical training in an industrial environment that would supplement classroom studies, the Practice School is the heart of MIT's Master of Science in Chemical Engineering Practice degree. In Practice School, students will reside at two host company stations. At each station, students will work on projects in teams and be supervised by a resident MIT staff member. These projects will be current, challenging assignments within the realm of the host company's line of business or research and will be for their benefit, using their facilities and in consultation with their technical staff. The students will have day-to-day interaction with company personnel and management teams and will be called upon to communicate the process and results of their work both orally and in writing.

The MIT Master of Science degree requires students to take 5 core modules, 1 elective and complete 16 weeks at Practice School. The NUS Master of Science degree requires the student to read 4 core modules and 6 electives. In addition, a total of 3 MIT modules are transferred as credits towards the NUS degree.

<u>MST</u>

The MST Programme offers the Dual Masters track where the ***MIT Degree of Master of Engineering in Manufacturing*** and the ***NTU Degree of Master of Science in Manufacturing Systems and Technology*** are awarded.

The MST Dual Masters track combines a broad based approach with independent research and concentrate on problems of emerging industries. Students will combine industry-based project experience with a university-based research derived from that experience. The MIT degree will be taken partly in residence at MIT attending coursework modules and by distance at NTU, and will be primarily coursework-based with a group project in industry supervised by MIT. The NTU degree will include coursework and independent research with NTU faculty supervision.

The MIT Masters of Engineering degree in Manufacturing requires students to take 9 core coursework courses and complete a thesis. The NTU Master of Science degree requires the student to take 5 core courses and 3 elective courses out of a choice of 12 courses and attend seminars on Emerging Manufacturing Industries. A total of 3 MIT modules are credit transferred and counted towards NTU degree. In addition, a student must complete a research project through independent exploration in specific areas.

3.2 By Research

The AMM&NS Programme offers the following graduate degrees by research:

- The Master-Ph.D. track where the ***MIT Master of Engineering in Materials Science and Engineering*** and the ***NUS/NTU Doctor of Philosophy in Advanced Materials for Micro- and Nano-Systems*** degrees are awarded.
- ***Doctor of Philosophy in Advanced Materials for Micro- and Nano-Systems***

In the Master-Ph.D. track, the MIT Master of Engineering degree requires students to take 5 core modules, 3 restricted electives and complete a thesis while the NUS/NTU Ph.D. degree requires students to read 6 modules which comprise 2 core modules, 2 thesis-related electives each from NUS/NTU and 2 core MIT modules which are transferred as credits towards the NUS/NTU degree.

The direct-entry Ph.D. track prepares students for advanced careers in industrial research and development centres, as well as research institutes or academic departments involved in cutting-edge research with a focus on applications in micro- and nano-systems. The coursework requirement is 6 modules which comprise 2 core and 2 thesis-related electives from NUS/NTU and 2 core MIT modules which are transferred as credits towards the NUS/NTU degree. Research topics range from problems in fundamental materials physics to development of new nano-scale devices.

CE

The CE Programme offers the following graduate degrees by research:

- The Master-Ph.D. track where the ***MIT Master of Science in Computation for Design and Optimization*** and the ***NUS/NTU Doctor of Philosophy in Computational Engineering*** degrees are awarded.
- ***Doctor of Philosophy in Computational Engineering***

The Master-Ph.D. degree track essentially includes the same coursework as the Dual Masters programme but additionally involves specialisation courses and a significant research component emphasising the formulation, analysis and implementation of new computational methods for the simulation and optimisation of problems of emerging practical and strategic interest. The MIT Master of Science degree requires students to take 2 or 3 core modules from MIT, 1 NUS/MIT joint module, 1 or 2 restricted electives and 1 unrestricted elective from MIT and complete a thesis. The NUS/NTU Ph.D. degree requires students to read 4 core modules and 2 breadth-modules from NUS/NTU and 2 electives from MIT which are transferred as credits towards the NUS/NTU degree. In addition, 1 of the 2 modules taken at MIT during their semester stay as part of their Ph.D. candidature will also be transferred for credits.

The intended audiences for the direct-entry Ph.D. track are scientists and engineers who wish to further develop their skills in the rapidly evolving field of numerical simulation, modeling, design and optimisation. It is expected that students will have a strong foundation in a core disciplinary area such as engineering, materials science, physics, biology or mathematics. The coursework requirement for the Ph.D. degree is 4 core and 2 breadth modules from NUS/NTU and 2 technical electives from either NUS/NTU or MIT.

CPE

The CPE Programme offers the following graduate degree by research:

- ***Doctor of Philosophy in Chemical and Pharmaceutical Engineering***

This is a research doctorate degree programme with an emphasis on synthesis skills, engineering design and interdisciplinary approaches focused on chemicals and pharmaceuticals. The training includes communication, problem solving and participation in cutting-edge research and technology with a focus on entrepreneurship and innovation. The Doctoral degree conferred by NUS/NTU prepares graduates for dynamic careers in industrial research and development centres, research institutes or academic departments interested in molecular engineering and chemical engineering processes. The Ph.D. degree provides training in a particular area of specialisation and students must read 6 modules which include 2 MIT modules transferred as credits towards the NUS degree. Students in the direct Ph.D. degree track must read 6 NUS modules.

MST

The MST Programme offers the following graduate degrees by research:

- The Master-Ph.D. track where the ***MIT Master of Engineering in Manufacturing*** and the ***NUS/NTU Doctor of Philosophy in Manufacturing Systems and Technology*** degrees are awarded.
- ***Doctor of Philosophy in Manufacturing Systems and Technology***

The Master-Ph.D. degree track includes essentially the same coursework as the Dual Masters programme but additionally involves specialisation courses and a significant research component emphasising critical technological roadblocks brought about by working at the micron and sub-micron-level length scale and on this new class of products.
The MIT Master of Engineering degree requires students to take 9 core courses and complete a thesis. The Ph.D. degree provides training in a particular area of specialisation and students must read modules which comprises 3 to 6 thesis related modules as well as attend seminars on Emerging Manufacturing Industries and undertake practical work.

Students in the direct Ph.D. track will be part of a concentrated research effort to address the critical technological roadblocks brought about by working at the micron and sub-micron-level length scale and on this new class of products closely supervise by Singapore and by distance MIT thesis advisors. The coursework requirements for the Ph.D. degree consists of 3 to 6 thesis-related modules depending on the number of modules exempted.

CSB

The CSB Programme offers the following graduate degree by research:

- ***Doctor of Philosophy in Computation and Systems Biology***

Offering the award of only a Ph.D. degree, the CSB programme prepares students to become independent, interdisciplinary researchers in post-genomic biology and related fields. There is a strong focus on quantitative methods and modelling, experimental design and device development.

The emerging field of systems biology represents an integration of concepts and ideas from the biological sciences, engineering disciplines and computer science. Systems modelling and design are well established in engineering disciplines but are relatively new to biology. Microsystems have been fundamental to advances in electronics and computing, but now have the potential to revolutionise biology as well. Advances in systems biology will require multidisciplinary teams to apply principles and tools from engineering and computer science to solve problems in biology and medicine.

