FEDERAL UNIVERSITY OF TECHNOLOGY OWERRI

AFRICA CENTRE OF EXCELLENCE IN FUTURE ENERGIES AND ELECTROCHEMICAL SYSTEMS (ACE-FUELS)

Handbook for Master of Science (MSc) Degree Programmes

ACE FUELS
Africa Center of Excellence in Future Energies & Electrochemical Systems

ACE-FUELS: HANDBOOK FOR MSc PROGRAMMES

TABLE OF CONTENTS

PREAMBLE

Name of Centre	**African Centre of Excellence in Future Energies and Electrochemical Systems (ACE-FUELS)**
Host Institution	Federal University of Technology Owerri
Institutional Address	FUTO Main Campus Owerri Nigeria
Head of Institution 	Name: Nnenna N. Oti Position/Title: Professor/**Vice Chancellor** Tel. # +234 670 7074 Email: vc@futo.edu.ng
Head of Centre 	Name: Emeka E. Oguzie Position/Title: Professor/ **Centre Leader** Tel. # +234 803 7026581 Email: emeka.oguzie@futo.edu.ng
Deputy Head of Centre 	Name: Chinyere A. Madu Position/Title: Professor/ **Deputy Centre Leader** Tel. #: +234 803 3469304 Email: cadamadu@futo.edu.ng

A WELCOME MESSAGE FROM THE CENTRE LEADER

It is a great pleasure to welcome you to the Africa Centre of Excellence in Future Energies and Electrochemical Systems (ACE-FUELS) at the Federal University of Technology Owerri, Nigeria (FUTO). I hope that you find the information you require and gain a good grasp of the breadth and scope our activities in this programme-specific Handbook, which forms part of the information kit, accessible from the Students Resources link on the Centre website (https://acefuels-futo.org/students-resources/). Other very necessary information resources therein include the ACE-FUELS Sexual Harassment Policy, ACE-FUELS Scholarship Policy, Handbook for English Language Support Programme, Regulations Governing Postgraduate Studies in FUTO (including student discipline and misconduct, on-campus residency rules and regulations). I urge you to study and familiarize yourselves with the content of these information resources and to seek clarifications where necessary.

Right from inception, we have focused on building partnerships with national, regional and international knowledge networks, in order to evolve novel technologies and approaches, which optimally engage local and regional scientific talents, while linking global expertise. I thus have no doubt that our researchers and partners possess the expertise and experience to train you to become highly motivated and result-oriented postgraduate students, with capacity to deliver meaningful solutions to technological problems and needs of the society in a timely manner. We have involved our industry and sectoral stakeholders in design, implementation and evaluation of all Centre activities and to appropriately set up our education, training and research agendas, in order to optimally attain our goals of training industry-ready and entrepreneurial postgraduate students. I therefore encourage you all to take advantage of the academic and cultural diversity within FUTO to enrich your postgraduate experience.

We at ACE-FUELS are committed to your continued wellbeing and comfort and have assigned dedicated staff to provide academic, technical, administrative and social assistance to all students at all times. Phone and email contacts of the relevant officers have been provided in this Handbook to enable you always identify and reach the support personnel.

Welcome to ACE-FUELS @ FUTO! Welcome to our learning community!

Prof. Emeka E. Oguzie,
Centre Leader, ACE-FUELS
Tel: +234 803 7026581
Email: emeka.oguzie@futo.edu.ng

