AIMS Structured Master's Programme in Mathematical Sciences

AIMS as a learning environment

An AIMS center provides a holistic learning environment. The intensity and the high pace of the academic program permeate all that transpires at the center. The around-the-clock availability of resources such as IT equipment, library and study space makes learning a constant option. Human interactions, including high lecturer availability, a carefully selected pan-African student body and individualized tutor attention, promote mature discussions around science as well as students' current and future endeavors.

Notably, while students acquire mathematical tools that enable them to pursue their interests, they also learn the empowering processes of problem solving and research, of networking and of recognizing opportunity. Furthermore, all basic needs, such as accommodation, commutes and meals, are fully catered for by the AIMS center, allowing students to focus fully on their academic pursuits. AIMS students typically embrace their courses with curiosity and keen interest. Should they encounter difficulties or need extra support, lecturers and tutors provide it.

Structure of Academic Program

The academic year at AIMS centers consists of three phases: the skills, review, and research phases. The skills and review phases are each divided into modular blocks, each block being three weeks in duration. The skills phase normally consists of three such blocks. All of the courses in the skills phase are compulsory because they are designed to ensure that all students are prepared and equipped with the tools required to take full advantage of the review courses that follow. The review phase consists of six three-week blocks and students must, with one exception, choose two courses from typically three options in each block. Over an 18-week period, a student thus normally completes eleven review courses.

Following the completion of the skills and review phases, the students carry out an individual research project lasting 10 weeks. The research phase ends with the students presenting the findings of their research project in a written report as well as orally in front of an examination committee. The academic year at AIMS ends with a graduation ceremony, at which successful students are granted the degree of Master of Science in Mathematical Sciences. A flowchart describing the program is shown below.

The academic program at each AIMS center is enriched through partnerships with local and international universities. These partnerships ensure that the academic program at each center is of the highest standard and integrated with undergraduate and Masters' courses of host country universities and connected to local postgraduate research opportunities, African networks and the global science community.

One-Year Structured Master's Program in Mathematical Sciences

Skills Courses (3 Months) ➢	Review Courses (5 Months) ➢	Research Phase (3 Months) ➢	Assessment ➢	Graduation
Mandatory foundational skills courses in mathematical and physical problem solving, computer skills and programming, mathematical modelling and data analysis, language and professional communication, and introduction to employability, entrepreneurship, and business skills.	Eleven courses selected from about 18 cutting-edge courses offered in mathematical sciences theory and applications and interdisciplinary topics such as financial mathematics and climate modelling. Language, communication and entrepreneurship training continues.	Students conduct individual research projects, involving some original research, on a topic chosen from an approved list of proposals offered by lecturers from local partner institutions, international scientists and industry. Each student writes a scientific report (mini-thesis) at end of Research Phase.	Students are continuously assessed throughout the program. Students present their individual research projects and defend them orally in front of external and internal examiners.	Graduates proceed to: • Internships • Job placements • Research work • Research Master's programs • PhD programs
← Weekly events and workshops that enrich learning →				

Teaching-Learning Model at the AIMS Centre

The AIMS teaching-learning model enables students to achieve the intended learning outcomes of the curriculum for the Master's programme. The context in which students learn at AIMS—the learning resources, the learning environment, the teaching team, and the student body—is unique. Combined, these factors promote both personal and academic development of AIMS students. The special features of the AIMS model can be described in four areas, as follows.

A. Our students

Each year the Master's programme at every AIMS center attracts hundreds of applications from all over Africa. Only the best-prepared applicants are selected for the programme, resulting in classes of students who are highly accomplished and motivated to succeed and advance themselves. The student selection process considers academic merit, experience, gender, subject major, nationality and cultural background of each student, yielding a pan-African, multicultural student body. Students with strong interest in mathematics but with few opportunities to shine are also considered in the process. Each student accepted for the programme possesses, as a minimum, a four-year Bachelor's or corresponding degree in mathematics or any science or engineering subject with a substantial mathematics component.

Bringing together a group of talented and highly-motivated students from all over Africa creates a very special environment. This educational situation spurs students to discuss and think about African development and various ways that they, as independent thinkers and mathematicians, can contribute to solving societal problems, expanding scientific knowledge and scientifically sound development across the continent. Students become part a growing dynamic network and, after graduation, a vibrant alumni community.

B. Our lecturers

All AIMS centers engage volunteer lecturers, selected from a pool of leading local and international scientists, recognized for their teaching abilities, to teach three-week courses. Every year, approximately 25 lecturers generously make themselves available to teach at each AIMS center, providing students with cutting-edge knowledge in their own respective field of specialization. As lecturers are not constrained by a fixed curriculum they are free to tailor their courses to maximize benefits to students. Each three-week course therefore is unique.

Furthermore, many lecturers seek to return to AIMS because they enjoy the special teaching environment and the enthusiasm of the students. The lecturers teach a wide range of mathematical and physics subjects and applications, many of them involving scientific computing using open-source software. Students thus encounter a range of topics, which enables them to make informed choices as to their future career direction.