The programme integrates coursework and research opportunities in biology, engineering, math, microsystems and computer science. Graduates of the programme will be uniquely prepared to develop original methods, make novel discoveries and establish new paradigms. They will also be well-positioned to assume critical leadership roles in both academia and industry, where this new research area is of growing importance.

The research projects will be conducted on problems identified within the Inter- University and Flagship Research Projects. The CSB Ph.D. curriculum draws from courses in the MIT CSBi Ph.D. programme as well as elective courses at MIT, NUS and NTU. Students will read 4 core courses for a foundation in systems and computational biology and 3 electives that expand the breadth and extend the depth of study. The core and elective courses will be offered at MIT, NUS and NTU either as long-distance or residence courses. Students are expected to complete most of their coursework in the first two years. Long distance courses are co-taught by MIT and Singapore faculty.

Research Degrees

Each programme requires candidates to read the prescribed number of modules before taking the PhD Qualifying Examination (QE). The QE will comprise an oral and/or written component, depending on the programme. The recommended coursework component comprises between 6 to 12 modules. The thesis research is co-supervised by a faculty member each from Singapore and MIT and in many cases, carried out in collaboration with researchers in Singapore's research institutes.

PhD students are also required to present their research to faculty members, graduate students and visitors as part of the Graduate Seminar requirement.

All direct-entry PhD students, upon successful completion of all the PhD degree requirements, are awarded either an NUS or NTU PhD degree with an SMA certificate.

4 Programme Requirements

4.1 Admission Requirements

Candidates for SMA programmes are enrolled at the beginning of July each year on a full-time basis only. For the dual degree programmes, successful applicants must independently satisfy the admission requirements at MIT as well as either NUS or NTU, as defined and approved for each programme by each co-hosting Alliance University and its faculties in accordance with their applicable policies, procedures and standards.

To qualify for admission to all SMA programmes hosted by either NUS or NTU, a student must have earned a good Bachelor's degree and/or Master's degree in the fields of Engineering, Science or Computer Science with a 1st Class or 2nd Class Upper Honours degree or its equivalent from a university of acceptable standing. **Students who are in their final-year of undergraduate studies,**

may be provisionally admitted on the condition that the academic results obtained up to the point of application meet SMA's academic entry requirements. Applicants are evaluated on the basis of their prior performance and professional promise, as evidenced by their academic records, letters of evaluation from individuals familiar with their capabilities and any other pertinent data they submit. While high academic achievement does not guarantee admission, SMA expects such achievement or other persuasive evidence of professional promise.

For admission as a PhD candidate, the candidate must submit evidence of adequate training and ability to undertake the proposed course of study. The student must first be admitted to the Singapore university which hosts the programme and subsequently re-register (if applicable) with the university to which his or her main thesis advisor is affiliated.

SMA requires the GRE general test scores to be submitted by each applicant when applying for admission into the dual degree programmes of AMM&NS, CE, CPE and MST. GRE is also required for direct PhD applicants but a written request for waiver of GRE can be submitted together with the application. Waiver may be granted on a case-by-case basis. Applicants with first degrees from NUS or NTU are exempted from the GRE requirement **ONLY** when the degree to be awarded is a direct PhD degree. You may obtain more information on GRE by visiting the Educational Testing Service (ETS) web site at http://www.ets.org.

Submission of the International English Language Testing System (IELTS) or Test of English as a Foreign Language (TOEFL) is required for applicants whose native language is not English. A minimum score of 7 is required for IELTS while a minimum computer-based score of 237 (92 internet-based, 580 paper-based) is required for TOEFL. For admission into all SMA programmes hosted by either NUS or NTU, the following categories of applicants are generally exempted from the IELTS/TOEFL requirement:

a. those who have received instruction in English in their primary and secondary schools.
b. those who have been in an English speaking country for four years or longer.
c. those who have received their degrees from American, British, Canadian, Australian or New Zealand universities.

Reimbursement of GRE and IELTS/TOEFL fees

All candidates (except for the category marked * indicated below) who meet the stipulated terms and conditions set out by SMA are eligible for reimbursement of the GRE and/or IELTS/TOEFL fees.

* Candidates who have received/will receive their first degrees from NUS or NTU and have enrolled in the CSB programme or direct PhD degree track in the AMM&NS, CE, CPE and MST programmes are not eligible to seek reimbursement for GRE and/or IELTS/TOEFL fees unless there is a requirement from the programme to submit these test scores.

The guidelines for the reimbursements are as follows:

a. GRE and IELTS/TOEFL tests must be taken at most up to 1.5 years before enrolment with SMA. For example, if you are admitted in the AY2009-2010 intake which begins in July 2009, the test dates should not be earlier than January 2008, in order to be eligible for the reimbursement.

b. Proof of payment in the form of original receipt and/or print-out of the electronic confirmation of the test booking with the payment indicated, must be enclosed with the completed claim form.

c. Reimbursements will be made only after you have completed all the coursework requirements for Semester 1: July to August 2009 and met the continuation requirements to proceed to the next semester of study. As far as possible, provided all the required documentation has been submitted, reimbursement will be made in either December or the following January.

4.2 Application process and fees

For application into any of the dual degree programmes, you must submit separate application materials to MIT and SMA. You will need to use the MIT host department's application materials to apply for the MIT degree and SMA's application materials to apply for admission into NUS or NTU.

The MIT application fee is US$70 while there is no application fee for NUS or NTU. However, there is an acceptance fee of S$50 (excluding GST) should you decide to accept the offer of admission into NUS or NTU.

4.3 Intake and Timelines

There is one intake in Singapore every July. You are expected to submit your application between October and December, depending on the programme you are applying for. The application deadlines are available on the SMA webpage. The offer of admission will be made in March or April and you are expected to indicate your acceptance in April or May.

4.4 Residency Requirements

NUS/NTU Residency Requirement

Students must reside in Singapore in accordance with the period stipulated by each university.

MIT Residency Requirement

The MIT residency requirements of each dual degree programme are as follows:

Programme	Duration of MIT Residency	Term During Candidature
AMM&NS	4 months (Sep – Dec)	1st Fall for all 3 degree tracks
CE	12 months (Sep – Aug)	1st Fall, 1st Spring & 2nd Summer for dual degree track
MST	4 months (Sep – Dec)	1st Fall for dual degree track
CPE	4 months (Sep – Dec)	1st Fall for dual degree track

Dual Masters students spend one semester at MIT. The PhD students in the Master-PhD degree track may spend up to a total of three semesters at MIT while the direct PhD students may spend up to a total of two semesters at MIT. The CSB programme has a fixed schedule for the residency at MIT which is as follows:

CSB	5 months (Jan – June) & 1 month	1st Spring & 3rd/4th year of candidature

4.5 Continuation and Graduation Requirements

For Degree conferred by NUS under the SMA Programmes

Coursework-based Programmes

A student pursuing a Master's degree by coursework must achieve a minimum CAP of 3.0 to be eligible for graduation. A student may read more than the minimum necessary modules (comprising all required modules and at least 30 MCs at level 5000 or 6000 within the subject or related disciplines). Only the grades for the minimum necessary modules shall be considered in assessing whether the student has met the degree requirement.