1. GENERAL INFORMATION

Centre Website: www.acefuels-futo.org
Email: info@acefuels-futo.org

1.1 Key Contacts at ACE-FUELS

Role	Name	Email	Mobile
Centre Leader	Prof. E.E. Oguzie	emeka.oguzie@futo.edu.ng	08037026581
Deputy Centre Leader	Prof. C.A. Madu	cadamadu@futo.edu.ng	08033469304
M&E Officer	Prof. N.V. Ogueke	nvogueke@futo.edu.ng	08053006458
Research Coordinator (PhD)	Prof. S.O. Onyekuru	sam.onyekuru@futo.edu.ng	08037175256
Research Coordinator (MSc)	Dr. K.L. Oguzie	Kanayo.oguzie@futo.edu.ng	08037069183
Administrative Team Lead	Mrs. Chinwe Appiah	uju.udedibie@futo.edu.ng	08033572585
Project Coordinator	Mr. C.E. Nwadike	chijioke.nwadike@futo.edu.ng	08035701517
Project Coordinator 2	Dr. C.I. Ikerionwu	charles.ikerionwu@futo.edu.ng	08022658935
Safeguards Officer	Prof. T.E. Ogbulie	toochukwu.ogbulie@futo.edu.ng	08035472379
Training & Education Coordinator	Dr. C. Chijioke	Chinonye.chijioke@futo.edu.ng	09031721544
Digital Learning Coordinator	Dr. N.P. Ohia	nnaemeka.ohia@futo.edu.ng	08063496741
PG Coordinator (PhD)	Dr. C.O. Akalezi	christogonus.akalezi@futo.edu.ng	08080587128
PG Coordinator (MSc)	Dr. S.C. Nwanonenyi	nwanonenyi.simeon@futo.edu.ng	08037727682
Head of Logistics/ICT	Mr. S. Diala	stanley.diala@futo.edu.ng	08032532325
Communication Officer	Dr. I.I. Ayogu	ignatius.ayogu@futo.edu.ng	08034178787
Project Accountant	Ms. Ifeoma Mgbenu	ifeoma.mgbenu@futo.edu.ng	08035033588
Student Representative	Mr. John Anyanwu	chemjc80@gmail.com	09031975124

1.2 Students Welfare

In addition to top-rate teaching, learning and research facilities, we also provide adequate and comfortable workspace and accommodation (in University Hostels) for the students and adequate recreational facilities. We have put in place an efficient and professionally run international office, with support personnel to ready to meet the social and personal needs of the students. Indeed, all staff of the Centre are committed to promoting student welfare, with an effective student welfare programme in place, with developmental, preventive and remedial aspects. An orientation programme shall be organized within the first week for all newly admitted students, as part of the onboarding activities to familiarize them with the Centre and larger University community as well as impart general personal development and inter-personal and leadership skills necessary for positive co-existence in a multicultural environment. Regional students shall be encouraged to participate in all student activities and initiatives. The international office shall provide assistance related to obtaining visas and resident permits, when required, for incoming regional students, as well as provide assistance related to obtaining insurance, flight/transportation arrangements and pick up when required and provide accommodation (in University Hostels) for the students and adequate recreational facilities.

Students will be assigned Programme Advisors to provide personalized academic guidance and support, as well as familiarize the students with the academic regulations of the University. All

student communications to the Centre Management shall be routed through the Programme Advisor, whereas communications to the University Management shall be routed through the Programme Adviser and the Centre Leader.

Students will also be assigned to research supervisors on registration. Supervisors will be matched to students based primarily on students' stated research interests and/or their participation in their research studies, although gender, background, or personal interests may also be considered. New incoming students will also be assigned as mentees to more experienced older student. In so doing, we shall adopt a strategy which places researchers and students with multiple levels of experience and education in research and education settings in a progressive mentoring structure that has a measurable impact on individuals at all levels.

1.3 Health & Wellbeing

Our University campus has a Department of Health Services and a medical centre, with pharmacy. Experienced counsellors are also available to provide confidential and professional support on personal, family, social, academic or other related matters. Emergency medical treatment is also available. With your student identity card, you will always be given attention.

1.4 Gender Issues

FUTO has an existing Institute of Women and Gender Development Studies, as well as strong gender policies to promote diversity and inclusion. The ACE-FUELS is adopting the FUTO gender policy that is sensitive to the needs of women with the ultimate goal as to achieve equity or equality. Such sensitivity entails searching, considering and accommodating social relations between women and men in their context, in any analysis of policy, planning and programming access to resources, opportunities and rewards of labour in terms of retention, position placement/rank, such as improved maternity condition with the objective of ensuring a positive impact on women and men and bridging gender disparities. Our University is committed to fostering an inclusive culture where equality is promoted and diversity is recognized. We also maintain a cordial working, learning and social environment in which the rights and dignity of all students are respected, irrespective of gender, tribe or religious beliefs. Any act of harassment or victimization is strongly regarded as unacceptable behaviour and is not tolerated in any form. The