The AIMS network has accumulated a database of several hundred lecturers from the global scientific community who have volunteered to teach at AIMS. Access though lecturers to the larger scientific community has helped many AIMS graduates in their careers, leading to post-graduate and research opportunities.

AIMS encourages lecturers from overseas to co-lecture, either by bringing a junior colleague or collaborator, or by partnering with a lecturer from an institution close to the AIMS center. Co-lecturing increases student-lecturer

exposure, and can strengthens local partnerships while also contributing to local capacity building.

Teaching-Learning Model at AIMS Centre, *continued*

C. Our teaching and learning environment

The teaching methodology is learner-centered. Classes at AIMS, in comparison with most formal lecture courses, are highly interactive and time is allocated for class discussions. In this way, AIMS provides a climate of inquiry and encourages collaboration. AIMS teaching philosophy is to promote critical and creative thinking, to experience the excitement of learning from true understanding, and to avoid rote learning directed only towards assessment.

Lecturers help and encourage students to develop their own ideas, both during and outside formal class times, and inspire them to absorb and test new ideas instead of presenting them with the finished product. The challenge for the lecturers is to create a sense of enquiry in all students who come from very diverse backgrounds. Each student should develop, and succeed, from their own particular starting point. AIMS considers the journey undertaken to reach a conclusion to be as important as the conclusion itself.

Resident tutors/teaching assistants help lecturers in their teaching and give students continuous support, responding to their personal needs, throughout the year. Teaching assistants attend the lecture courses, arrange tutorials if need arises, assist with the marking of assignments, provide assistance to foreign language speakers, and assist the students with computing and research project writing. During the evenings, the tutors also provide guidance to students with completing their assignments.

In-house resources at each center include academic directors who develop the program and coordinate and oversee its implementation. They also monitor continuously the progress of each student to ensure that anyone who needs extra support receives it promptly. A center also has dedicated language teachers who teach students English and French as needed and also teach communication skills throughout the year. Each centers also has an IT-manager who supports students in the IT-lab.

The small student groups and the residential nature of the AIMS environment are conducive to a high degree of human interaction. This arrangement allows far greater contact time between lecturers and students than is possible in a typical university setting. The arrangement maximizes the students' contact with lecturers and tutors; provides constant access to high-quality computers, internet, and library resources; and fosters a strong community within which students develop strong personal and professional networks, gain confidence in their academic abilities, and develop a better understanding of development problems faced by African countries and the need to solve them.

In addition to the courses taught, the learning is continually enriched with programming that conveys non-compulsory technical or career-preparatory skills, science-culture knowledge, visits to local industries. These components of the program serve to inspire, capacitate and contribute to a culture of motivation and openness to opportunity.

Teaching-Learning Model at AIMS Centre, *continued*

D. The curriculum

The AIMS curriculum is designed to foster well-rounded scientists. Students typically come to AIMS well trained. The courses at AIMS not only add to students' knowledge but also demonstrate how to apply their scientific abilities to a variety of problems. For many students, the courses at AIMS have an unlocking effect, the knowledge gained during many years of prior training suddenly becomes useful. Each year, the staff at AIMS centers, supported by their respective academic advisory committees, develop the course program. Topics that are relevant to national and regional needs are considered when designing the course program.

The courses illustrate how mathematical theory can be applied to solve problems and thus to address some of the African continent's most pressing development challenges. On the whole, the learning activities at AIMS are designed to develop the skills young scientists need to become the researchers, innovators, and problem-solvers of tomorrow engaged in private and public sectors, academia, business and civil society in Africa and globally. The curriculum required for earning the one-year structured Master's degree in mathematical sciences runs over three phases as described below.

SKILLS PHASE (9-10 WEEKS)	**REVIEW PHASE** (18 WEEKS)	**RESEARCH PHASE** (12 WEEKS INCLUDING EXAMS)
Skills courses are designed to: ▪ provide introductory and foundational material to the students in preparation for the rest of the year; ▪ train students in mathematical and physical problem solving using a wide range of mathematical and computing methods; ▪ provide a working knowledge of mathematics, physics and selected topics; ▪ provide training in mathematical modelling and data analysis; ▪ provide training in language and professional communication (scientific writing in English and when appropriate French); and ▪ introduce students to career development activities such as skills for employment and entrepreneurship. All skills courses are compulsory and structured to achieve pre-defined outcomes, with limited flexibility in their content.	The review phase encompasses six three-week blocks. Students are required to complete two out of typically three course options offered in each block. Each student thus completes a total of 12 review courses. The review phase offers variety and flexibility and thus is rather different from the skills phase. The review courses include a wide range of fundamental and applied subjects and are flexibly designed. The courses offered in each block will be balanced with respect to focus on mathematics, physics, interdisciplinary and applied content. Topics may, for example, include computational algebra, mathematical biology, and quantum theory. The review courses have career-preparatory content as applicable.	Students work for 10 weeks on a research project, which is proposed and supervised by a local lecturer, possibly jointly with an international scientist. Each student then prepares a scientific report (mini-thesis) summarizing the project findings and presents them orally in front of an examination committee at the end of the academic year. Students are not expected to do original work to achieve a passing grade. However, to receive the grade of *Pass with Distinction*, the research project should qualify as the basis of a Research Master's thesis. For example, it could be publishable in a scientific journal, or form an outstanding introduction to the field that could be used by other students entering the area. During the research phase, targeted communication skills and computing classes may continue, at the lecturers' and tutors' discretion. The purpose of the research project is: ▪ to give students the opportunity to work with an expert supervisor on a research project; ▪ to go through the process of independently reviewing, understanding and explaining scientific or mathematical material; ▪ to optionally do experiments — using a computer or otherwise — and report the results; and ▪ to write a scientific report.