A student whose CAP falls below 2.5 for two semesters or 3.0 for three semesters will have his or her candidature terminated. These semesters, not necessarily consecutive, would be those during which modules read count towards either the NUS or NTU degree. However the computation of CAP would exclude those modules which are double counted towards the MIT degree. The modules which are double-counted will be considered as transfer of credits. For any semester in which the student's CAP falls below 3.0, he or she will be issued a warning. If, in the next semester, his or her CAP again falls below 3.0, but above 2.5, he or she will be placed on probation.

Research-based Programmes

To be eligible for graduation, a student pursuing a PhD degree by research must achieve a minimum CAP of 3.5 for all required modules and have passed the PhD qualifying examination, oral examination and PhD thesis.

For continuation of candidature, students must ensure that his or her CAP does not fall below 3.0 for 2 semesters or 3.5 for 3 semesters. These semesters, not necessarily consecutive, would be those during which modules read count towards either the NUS or NTU degree. Computation of CAP would exclude modules which are transferred as credits towards the NUS degree. Termination of candidature would result if a student fails to maintain the minimum CAP. For any semester in which the student's CAP falls below the CAP required for graduation, he or she will be issued a warning. If in the following semester, the student's CAP again falls below the graduation requirement, but not sufficiently to warrant immediate termination, he or she will be placed on probation. A student may also be issued a warning or placed on probation for poor performance on the Qualifying Examination, research thesis or other programme requirements.

There is no stipulation for students to graduate with a Master's by research degree in the event he or she does not fulfill the continuation and graduation requirements for a PhD degree.

<u>For Degree conferred by NTU under the SMA Programmes</u>

Coursework-based Programme

A student pursuing a Master degree by coursework must achieve a minimum CGPA of 2.5 at the completion of the course as well as successfully completed all requirements prescribed by the programme of study to be eligible for graduation.

A student whose TGPA falls below 2.5 for two semesters will have his or her candidature terminated. These semesters, not necessarily consecutive, would be those during which modules read count towards the NTU degree. However the computation of TGPA would exclude those MIT modules which are double-counted towards both the MIT and NTU degrees. These modules which are double-counted will be considered as transfer of credits. For any semester in which the student's TGPA falls below 2.5 in any term of study, he or she will be issued an academic warning.

Research-based Programme

To be eligible for graduation, a student pursuing a PhD degree must achieve a minimum CGPA of 3.5 for all required modules, and have successfully completed all the requirements as prescribed by the programme of study or the School.

To continue in a PhD programme, a student must ensure that his or her TGPA does not fall below 3.5 in any semester of study. These semesters, not necessarily consecutive, would be those during which modules read count towards the NTU degree. Wherever applicable, the computation of TGPA/CGPA would exclude those modules which are double-counted towards the MIT degree. The modules which are double-counted will be considered as transfer of credits.

A research student will be issued with an academic warning if his or her TGPA in any term of study is below 3.5 or has received a grade point of less than 2.5 (below C+) for subjects taken.

Termination of financial aid/candidature would result if a student fails to maintain a TGPA of above 2.5 in two semesters or 3.0 in three semesters as well as failure to complete all subject requirements within the stipulated period.
There is no stipulation for students to graduate with a Master's by research degree in the event he or she does not fulfill the continuation and graduation requirements for a PhD degree.

4.6 Assessment Mode/Examination Rules

Appeal

For the NUS/NTU degree, a student whose candidature has been terminated may appeal in writing to the SMA Singapore Co-Director for reconsideration.

Academic Honesty

Cheating, plagiarism, unauthorised collaboration and other forms of academic dishonesty are considered serious offences for which disciplinary penalties will be imposed.

Some academic offences by students can be handled directly between the Course Co-ordinator and the students involved. In some cases, it may be necessary for the Programme Co-Chair to review, or otherwise to assist in, the resolution of the matter. When a dispute cannot be resolved satisfactorily within the programme, or if it seems appropriate, a complaint against a student can be brought to the attention of the Co-Director who is the final authority for academic conduct. Based on the decision of the Co-Director, the student will be informed of the penalty to be imposed. This could include not taking into account the marks and grades for that particular assignment/quiz/examination.

Excused Absences from Quizzes/Examinations

A student may be excused from scheduled quizzes/examinations for reasons of illness. In the event a student falls ill on the scheduled date of quizzes/examinations, the student should contact the SMA Office which will then inform the Module Co-ordinator and the Programme Co-Chair. The student then needs to submit the Medical Certificate together with the University's prescribed form certified by the medical doctor.

The Module Co-ordinator, in consultation with the Programme Co-Chair, will review the case and if they make a decision not to take into account the particular component when collating the final marks and grades for that particular assignment/quiz/examination, they must be prepared to submit a final mark and grade based on other evidence.

5 SMA Graduate Fellowship

All candidates successfully admitted into SMA will be awarded SMA Graduate Fellowships and be known as SMA Graduate Fellows. The SMA Graduate Fellowship monthly stipend is S$2000 for foreign students and S$2500 for Singapore citizens and Singapore permanent residents. In addition, a living allowance of US$1000 per month, up to a maximum of US$6000, will be given for the residency at MIT. The SMA Office will fund an economy-class roundtrip airfare to Boston.

PhD students will receive an additional S$500 per month upon passing the PhD Qualifying examination. The tuition fee imposed by the Singapore universities and MIT will be fully borne by the SMA Office.

6 SMA Internship Programme

For degrees awarded by NUS/NTU, all Master's students except for those in the CPE programme are required to undergo an Internship Programme with industry as part of the degree requirements.

The objectives of the SMA internship are to:

a. provide opportunities for the students to use their initiative and creativity;
b. to challenge the students to deploy problem solving skills and use new approaches when faced with problems;
c. to stretch the student's potential and ability to the maximum;
d. to encourage cohesiveness and synergy

Through this SMA internship, the students will familiarise themselves with the industry requirements and be able to envision the direction in which the industry should be heading to meet new challenges. The training received should be comprehensive and include achieving the following competencies:

a. innovation, creativity, entrepreneurial practices, technopreneurship, best practices, systems thinking and organisation learning.
b. team learning
c. use of up-to-date software technology
d. cost and return on investment analysis
e. total quality management and quality control circles

f. reliability measures
g. marketing and sale strategies

SMA supervisors/facilitators appointed from among the SMA Fellows are assigned to assist in formulating a work schedule and tracking the progress of the student(s) during the SMA internship. This is done in collaboration with the supervisor from the company involved in the project. Students are required to submit the project dissertation at the end of the internship.

The internship is generally for between 4 to 6 months and carried out from July/August to December each year.

7 Other Administrative and General Information

7.1 SMA Academic Calendar

Each academic year starts in July and ends in the following June. There are three semesters in one academic year, Semester 1 (July – Aug), Semester 2 (Sep – Dec) and Semester 3 (Jan – June).