ACE-FUELS Sexual Harassment Policy spells out mechanisms for enforcing laws that regulate and penalize all harmful cultural, religious and social gender-biased discriminatory practices, which reproduce or promote gender inequality. This will help to achieve equity and equality in employment opportunities and eliminate all discriminatory and abusive practices (on the grounds of sex, ethnicity, class, religion, age, disability, or marital status) against the employment or enrolment of women in the Center. The ACE-FUELS Sexual Harassment Policy is available on (https://acefuels-futo.org/resources/).

1.5 Scholarship and Research Policies

The ACE-FUELS Scholarship Policy establishes the framework for consideration and award of the Centre's portfolio of scholarships can be found on (https://acefuels-futo.org/resources/). The selection of scholarship recipients shall be merit-based, fair, transparent, gender-balanced, coherent and specified in the ACE-FUELS Scholarship Policy document. We have set out organizational mechanisms to give special preferences to individuals with disabilities, economically disadvantaged people, students from fragile and conflict affected states, especially when

considering scholarships and awards. For applicants with equivalent academic level, preference shall be given to candidates from less advantaged socio-economic backgrounds, those from fragile and conflict affected states and those with disabilities. Non-discriminatory clauses prohibiting exclusion on account of ethnic grouping, sex, place of birth or family origin or religion or political persuasion from studentship, employment or membership of anybody will be established. This will help to build a community devoid of discrimination, guaranteeing equal access to academic and research opportunities for all.

Scholarship holders are expected to maintain high level of achievement in their studies and will be monitored against the relevant regulations throughout the tenure of the scholarship to ensure that their eligibility to hold the scholarship is maintained. The minimum scholarship requirements shall apply to all students who have been offered any form of scholarship by the Centre. Any student who falls below the specified minimum at the end of any given semester may have their scholarship withdrawn.

1.6 English Language Support Programme (ELSP)

All ACE-FUELS programmes shall be run in English language. English language appreciation courses are available under the ELSP at the FUTO Language Laboratory, for Regional/International students who do not speak English as first language. ELSP offers English language lessons, tutorials and interactive sessions to improve academic English language skills. The Handbook for the English Language Support Programme is available on (https://acefuels-futo.org/resources/).

1.7 Worship Centers

Our university campus accommodates diverse religious beliefs, has facilities for different religions, groups and services. Students have open access to chapels, meditation spaces and worship areas for many religious beliefs, with readiness to accommodate newer ones. There is zero tolerance for religious discrimination on campus.

1.8 Academic Calendar

The FUTO Academic Session begins each year in October, with the Harmattan Semester (October – February) and ends in August with the Rain Semester (April – August). The Academic Calendar for each new session is approved by the University Senate before the end of the preceding session.

1.9 Other University Resources

Some other relevant academic and administrative resources of the University available to students are listed in Table 2. Detailed information on these resources and more are freely available on the University website: https://futo.edu.ng/#

Table 2. Some Relevant University Resources

Some Relevant Academic Centers and Units	Some Relevant Administrative Units
Centre for Research & International Development (CRID) Institute for Women, Gender & Development Studies (IWoGDS) Academic Planning & Development Unit (APDU) Intellectual Properties and Technological Transfer Office (IPTTO) Pre-Degree Unit Students Industrial Work Experience Scheme (SIWES) University Library (UL) University Computer Center (UCC) University Admission Office (UAO) FUTO International Secondary School University Staff School (USS)	Anti-Corruption & Transparency Unit (ACTU) Council Matters Unit (CMU) Estate and Works Unit Information and Public Relations Unit (IPRU) Linkages and Advancement Unit (LAU) Legal Matters Unit (LMU) Physical Planning and Development Unit Student Affairs Unit (SAU) Quality Assurance Unit (QAU) Catering Unit (CU) FUTO Bookshop FUTO Bus Unit FUTO Security Unit