E. Assessment

The academic assessment of students for the AIMS Structured Master in Mathematical Sciences is completed in three ways:

(i) Continuous assessment through written assignments, tutorial sessions, short tests and presentations requested by the lecturers;

(ii) A written report of a research project that the student is required to present orally to a panel of examiners, including the local AIMS center director, academic director, the project supervisor, a teaching assistant and external examiners.

(iii) Integrated assessment - a portfolio for each student is compiled, containing the grades achieved for each of the courses attended as well as observations on their presentations, all their assignments, completed exercises and their final research project.

In the following section, the overall expectations and intended learning outcomes of the curriculum are summarized.

Overall Expectations and Intended Learning Outcomes of the AIMS Curriculum

By the end of the One-Year Structured Master's Programme in Mathematical Sciences, students should be able to:

A. Reasoning and Research Skills

1. Apply theory to the problem under scrutiny using intuition regarding the physical laws of nature and through computer work.
2. Demonstrate the skills of a well-rounded scientist, capable of thinking critically and creatively, solving problems, and being innovative in finding new ways and approaches to solving problems.
3. Demonstrate that they can apply the necessary tools for continued research in the mathematical sciences as well as for decision making and policy analysis.
4. Perform the steps of the research process including conducting literature reviews, searching for relevant information, and following ethical norms in research and writing.

B. Pure and Applied Mathematics

5. Demonstrate a comprehensive and focussed knowledge and understanding in one or more specialisations in the mathematical sciences.
6. Describe and explain the scope and limitations of scientific measurement and data, together with relevant notions of error, dispersion and reliability.
7. Perform problem formulation, estimation, prioritization, and generally applicable mathematical and computing methods, and to write clear and concise scientific reports.
8. Apply mathematical techniques to solve real-world problems using, for example, differential equations, mathematical statistics, probability, or mathematical modeling.
9. Apply simple ideas and models to complex problems as first approximations.
10. Use mathematical modelling as a tool to solve problems in the natural sciences (such as physics and biology), engineering disciplines (such as computer science) and social sciences (such as finance and economics).
11. Appreciate the indivisibility of knowledge in the modern mathematical sciences and its embodiment in interdisciplinary work.
12. Explain the nature and use of analytical, numerical, physical (scale) and statistical models in science.
13. Assemble mathematical models of selected natural systems, evaluate those models by comparison with data, and explore the behaviour of those systems using the model.
14. Apply probability theory and statistical inference to a variety of situations.

C. Computer Technology

15. Use appropriate software packages such as visualization software or statistical packages, to solve problems, test conjectures, or visualize concepts.
16. Analyze a problem, and identify and define the computing requirements appropriate to its solution.

Overall Expectations and Intended Learning Outcomes of the AIMS Curriculum, *continued*

D. Communications

17. Demonstrate oral and written skills that are appropriate to the level expected of professional mathematicians.
18. Read and understand basic technical mathematics, and present mathematical ideas (to expert, as well as general audiences) in a coherent, literate fashion, both orally and in writing.
19. Demonstrate a working knowledge of English (and when appropriate French) and write a scientific report.
20. Perform as inter-cultural communicators, drawing on their experience of interactions within a diverse student body and with international lecturers and tutors.

E. Personal and Career Development

21. Perform as self-educators and self-directed learners who can teach themselves from original source material, critically evaluate literature and evidence, cope with contradictions and make scientifically defensible judgements.
22. Describe and discuss development issues in Africa and specify ways that they could use their mathematical knowledge and skills to solve development problems faced by African countries (e.g., food production, climate change, education failings, diseases, management of natural resources and other facets of economic development).
23. Discuss, from an ethical perspective, the implications of how one uses scientific knowledge and how to assess whether the consequences of one's work are ethically defensible.
24. Discuss scientific misconduct and explain how plagiarism is a serious breach of publication ethics.
25. Explain and discuss the responsibilities of citizens in a democratic society and the role that they must play in building a better society and civic governments.
26. Demonstrate important personal management and teamwork skills such as organizing and managing time responsibly and working effectively with others in teams and projects.
27. Identify career and employment opportunities in mathematical sciences in all areas of government, business, and industry.
28. Explain and discuss the importance of acquiring employability skills as preparation to gain employment in the world of business or to work in industry
29. Explain what skills and actions are needed to become a successful entrepreneur and prepare a business plan to launch, finance, and market an innovative product or service in the marketplace.
30. Recognize and pursue opportunities for both conducting research and initiating entrepreneurial activities that can better the livelihood of people
31. Demonstrate that they have developed selected professional development and entrepreneurial skills and attributes required to succeed in business or industry.