7.2 Holiday Leave

Masters students are given a holiday leave entitlement of 10 days per calendar year while PhD students have 21 days of holiday leave per calendar year. Unused leave cannot be rolled over to the next academic or calendar year for both coursework and research students. Any leave taken in excess of the entitlement will be treated as unpaid leave and the monthly stipend and allowances will be deducted accordingly.

7.3 Housing Services

Accommodation in Singapore can be arranged through the Office of Student Affairs at NUS or International Student Center at NTU. If you choose to secure your own accommodation, select one which has convenient transport to the university where the lectures are held, bearing in mind that the lectures which are held via video conferencing would take place in the early morning or late evening hours. If you choose to stay at the university on-campus accommodation, you must stay for at least one semester.

7.4 Insurance Schemes

It is mandatory for all students to enrol either in the NUS Group Medical Insurance Scheme (GMIS) or NTU Group Hospital & Surgical Insurance (GHSI) scheme.

7.5 Campus Services

The Office of Student Affairs at NUS and the International Student Center at NTU provide a range of services to international students. The Office of Student Affairs in NUS provides students instant access to service information anytime, anywhere. In addition, students may pose new questions relating to services handled by the NUS Student Service Centre. Please visit: www.askstudentservice.nus.edu.sg.

Details of these services can be found on the websites of the respective university. Regular internal bus services operate within both the campuses. Feeder services are available from the campuses to the Mass Rapid Transit (MRT) stations.

7.6 Student Life in Singapore

Situated almost on the Equator, Singapore enjoys year-round sunshine and temperatures that seldom fall below 22°C. Short, heavy downpours and the occasional deluge are a blessing rather than a nuisance as they refresh the hot and humid atmosphere.

Refuge from the heat is easily available, as most public buildings and public transport are air-conditioned, as are all offices, lecture theatres, laboratories and libraries in the Universities.

The Universities are well connected with the rest of the island. It takes about 30 minutes to reach the main business and shopping areas by bus or by the very efficient MRT (Mass Rapid Transit) system.

Thanks to Singapore's multi-cultural background, Chinese, Malay, Indian and Western food are found in every corner of the island.

The cuisine of a hundred other lands are at hand, attesting to the cosmopolitan nature of Singapore as well as to the "national pastime" of Singaporeans: their passion for good food.

You can obtain more information from http://www.visitsingapore.com/

7.7 International Students: When arriving in Singapore

Each international student admitted to the SMA Programme needs an international passport issued by the government of their country. The passport should be valid for at least one year at the point of admission. International students will have to make their own arrangements and pay for their round-trip travel from their home countries to Singapore.

The Singapore government requires international students of certain nationalities to have entry visas to enter Singapore. Once a student accepts the offer for admission to SMA, the student is required to apply the entry visa online. Once the entry visa request is approved, an 'In Principal Approval' (IPA) letter, which has a validity period for a one-month stay in Singapore, will be sent to the student. The student can then use this letter to enter Singapore without applying for any other travel documents.

It is mandatory for **ALL** international students, irrespective of nationality, to take and pass the medical examination required by ICA. The medical examination can be either taken in your home country or upon arrival in Singapore. We strongly recommend that you take the medical examination in your home country. Details of this will be sent to you together with the offer of admission.

Upon registration at the SMA Office, the IPA letter will be stamped. You will need to bring this to the ICA together with the medical report and relevant documents. You will then be issued a Student's Pass together with a Visit Pass & Disembarkation/Embarkation Card for the entire period of candidature.

7.8 Expenses in Singapore

The table below provides an estimate of expenses that a student could incur while in Singapore.

Item	Estimate in S$
Off-campus housing Rented room (Single) Rented room (Double)	 650-800 pm 450-500 pm
Food Off-campus stalls or university canteens	300-350 pm
Books	300-500 pa
Transport Bus fare	 200 pm
Incidental expenses toiletries, laundry, etc.)	 200-300 pm
Examination Fee Master's/PhD payable once throughout candidature	267.50/535* (NUS) 157.50/210* (NTU)
Acceptance & Student Card payable once throughout candidature	53.50 (NUS)* 63.00 (NTU)*
Other University Fees	~ 210 pa (NUS) ~ 90 pa (NTU)
Contingency	2,500 pm

pm-per month   pa-per annum
* includes GST and is subject to change

7.9 The Singapore Campuses

A vibrant social and cultural scene on both the NUS and NTU campuses complements the atmosphere of serious study in the lecture halls. Students can develop their appreciation for the arts or pursue their own special interests in many ways.

NUS, the campus on the west coast of Singapore, is fast becoming a top-league university. More information on NUS can be found at:
http://www.nus.edu.sg/corporate/about/

NTU has a 200-ha campus in Jurong. NTU, an intelligent campus is paving the way to an era when everyone is just a button away from each other and the rest of the world. More information on NTU can be found at:
http://www.ntu.edu.sg

7.10 Teaching Facilities

Classes are conducted using a combination of face-to-face lectures and state-of-the-art interactive distance learning technology via Internet2. The distance education facilities are located at the Centre for Instructional Technology (CIT), Centre for IT & Application (CITA) at Engineering Faculty at NUS as well as the Centre for Educational Development (CED) at NTU. The beaming of lectures takes place during the early morning or late evening hours to coincide with the time difference between Singapore and Boston. CIT, CITA Engineering and CED are the IT support arms for SMA's interactive distance learning at NUS and NTU.

7.11 Research Facilities

Both NUS and NTU have made their marks as research-intensive universities. The research focus is collaborative and multi-disciplinary. The research undertaken is focused on contributing to Singapore's development as a scientific and technological hub. Research is conducted at the academic departments, research centres and national research institutes to which the SMA Fellows are affiliated. The relevant research facilities at NUS or NTU are generally available to the SMA students registered with that university.

7.12 Student Location

Students work together in the Atheneum, an open learning environment, where each is assigned a cubicle and personal computer.

7.13 Computer Centre/Centre for IT Services

Computer Centre (CC) has built an IT-vibrant environment on campus by continuously strengthening its IT computing and networking infrastructure, upgrading its resources and services to support the academic and administrative goals. It constantly adopts the best and advanced technology, systems and applications which are strategic in maintaining competitiveness. This emphasis has ensured that the university receives nothing short of excellent IT support and services and continues to be a major power house in the development of Singapore as an intelligent island of the new millennium.

At NTU, the Centre for IT Services (CITS) exploits IT to make learning, working and interacting more effective by continuously providing better services. Professional and personal communications are done via the university's electronic highway network.
Both the CC and CITS spearhead the development of an IT-intensive environment on campus and provide a comprehensive computing and networking infrastructure to enable the university community to fully exploit IT for effective teaching, learning, research and administration. Students are encouraged to purchase notebooks through the university Notebook Ownership Scheme.