2. INTRODUCTION TO ACE-FUELS @ FUTO

The Africa Centre of Excellence in Future Energies and Electrochemical Systems (ACE-FUELS) is established to fill a growing education, skills and information gap in the field of renewable and other clean energy sources within the sub region and in this way address the regional development challenge of poor availability and access to energy. Indeed, there is really no shortage of energy in the sub region, which has an abundance of renewable energy resources (solar, wind, biomass, hydrothermal, clean hydrocarbon). What is lacking is the requisite skilled human resources as well as the technological, educational, physical and economic infrastructures for efficient and inexpensive exploitation of the available resources, to effectively navigate this challenging and complicated transition from the conventional to clean energies. The Centre shall prioritize training, research and development, knowledge sharing and dissemination, community education, technical skills and capacity development, stakeholder engagement, industry partnerships, research translation and commercialization as its core functions. The Centre's functionality shall bear a national and regional outlook, which would ultimately facilitate development of local, national and regional capacities and competences.

The mission of ACE-FUELS Centre align perfectly with the mission of the Federal University of Technology Owerri; "…..to operate practical and result-oriented programmes and training geared towards transforming the nation's economy from consumer-oriented to production-oriented, with a sound technological base. The initiative satisfies the energy priority of the New Partnership for Africa's Development (NEPAD), to fully utilize the opportunities that promote greenhouse gas mitigation, as well as the National Economic Empowerment and Development Strategies (NEEDS) on the development of power generation infrastructure. Moreover, energy is central to virtually all MDGs, as access to equitable and sustainable energy is a precursor to poverty reduction/eradication, wealth generation, good health
services, women empowerment and enhancing literacy.

2.1 Centre Objectives:

ACE-FUELS is envisaged to:

1. Develop a critical mass of well-trained researchers to meet requirement of R&D professionals for clean energy and related high technology applications.
2. Initiate and support high end research, to extend knowledge beyond the existing practice in the industry.
3. Promote local content in research and innovations by initiating necessary value-driven industry-academia collaborations.
4. Partner with local content industry initiatives within the region to help develop competencies by providing bespoke work-based learning events, activities and tools in line with global best practices.
5. To set up standard laboratories, with facilities for multi-disciplinary research projects based on electrochemical and energy related technologies.

2.2 Centre Activities

An outline of the proposed activities of the Centre is given in **Table 1**; with six core activities through which the Centre relates to the outside world.

TABLE 1: Description of activities at ACE-FUELS Centre

ACTIVITY	STAKEHOLDERS	OUTPUT
Education	Researchers and Students for PhD, MSc, PGD and professional short courses	• Teaching, learning, research • Technical & entrepreneurial skills development • Institutional, national and regional capacity development • Revenue to the Centre
Research & development	Researchers, students, industry /sectoral partners	• Improved creativity & innovation. • Develop new processes & product lines • More efficient RE generation and deployment systems
Commercial Research & Laboratory Analysis	Researchers & students from different national & regional universities; Industries, Government agencies.	• Local, national & regional improvements in research quality • Improved research capacity and research output • Industrial contract testing & Revenue to the Centre
Products testing, standardization & certification	Industries, product developers, marketers, Regulatory Agencies	• Develop products/process standards • Product/market regulation & Consumer protection • Revenue to the Centre
Information dissemination	Consumers/general public; Government, Decision makers	• Wider acceptability/improved regulations promoting RE • Increased investments and businesses in RE • Improved patronage of the Centre & Revenue to the Centre
Technology and Knowledge transfer	Industries, product developers, marketers, Consumers/general public	• Research translation & start-ups • Commercialize new processes/products & Revenue to the Centre

EDUCATION AND TRAINING: ACE-FUELS shall achieve its core education mandate by strengthening/modifying the relevant existing programmes in our partner Departments in order to appropriately link science with technology, in line with the Centre's goals. The Partner Departments include:

- Chemistry
- Physics
- Electrical/Electronic Engineering
- Mechanical Engineering
- Petroleum Engineering
- Polymer and Textile Engineering
- Chemical Engineering
- Metallurgical and Materials Engineering
- Geology
- Biotechnology
- Microbiology
- Environmental Management

The Centre has also introduced novel, bespoke multidisciplinary PhD and MSc programmes related to the focus disciplines of the Centre.