7.14 Library Facilities

Both the National University of Singapore and Nanyang Technological University have library facilities that offer a rich and diverse collection of materials in various disciplines to encourage and support scholarly pursuits and research activities of the faculty and students. A comprehensive range of services is provided in each library, including loans, online renewal and reservation, inter-library loan, reference service, online information search, document delivery, and the use of audiovisual and microform materials. More information on the libraries can be found at the following websites:

http://libpweb1.nus.edu.sg/web/appmanager/lib/desk
http://www.ntu.edu.sg/library/home/

8 Course Listings

8.1 SMA Graduate Seminar Module

SMA6779 Doctoral Seminar

Modular Credits: 4

Workload: NA-NA-NA-NA-NA

Pre-requisite(s)/Preclusion(s)/Cross-listing(s): Nil

This course is for SMA PhD students and it requires students to 1) attend at least one technical parallel session during the SMA Annual Symposium and 2) present at least 2 seminars on their research during their candidature, excluding the qualifying examination oral and final oral defence but including the SMA Annual Symposium. For each seminar presentation, the abstract, presentation materials (such as Powerpoint file), etc are to be printed and submitted to the SMA Office. Grading is on S/U on the basis of attendance, participation and presentation.

8.2 Advanced Materials for Micro- and Nano-Systems (AMM&NS)

AMN5120 Fundamentals of Semiconductor Device Physics

Modular credits: 4
Workload: 3-1-NA-NA-6
Pre-Requisite: Permission of instructor
Preclusion(s)/ Cross-listing(s): NA
This course will help in providing strong foundation in the area of Semiconductor Devices and Physics. Drift and diffusion of carriers. Generation and recombination. Current continuity equations in semiconductors. Forward and reverse-biased p-n junctions. Current injection. Zener and avalanche breakdown. Ideal and non-ideal metal-oxide-semiconductor capacitors. Structure and operation modelling of metal-oxide-semiconductor field effect transistors and bipolar junction transistors.

AMN5121 Yield, Reliability & Failure Analysis of Microsystems

Modular credits: 4
Workload: 3-1-NA-NA-6
Pre-Requisite: Permission of instructor
Preclusion(s)/ Cross-listing(s): NA
This course provides an understanding in the yield, reliability and failure mechanisms of microsystems. Students would be able to design test plans to determine reliability, for accelerated stress testing, failure analysis and materials analysis of microsystems. Topics include: Overview of yield, reliability and failure mechanisms in Microsystems. Mechanisms of integrated circuit yield loss. Modeling of yield loss mechanisms. Mathematics of failure distributions, reliability and failure rates. Reliability assessment strategies, accelerated stress testing and burn-in screen. Failure analysis methodology. Fault localization and failure identification. Failure mechanisms. Failure analysis tools and techniques. Interconnect reliability. CMOS latchup. Gate oxide and hot-carrier reliability. Packaging-related reliability. Reliability case study on photonics, MEMS and/or BioMEMS Microsystems.

AMN5122 Compound Semiconductors and Devices

Modular credits: 4
Workload: 3-1-NA-1-7
Pre-Requisite: Permission of instructor

Preclusion(s)/ Cross-listing(s): NA
This course introduces the physics, modeling, application, and technology of compound semiconductors (primarily the Ill-Vs) in electronic, optoelectronic, and photonic devices and integrated circuits. The distinguishing feature of compound semiconductors is the wide variety of materials that can be used to form hetrostructures with unique electrical and optical properties. The course introduces material concepts such as strain and bandgap engineering and how they can be utilised to advantage for enhancing the performance of devices. Topics include: properties, preparation, and processing of compound semiconductors; theory and practice of heterojunctions, quantum structures, and pseudomorphic strained layers; metal-semiconductor field effect transistors (MESFETs); heterojunction field effect transistors (HSFETs) and bipolar transistors (HBTs); optoelectronic devices including light emitting diodes, laser diodes, and photodetectors.

SMA5199 Internship Project

Modular credits: 12
Workload: NA-NA-NA-15-20-NA (Total workload: Min of 390 hours over a period of 6 months)
Pre-Requisite(s)/Preclusion(s)/Cross-listing(s): NA
This course provides the opportunity for the student to develop his/her independent research capability by conducting an investigation in a topic under the guidance of supervisor(s). Each student is to research independently on an approved topic under the guidance of Supervisor(s). A Thesis is to be submitted at the end of this course. The work may relate to the following areas: feasibility studies, design work, materials & device characterisation, failure analysis, process course development, stimulation & modelling.

3.205 Thermodynamics and Kinetics of Materials

Modular credits: 4
Workload: 4-NA-NA-NA-8
Pre-Requisite: Permission of instructor
Preclusion(s)/ Cross-listing(s): NA
An MIT subject which provide an understanding in both the thermodynamics and kinetics aspects at the end of the course. The thermodynamics aspect includes laws of thermodynamics, solution theory and equilibrium diagrams. The kinetics aspect includes diffusion, phase transformations, and the development of microstructure. Topics include: Entropy and free energy; Energies of defects; Diffusion-mechanisms; Transition state theory and field effects; Solution theory; Phase diagrams; Nucleation in condensed phases; Interfaces; Crystal growth – atomistics, dendritic growth, solute redistribution and cellular growth; Phase transformation theories; Coarsening; Spinodal decomposition.

3.225 Electronic and Mechanical Properties of Materials

Modular credits: 4
Workload: 4-NA-NA-NA-8
Pre-Requisite: Permission of instructor
Preclusion(s)/ Cross-listing(s): NA
An MIT subject which allows students to learn the roles of bonding, structure (crystalline, defect, energy band, and microstructure), and composition in influencing and controlling physical properties from case studies drawn from a variety of applications including semiconductor diodes, optical detectors, sensors, thin films, biomaterials, composites, and cellular materials. Topics include: Hydrodynamic representation of electrons; Origins of Ohms law; Hall effect; Electron energy bands; Electron waves; Effective mass; Origin of mechanical properties; Basic mechanics concepts; Stress at a point; General tensors; Microscopic and macroscopic aspects of plasticity; Dislocations in structural materials and thin films; Basics of viscoelasticity and creep; Fracture mechanics and micromechanisms; Fatigue damage and failure; Mechanical and electrical properties of semiconductors; Dielectric and optical properties; Coupled electrical/mechanical behaviour and piezoelectricity; Microscopic origin of magnetization; Exchange and ferromagnetism.

3.57 Materials Selection, Design and Economics

Modular credits: 3
Workload: 3-NA-NA-NA-7
Pre-Requisite: Permission of instructor
Preclusion(s)/ Cross-listing(s): NA
An MIT subject which allows students to learn how to use analytical techniques to develop a plan for starting a new materials-related business. Theory and application of systems analysis techniques and

engineering principles for identifying optimal materials, designs and processes for specific applications. Topics include production functions, cost modelling, mathematical optimisation, materials selection algorithms, property charts and performance indices, materials demand modeling.

For MIT courses offered by Department of Materials Sciences and Engineering, please visit: http://ocw.mit.edu/OcwWeb/Materials-Science-and-Engineering/index.htm

8.3 Computational Engineering (CE)

CME5238 Computational Linear Algebra

Modular credits: 4
Workload: 3-1-NA-3-3
Pre-Requisite: Permission of instructor
Preclusion(s)/ Cross-listing(s): NA
Basic subject on matrix theory, linear algebra, and related computations, emphasizing topics useful in other disciplines, including matrix norms, systems of equations, matrix factorizations, orthogonality, least squares problems and the QR algorithm, singular values, eigenvalues, positive definite matrices, and iterative solution methods.