1. MSc/PhD in Future Energies
2. MSc/PhD in Nanotechnology
3. MSc/PhD in Electrochemical Technology
4. MSc/PhD in Corrosion Technology

The Centre also offers the ACE-FUELS professional training and career development courses designed to enhance the practical skills, expertise and credentials of science and technology professionals, as well as ACE-FUELS Training and Skills Support Programme, designed to offer hands-on training for young professionals without academic qualifications. The Centre has put in

place incentives and facilities to attract and retain talented female students, as well as regional students. We shall strive to ensure that all our programmes have the highest national and international accreditation possible. The Centre provides standard facilities for teaching, learning and capacity development, with exciting and interactive learning opportunities for optimal development of technical and entrepreneurial skills, in order to solve pressing problems hindering energy and technology availability and access. ACE-FUELS utilizes the existing OYLEX online learning management system (LMS) in FUTO, which is a highly intuitive tool for delivering online courses and education that supports the whole learning spectrum. This OYLEX LMS provides learner-centred instructions and access to resources. It serves as a support system to deliver quality lessons, conduct assessments and track/analyze performance, while fostering improved/enhanced student-instructor communication. Lesson contents can be accessed anytime and anywhere for personalized learning and standardization of materials.

RESEARCH: Research at FUTO is built around dedicated and multidisciplinary research units spread over nine (10) Schools and 52 Departments. Each of the Engineering and Science Departments has dedicated demonstration laboratories and research laboratories, providing facilities for undergraduate and postgraduate research. The Federal Ministry of Environment (FMEnv) recently accredited FUTO Environmental Laboratories to provide Environmental Laboratory Services. Many of our researchers work in research centres like the Centre for Energy & Power Systems Research (CEPSR), Centre for Nuclear Energy Studies & Training (CNEST) and a Centre for Industrial Studies (CIS). FUTO has established 4 key research priority areas (RPAs) that engage researchers in all Schools and Centres/Institutes in interdisciplinary research. Each area comprises a number of smaller research clusters. The relevant RPAs like Energy and Environment and Advanced Materials are directly linked to the mandate of ACE-FUELS as outlined in **Figure 1**.
All the national, regional and international institutions selected as partners on this project possess modern facilities, expertise, resources and data, as well as unique and outstanding capacity to immensely improve the scale and scope of research projects, thereby enhancing the capacity for innovation and new discoveries. There is therefore no doubt that our researchers and partners possess the expertise and experience to train highly motivated and result-oriented postgraduate students and to deliver meaningful solutions to technological problems and needs of the society in a timely manner, as envisaged within the framework of the proposed ACE-FUELS.

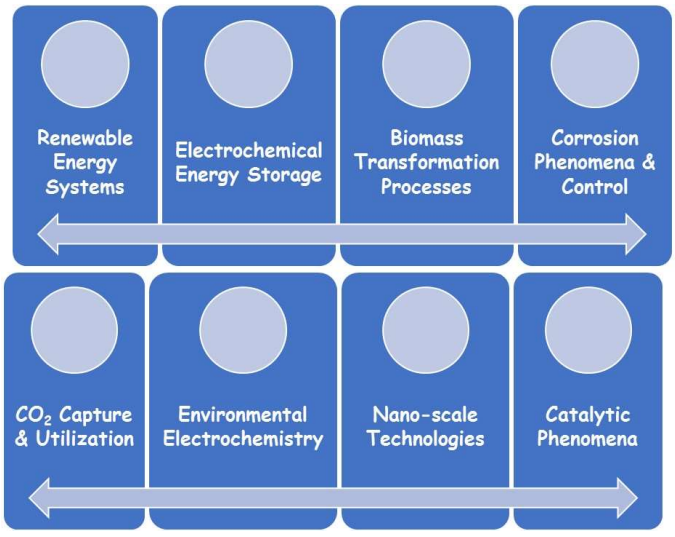

FIGURE 1: ACE-FUELS Research Priority Areas (RPAs)