CME5231 Computing Technology and Tools

Modular credits: 4
Workload: 8-NA-6-2-4
Pre-Requisite: Permission of instructor
Preclusion(s)/ Cross-listing(s): NA
This hands-on course gives students from various backgrounds in computing and programming an equal start. Various aspects of computing technology and tools will be covered: such as an introduction to Linux operating system, common software packages, programming methodology, data structure, and algorithmic complexity. The course will cover Mathematica and matlab in some details. It will spend more than half of time on C and C++ programming. It will also give an introduction to Fortran.

CME5232 Cluster And Grid Computing Technologies For Scientific Computing

Modular credits: 4
Workload: 3-NA-3-8-6
Pre-Requisite: Permission of instructor
Preclusion(s)/ Cross-listing(s): NA
The course introduces basic concepts of parallel computing on clusters and the grid and their influence on numerical algorithms that are commonly used in the numerical modeling of large scale engineering simulation and optimization problems. Elements of MPI are covered to enable both cluster and grid implementation of numerical algorithms written in FORTRAN and C on parallel computers in an efficient manner. The advantages and disadvantages of using a parallel programming paradigm like MPI for cluster and grid computing are discussed. Hands-on computational laboratory exercises on selected numerical algorithms and parallel numerical libraries are included to give insight into performance measures and the influence of computer architectures on the programming and performance of selected numerical algorithms.

SMA5233 Particle Methods and Molecular Dynamics

Modular credits: 4
Workload: 2-NA-4-4-4
Pre-Requisite: Permission of instructor
Preclusion(s)/ Cross-listing(s): NA
This course provides an overview of the theory and algorithms that form the basis for molecular modeling at different levels of approximation. Review of Monte Carlo and molecular dynamics simulation techniques: molecular mechanics via empirical force field models. Energy minimization methods and conformational analysis. Quantum simulation techniques. Introduction to particle methods. Introduction to simulation software, e.g. Celrius 2 , insight II, MOPAC, Application examples: structure phase transitions, surfaces, protein simulation, and drug design.

SMA5299 Internship Project

Modular credits: 12
Workload: NA-NA-NA-15-20-NA (Total workload: Min of 390 hours over a period of 6 months)
Pre-Requisite(s)/ Preclusion(s)/ Cross-listing(s): NA
This course provides the opportunity for the student to develop his/her independent research capability by conducting an investigation in a topic under the guidance of supervisor(s). Each student is to research independently on an approved topic under the guidance of Supervisor(s). A Thesis is to be submitted at the end of this course. The work may relate to the following areas: software product, production process, fast algorithm applications, engineered systems, optimisation applications, innovative IT.

6.336J Introduction to Numerical Simulation
Modular credits: 4
Workload: 3-1-NA-NA-6
Pre-Requisite: Permission of instructor
Preclusion(s): NA
Cross-listings: 16.190J, 2.096J (MIT)
This MIT course is an introduction to computational techniques for the simulation of a large variety of engineering and engineered systems. Applications are drawn from aerospace, mechanical, electrical, and chemical engineering, as well as materials science and operations research. Topics include mathematical formulations; network problems; sparse direct and iterative matrix solution techniques; Newton iteration for nonlinear problems; solution techniques for eigenvalue problems; discretisation methods for ordinary differential equations and differential-algebraic equations; discretisation methods for partial differential and stochastic partial differential equations; methods for the solution of integral equations; and Monte Carlo techniques and higher dimensional problems.

15.093J Optimization Methods
Modular credits: 4
Workload: 3-1-NA-NA-6
Pre-Requisite: Permission of instructor
Preclusion(s): NA
Cross-listing: 2.098J (MIT)
This MIT course is an introduction to the principal methods for linear, network, discrete, nonlinear optimisation, as well as dynamic optimisation and optimal control. Emphasis is on methodology and the underlying mathematical structures and their connection to computational procedures. On completing this course, one will be in a position to formulate interesting optimization problems in various application areas, judge whether these problems are tractably solvable, and be able to solve them using appropriate techniques.

16.920J Numerical Methods for Partial Differential Equations
Modular credits: 4
Workload: 3-1-NA-NA-6
Pre-Requisite: Permission of instructor
Preclusion(s): NA
Cross-listing: 2.097J (MIT)
This MIT course covers the fundamentals of modern numerical techniques for a wide range of linear and nonlinear elliptic, parabolic, and hyperbolic partial differential and integral equations. Topics include: mathematical formulations; finite difference, finite volume, finite element, and boundary element discretisation methods; and direct and iterative solution techniques. The methodologies described form the foundation for computational approaches to engineering systems involving heat transfer, solid mechanics, fluid dynamics, and electromagnetics. Computer assignments requiring programming.

For MIT courses offered by Computation for Design and Optimization, please visit: http://web.mit.edu/cdo-program/curriculum/index.html

8.4 Manufacturing Systems and Technology (MST)

MST6320 Finite Element Method: Technique and Applications
Modular credits: 4
Workload: 2-1-3-3-11
Pre-Requisite: Permission of instructor

Preclusion(s)/ Cross-listing(s): NA
The basic concepts for finite element method and the theoretical framework for the formulation of finite elements are discussed, which includes interpolation and shape functions, numerical integration, stiffness matrix, calculation of stresses and strains, and the application of boundary conditions etc. Various modelling techniques are presented and they are illustrated by case studies in a variety of disciplines. The limitations and traps of FEM are highlighted. Hand-on experience using a commercial FEM package is provided. Practical experience is gain through laboratory and project work.

MST6328 Product Design and Development
Modular credits: 4
Workload: 3-NA-3-4-NA
Pre-Requisite(s)/Preclusion(s): NA
Cross-listing: 2.739J (MIT)
This course covers modern tools and methods for product design and development. The cornerstone of this subject is a project in which terms of management, engineering and industrial design students conceive, design, and prototype a physical product. Class sessions are conducted in workshop mode and employ cases and hands-on exercise to reinforce key ideas.

MST6399 Independent Research Project
Modular credits: 12
Workload: NA-NA-NA-15-20-NA (Total workload: cover a period of 4 months)
Pre-Requisite: Permission of instructor
Preclusion(s)/ Cross-listing(s): NA
This course provides the opportunity for the student to develop his/her independent research capability by conducting an investigation in a topic under the guidance of supervisor(s). Each student is to research independently on an approved topic under the guidance of Supervisor(s). A Thesis is to be submitted at the end of this course. The projects will be chosen to explore innovations in technology, systems and business strategy. These would be in the disciplines of: materials and processes for production, process equipment and tooling, equipment automation and control, metrology and quality control, design for manufacturing, factory system design and control and supply chain design and coordination.