PARTNERSHIPS: ACE-FUELS is partnering directly with 22 national, regional and international academic institutions for education and research collaborations in such areas as training, research and co-supervision, lecture delivery, access to facilities, joint workshops etc. We are as well partnering with 12 industrial/sectoral partners who partake in setting training and research agenda, and offer adjunctships, fellowships, student internship positions etc. The Centre has forged cooperation with broad-based national, regional and international knowledge networks like the Pan African Electrochemistry Network, Green Africa Innovation Network and recently the West African Centres of Excellence in Energy Network, to evolve novel technologies and approaches, which optimally engage local and regional scientific talents, while linking global expertise. ACE-FUELS programmes, processes and facilities shall be made to undergo relevant national and international accreditations as a means to extend acceptability and influence.

CONTRACT RESEARCH AND LABORATORY SERVICES: ACE-FUELS plan for contract research shall be to incorporate a Consultancy Unit, overseen by the Industry Liaison Officer. In this way, the Centre shall respond to tenders for contracts and consultancy services. Accordingly, the laboratories shall be configured to offer commercial laboratory testing and analytical services to researchers and students of other local, national and regional institutions as well as to government and private agencies. The Centre shall provide the research community with high quality research data on energy, electrochemical technologies and functional materials. Postgraduate students from other universities and research institutes from within and outside the country can apply for laboratory bench work at the Centre for a fee. The proposed Centre shall, through its Consultancy Unit, provide national and regional product testing, standardization and certification services to industry and thus assist in regulating the quality of products and services in the sector for more effective consumer protection.

3. MSc PROGRAMME DESCRIPTION/STRUCTURE

3.1 Philosophy of the Programme

In line with the overall philosophy of the Federal University of Technology Owerri (FUTO), Nigeria, the MSc programmes of the Africa Centre of Excellence in Future Energies and Electrochemical Systems (ACE-FUELS) at FUTO are designed to nurture high-skilled professionals in Future Energies, Electrochemical Technology, Nanotechnology and Corrosion Technology, who will have the capacity to develop novel technologies and new materials for efficient exploitation of the region's abundant energy resources and in this way address the regional development challenge of poor availability and access to energy.

3.2 Aim/Objectives of the Programme

The primary goal in creating ACE-FUELS Centre is to actively contribute towards the development and deployment of renewable and clean energy technologies in Nigeria and indeed Sub Saharan Africa. Thus, ACE-FUELS programmes are designed to:

(i) Develop a critical mass of well-trained researchers to meet requirement of R&D professionals for clean energy and related high technology applications.

(ii) Initiate and support high end research, to extend knowledge beyond the existing practice in the industry.

(iii) Promote local content in research and innovations by initiating necessary value-driven industry-academia collaborations.

3.3 Programme Description

The ACE-FUELS MSc programmes are designed as 18-month full-time courses. Students in the programme spend a 12-month period of learning, instruction and research on campus, at the end of which they submit their thesis. The students undergo oral examination of their thesis before they can graduate from the programme.

Each MSc programme of study is made up of three (3) essential modules of instruction:
(1) Mandatory Module
(2) Module of Specialization
(3) Project Module

The modules include lectures, tutorials, seminars, hands-on sessions as well as guest lectures by industry subject-matter experts. The minimum number of credit units for the ACE-FUELS MSc programme is 50 units.

3.4 Programme Structure

Each of the ACE-FUELS MSc programmes is structured into three (3) modules, totaling 50 credit units. Each credit unit corresponds to 15 hours of instruction.

MODULE 1:

Name	Credit Units	Duration
Mandatory Module	20	6 weeks

The Mandatory Module is made up of six (6) carefully designed courses, aimed at providing comprehensive and broad-based education in the general area of the programme. All the contents

of the Mandatory Module for each MSc programme must be taken by all students enrolled in the programme, irrespective of area of interest or specialization.

MODULE 2:

Name	Credit Units	Duration
Module of Specialization	15	6 weeks

The Module of Specialization is more flexible and designed to offer courses that are most suited for each student's area of specialization and research interest. The Module is made up of three (3) fundamental courses in the area of specialization (9 Credit Units) and any three (3) courses from a list of elective courses (6 Credit Units).

MODULE 3:

Name	Credit Units	Duration
Project Module	20	36 weeks

In the Project Module, each student will be guided to undertake and complete an in-depth individual research project involving experimental, theoretical or computational studies in the area of interest. Each student will be guided by a principal supervisor and a co-supervisor who are academics and experts in the area. An industry-based supervisor may be included where necessary. The team of supervisors shall be assigned at the start of the programme and will work closely with the student all through the study period. The Project Module includes three (3) seminar sessions: Seminar I (Research Proposal); Seminar II (Progress Report); Seminar III (Final Report).

Internship Programme

Students who are successful in all three (3) modules and submit their draft thesis at the end of the 12-month period will proceed for the internship with an industry partner. The internship is to enable the student to integrate and function effectively, applying scientific knowledge and practice in an industrial setting, in conformity with laid down rules and regulations. Final oral examination of the thesis shall take place after successful completion of the internship programme.

3.5 Expectations from Students

(i) ***Research Publications:*** Each student is expected to co-author and publish at least one (1) article from their research work in a relevant Tier 1 peer-reviewed journal indexed by Thompson Reuters.

(ii) ***Presentations***: Each student is expected to attend and present papers (oral or poster) at a national/regional professional body conference.

(iii) ***Workshop/Seminar Participation:*** All students are expected to attend and participate in all workshops, seminars, guest lectures and other activities organized by the Center.

4. RESEARCH AND CAREER OPPORTUNITIES

4.1 MSc. FUTURE ENERGIES

Research Areas

Future Energies research areas focus on development of novel low-cost renewable energy technologies and devices for innovative and efficient exploitation of the region's abundant energy resources. This includes design and construction of solar, wind, hydro, marine and geothermal energy devices for efficient clean energy harvesting and storage. The solar energy research projects are based on improving design and performance of organic, inorganic, thin film, hybrid solar cells and 3-D printed solar cells, solar thermal systems, development of novel conducting polymers, semiconductors and nano-structured materials used in solar cells etc. Our hydro energy research projects are focused on development and domestication of the technology for small and micro hydro-turbine production using locally sourced materials. We are also interested in biomass conversion systems research with focus on improving the efficiency of bio-fuel, bio-ethanol and biogas production systems, microbial technologies for bio-energy production. Our research is also centred on developing efficient and inexpensive catalysts for the complex electrochemical conversion of carbohydrates for electricity generation using carbohydrate fuel cell and bio-fuel cells, with focus on starch-rich process water from cassava processing plants. In Future Energies research, we are also interested in field analysis and performance measurement of sustainable renewable energy systems; carbon capture and sequestration technologies; design and construction of bio-diesel and bio-oil production plants; next generation energy systems for domestic and industrial applications; modelling, simulation and optimization of renewable energy systems.

Career Opportunities

Career prospects in the renewable energy field are very excellent. Energy plays a key role in the economy and environment. According to experts, there is a huge and growing demand for energy that is reliable, cheap and clean, with the potential to counter poverty and climate change. Renewable energy projects require a workforce with diverse background and skills-set. There are job opportunities for Materials Scientists, Engineers, Chemists, Ecologists, Biologists, Physicists, Geologists, Architects, Project Managers, Computer Scientists and Communication professionals. In fact, if you are looking for a stable job that pays well, a career in Future Energies is what you need.