2.830 Control of Manufacturing Processes
Modular credits: 4
Workload: 3-NA-NA-6-3
Pre-Requisite: Permission of instructor
Preclusion(s)/ Cross-listing(s): NA
The objective of this MIT subject is to understand the nature of manufacturing process variation and the methods for its control. First, a general process model for control is developed to understand the limitations a specific process places on the type of control used. A general model for process variation is presented and three methods are developed to minimize variations: Statistical Process Control, Process Optimization and in-process Feedback Control. These are considered in a hierarchy of cost-performance tradeoffs, where performance is based on changes in process capability.

15.762 Supply Chain Planning and Design

Modular credits: 4
Workload: 3-1-NA-NA-12
Pre-Requisite(s)/Preclusion(s): NA
Cross-listing: 15.763 (MIT)
The MIT course provides ways to plan and design manufacturing systems and supply chains, with exposure to key tradeoffs and tactics such as inventory, flexibility, risk pooling, batch sizing. Supply chain planning: network inventory models, flow planning, system dynamics, impact of variability and constraints and tactical counter measures, value from supply chain integration for various network topologies and for various market contexts. Manufacturing system design: integration with product development, capacity planning and flexibility, network location decisions, impact of product variety, impact of short product life cycles, make-buy and supplier choice decisions.

For MIT courses offered by Department of Mechanical Engineering, please visit: http://ocw.mit.edu/OcwWeb/web/courses/courses/index.htm#MechanicalEngineering

8.5 Computation and Systems Biology (CSB)

SMA5301 Computation and Systems Biology
Modular credits: 4
Workload: 3-2-NA-3-4
Pre-Requisite: Permission of Instructor
Cross-listing: 7.548J /BE400 (MIT)
Preclusion(s): NA
Develops and applies scaling laws, the methods of continuum mechanics and computational models to biomechanical and biochemical phenomena over a range of length scales. Topics include: structure of tissues and the molecular basis for macroscopic properties; chemical and electrical effects on cellular behavior; cell mechanics, motility and adhesion; biomembranes; biomolecular mechanics and molecular motors. information processing in cells. Experimental methods for probing structures at the tissue, cellular, and molecular levels.

SMA5302 Optical Microscopy and Spectroscopy for Biology and Medicine
Modular credits: 4
Workload: 3-NA-NA-4-3
Pre-Requisites:18.03 and 7.012 or permission of instructor
Cross-listings:2.996J/BE949J (MIT)
Preclusion(s): NA
Introduces the theory and the design of optical microscopy and its applications in biology and medicine. The course starts from an overview of basic optical principles allowing an understanding of microscopic image formation and common contrast modalities such as dark field, phase, and DIC. Advanced microscopy imaging techniques such as total internal reflection, confocal, and multiphoton will also be discussed. Quantitative analysis of biochemical microenvironment using spectroscopic techniques based on fluorescence, second harmonic, Raman signals will be covered. We will also provide an overview of key image processing techniques for microscopic data.

SMA5303 Advanced Statistical Theory and Data Mining
Modular credits: 4
Workload: 3-NA-NA-3-5
Pre-Requisites: Permission of instructor
Cross-listings:15.076 and 15.077 (MIT) half-semester courses
Preclusion(s): NA
Introduction to the theory of statistics, concentrating on techniques used in management science, finance, and biology. Primarily for PhD, SM, and MBA students with good backgrounds in probability and matrix algebra. Topics: sampling; theory of estimation; testing; nonparametric statistics; analysis of variance; categorical data analysis; and regression analysis. S+, SAS, Matlab or similar package used for statistical computing.

Supervised statistical learning and multivariate analysis, concentrating on methods most often used in management science, finance, and biology. Topics selected from: multiple and multivariate regression; logistic regression; principal components and dimension reduction; discrimination and classification analysis; trees; partial least squares; nearest neighbor and regularized methods; support vector machines; boosting and bagging; and nonparametric regression. S+, SAS, Matlab or similar statistics package used for data analysis and data-mining.

SMA5304 Biomedical Information Technology
Modular credits: 4
Workload: 4-NA-NA-2-7
Pre-Requisites: Experience with web-based computing, experience with programming languages (Java, C++, C etc.)
Cross-listings: BE453J, 2.771J/20.453J/HST.958J (MIT)
The objective of this subject is to teach the design of contemporary information systems for biological and medical data. These data are growing at a prodigious rate, and new information systems are required. This subject will cover examples from biology and medicine to illustrate complete life cycle information systems, beginning with data acquisition, following to data storage and finally to retrieval and analysis. Design of appropriate databases, client-server strategies, data interchange protocols, and computational modeling architectures will be covered. Students are expected to have some familiarity with scientific application software and a basic understanding of at least one contemporary programming language (C, C++, Java®, Lisp, Perl, Python, etc.).

7.63 Immunology
Modular credits: 4
Workload: 3-NA-NA-NA-7
Pre-Requisites: Permission of Instructor
Cross-listings: NA
Principles of immunology, including immunochemistry and developmental, cellular, and molecular immunology. An in-depth critical analysis of current literature in the field. Particular attention is paid to the function of the immune system as a whole as studied by modern methods and techniques. Discussions of original papers and team projects supplement lectures.

7.82 Topics of Mammalian Development and Genetics
Modular credits: 4
Workload: 3-NA-NA-2-5
Pre-Requisites: Permission of Instructor
Cross-listings: NA
Seminar covering embryologic, molecular, and genetic approaches to development in mice and humans. Topics include preimplantation development; gastrulation; embryonic stem cells, gene targeting and nuclear cloning; genomic imprinting; X-inactivation; sex determination; germ cells; association and linkage analysis.

7.95 Cancer Biology
Modular credits: 4
Workload: 2-NA-NA-4-4
Pre-Requisites: 7.03 and 7.05
Cross-listings: NA
Intensive analysis of historical and current developments in cancer biology. Topics covered in lecture and through critical reading of relevant literature include: principles of transformation, viral and cellular oncogenes, tumor suppressor genes, tumor cell growth, apoptosis, principles of cancer biology, and cancer genetics.

6.555J Biomedical Signal and Image Processing
Modular credits: 4
Workload: 2-NA-2-3-3
Pre-Requisites: 6.003 or 2.003 or 16.040 or 18.085
Cross-listings: 16.456J
This course presents the fundamentals of digital signal processing with particular emphasis on problems in biomedical research and clinical medicine. It covers principles and algorithms for processing both deterministic and random signals. Topics include data acquisition, imaging, filtering, coding, feature extraction, and modeling. The focus of the course is a series of labs that provide practical experience in processing physiological data, with examples from cardiology, speech processing, and medical imaging. The labs are done on Athena in MATLAB® during weekly lab sessions that take place in an electronic classroom. Lectures cover signal processing topics relevant to the lab exercises, as well as background on the biological signals processed in the labs.

6.807, Computational and Functional Genomics
Modular credits: 4
Workload: 2-NA-2-3-3
Pre-Requisites: 6.003 or 2.003 or 16.040 or 18.085
Cross-listings: 7.28 or Permission of instructor
Study and discussion of computational approaches and algorithms for contemporary problems in functional genomics. Topics include biological complexity, genome structure and function, high-throughput experimental data, data normalization, data representation, gene clustering, statistical network models, continuous dynamic models, statistical metrics for model validation, model elaboration, experiment planning, and the computational complexity of functional genomics problems. Meets with graduate subject 6.874J, but assignments differ.

BE481 Fundamental Limits of Biological Measurements
Modular credits: 4
Workload: 3-NA-3-2-2
Pre-Requisites: 6.003 or 2.003 or 16.040 or 18.085
Cross-listings: 7.86 and MAS.866J
Introduction to physical principles that govern the ultimate limits for measuring force, charge, and optical signals in biological systems. Lecture material will be motivated by recent experiments in three

areas of biology: detecting single molecule forces, engineering biomolecular microarrays, and imaging cells with fluorescent probes. Topics include wave theory, diffraction and imaging, equipartition theorem, dissipative systems, and noise analysis. Lab modules cover DNA manipulation, force spectroscopy and single molecule measurements. Parallel introductory tracks will be offered to accommodate students with both engineering and biology backgrounds.

6.524J Molecular & Cellular Tissue Biomechanics
Modular credits: 4
Workload: 3-NA-NA-5-2
Pre-Requisites: 7.012 and 2.002 or 2.006 or 6.013 or 6.014 or 10.301 or 10.302
Cross-listings: 2.798J, 3.971J, 10.537J, BE.410J
Develops and applies scaling laws and the methods of continuum mechanics to biomechanical phenomena over a range of length scales. Topics include: structure of tissues and the molecular basis for macroscopic properties; chemical and electrical effects on mechanical behavior; cell mechanics, motility and adhesion; biomembranes; biomolecular mechanics and molecular motors. Experimental methods for probing structures at the tissue, cellular, and molecular levels.

For information on Computation Systems and Biology, please visit: http://csbi.mit.edu:8080/infoglueDeliverWorking/Education/Program_Structure#curr

8.6 Chemical and Pharmaceutical Engineering (CPE)

SMA5430 Kinetics of Chemical & Biological Systems
Modular credits: 4
Workload: 3-1-NA-5-3
Pre-Requisite: A degree in Chemical Engineering or by permission of instructor
Preclusion(s)/ Cross-listing(s): NA

The module focuses on a comprehensive treatment of the kinetics of complex chemical reactions, physical processes, and biological processes. It begins with a fundamental analysis of reaction order in homogeneous reactions and proceeds with the kinetics of heterogeneous systems and catalytic reactions. Methods of measuring and calculating reaction rate constants will be included. After a basic stoichiometric analysis of biological reaction networks, the course will discuss kinetics of enzymatic reactions and extensions to kinetic characteristics of reaction pathways and bioreaction networks. Similarities and differences between chemical and biological kinetics are discussed along with concepts of rate-limiting steps and distribution of control among several reactions in a pathway. The course concludes with applications to the kinetic analysis of chemical and biological reaction systems in the chemical and pharmaceutical industries.

SMA5431 Systems Engineering
Modular credits: 4
Workload: 3-NA-NA-3-6
Pre-Requisite: A degree in Chemical Engineering or by permission of instructor
Preclusion(s)/ Cross-listing(s): NA

The course has been designed as an introduction to the elements of systems engineering and its application to the chemical engineering academic or industrial research and practice. The 'Systems Approach' is introduced as a basic paradigm for solving complex engineering problems, and emphasis is placed on developing skills in problem formulation, system synthesis, and use of analytical tools. Some of the topics to be presented include: graph theory as applied to systems engineering problems, sequential modular and equation oriented process modelling tools (Aspen Plus, ABACUSS II), mathematical systems and control theory, treatment of data and experimental design, generation of models from data, and optimization theory and algorithms. Application of these methodologies and tools will be illustrated with a series of case studies involving steady-state and dynamic process simulation, control system synthesis, new product and process design, plant wide diagnosis and planning, formulation and decomposition of large scale problems, and systems biology.
CN6999 Doctoral Seminar
Students have to satisfy the seminar requirements set by Department of Chemical and Biomolecular Engineering. Students have to 1) attend at a minimum of 6 Postgraduate seminars per semester (up to 6 semesters for PhD) 2) satisfactory performance at the 1-day Presentation Skills Workshop 3) attend 2 seminars on Lab Safety organized by the Department 4) attend 1 seminar on Scientific Report Writing and Ethics in Research 5) Attend Lecture Series on Research Ethics 6) present at least 2 seminars on your research during your candidature, excluding the Qualifying Examination oral

and final oral defence but including the SMA Annual Symposium. For each seminar presentation, the abstract, presentation materials (such as Powerpoint file), etc are to be printed and submitted to the SMA Office.

The seminar requirement for point 1 includes attendance of MIT seminars and SMA Annual Symposium. It also includes attendance for Oral Defence held by Department of Chemical and Biomolecular Engineering.

10.34 Numerical Methods Applied to Chemical Engineering
Modular credits: 3
Workload: 3-NA-NA-NA-9
Pre-Requisite: Permission of instructor
Preclusion(s)/ Cross-listing(s): NA
This MIT course focuses on the use of modern computational and mathematical techniques in chemical engineering. It introduces mathematical analysis, numerical methods, probability and statistics, solving partial differential equations. Starting from a discussion of linear systems as the basic computational unit in scientific computing, methods for solving sets of nonlinear algebraic equations, ordinary differential equations, and differential-algebraic (DAE) systems are presented. Probability theory and its use in physical modeling is covered, as is the statistical analysis of data and parameter estimation. The finite difference and finite element techniques are presented for converting the partial differential equations obtained from transport phenomena to DAE systems. The use of these techniques will be demonstrated throughout the course in the Matlab® computing environment.

10.40 Chemical Engineering Thermodynamics
Modular credits: 4
Workload: 4-NA-NA-NA-8
Pre-Requisite: Permission of instructor
Preclusion(s)/ Cross-listing(s): NA
This MIT course aims to connect the principles, concepts, and laws/postulates of classical and statistical thermodynamics to applications that require quantitative knowledge of thermodynamic properties from a macroscopic to a molecular level. Basic postulates of classical thermodynamics. Application to transient open and closed systems. Criteria of stability and equilibria. Constitutive property models of pure materials and mixtures emphasizing molecular-level effects using the formalism of statistical mechanics. Phase and chemical equilibria of multicomponent systems. Applications emphasized through extensive problem work relating to practical cases.

10.50 Analysis of Transport Phenomena
Modular credits: 4
Workload: 4-NA-NA-NA-8
Pre-Requisite: Permission of instructor
Preclusion(s)/ Cross-listing(s): NA
This MIT course introduces concepts of mass transfer, heat transfer and fluid mechanics for chemical engineers. Unified treatment of heat transfer, mass transfer, and fluid mechanics, emphasizing scaling concepts in formulating models and analytical methods for obtaining solutions. Topics include conduction and diffusion, laminar flow regimes, convective heat and mass transfer, and simultaneous heat and mass transfer with chemical reaction or phase change.

For MIT courses offered by Department of Chemical Engineering, please visit: http://ocw.mit.edu/OcwWeb/Chemical-Engineering/index.htm