4.2 MSc. ELECTROCHEMICAL TECHNOLOGY

Research Areas

Research projects on electrochemical technologies at the Centre are focused on electrochemical energy conversion and storage systems *(Solar cells, Fuel cells, Batteries, Supercapacitors), including* 3-D printed solar cells and 3-D printed graphene-based energy storage devices. These devices are indispensable enabling technologies for storage and transmission of electricity from renewable energy, with market demand in the multibillion US Dollar range. We are also interested in development of new carbon-based materials for electrochemical devices, from abundant local carbonaceous materials and agricultural wastes. Research shall also explore Nigerian rich biodiversity to develop locally produced nanomaterials for applications in electrochemical storage devices, bioethanol in proton exchange membrane and solid oxide fuel cells. We are interested in developing new conversion technologies to enable more innovative exploitation of the starch-rich process water from cassava processing plants, including design and fabrication of a prototype "indirect fuel cell" device. Environmental electrochemistry research focus is on design and

fabrication of electrochemical sensors of different dimensions, including 3-D printed electrochemical sensors for environmental monitoring, as well as electrochemical detection for the monitoring of corrosion inhibitors. We are focusing on electrochemical treatment of wastewater via electrolysis, advanced oxidation processes and heterogeneous photocatalysis using different semiconductor electrodes. We are also interested in the electrokinetic remediation of contaminated soils and sediments, metal recovery and electrochemical effluent gas treatment.

Career Opportunities

Graduate students with training in electrochemical science and technology find ready career opportunities with international relevance in such industrial sectors as utilities, transportation, aerospace, automobile, aviation, chemical, petrochemical, oil and gas, metallurgical, pulp and paper, pharmaceutical, natural resources, environmental protection, new products development, etc., as Industry R&D scientist, industrial management, founder of startup company, industrial consultant, government specialist. MSc degree in electrochemical technology prepares students for careers in the academia, industrial R&D, government and regulatory laboratories.

4.3 MSc. NANOTECHNOLOGY

Research Areas

Nanotechnology research is focused on development of novel low-cost materials for photovoltaic and photoelectrochemical cells and explore opportunities to link up local developmental needs using locally produced nanomaterials. This includes production, modification and functionalization of nanofillers from agro-industry waste, preparation of polymer/clay nanocomposites and nanocomposite thin films for photovoltaic surfaces as well as for surface modification and anticorrosion protection. We are also interested in development of nano-structured ceramics membranes for carbon capture applications from various gas streams for clean energy production.

Career Opportunities

Nanotechnology is an interdisciplinary field of study, requiring expertise within physics, chemistry, biotechnology, mathematics, and materials science. Graduate students with such interdisciplinary education and qualifications are thus invaluable with respect to solving the many challenging materials problems present on the nanoscale. Career opportunities exist globally in such industrial sectors as chemical/allied, agriculture, food, pharmaceutical, cosmetics, natural resources, environmental etc., as Industry R&D scientist, nano scientist, industrial management, founder of startup companies, industrial consultant, government specialist. MSc degree in nanotechnology prepares students for careers in the academia, industrial R&D, government and regulatory laboratories.

4.4 MSc. CORROSION TECHNOLOGY

Research Areas

Corrosion research at ACE-FUELS is focused on corrosion control of iron and steel and other structural materials deployed in service in different aggressive environments as found in oil and gas operations, including development of novel inexpensive and non-toxic corrosion inhibitors from local biomass resources and other sources, functional anticorrosion coatings like superhydrophobic coatings and self-healing coatings. Such investigations have profound relevance for the oil and gas industry in Nigeria, which loses up to $765 Million USD yearly to corrosion, with profound environmental degradation due to products spillage. We are also interested in corrosion phenomena

in renewable energy systems, like corrosion protection in hydroethanolic media and in biodiesel, as well as the corrosion behaviour of solar panels and other energy materials, in order to develop more corrosion resistant and long-lasting PV panels and structures, hence increase the durability and reliability of PV systems. Efficient corrosion monitoring and control is especially important for solar energy systems, which are expected to last for decades.

Career Opportunities

Employability is about more than just securing a job placement. We believe in helping our students gain the necessary experience for a successful career in the future, along with the skills to identify opportunities and make the most of them. This postgraduate programme in Corrosion Technology provides access to a fulfilling career in diverse industries like oil and gas, energy, construction, utilities, shipping, aviation, chemical, petrochemical etc. as Industry R&D scientist, corrosion engineer, industrial management, founder of startup company, industrial consultant, government specialist. MSc degree in Corrosion Technology prepares students for careers in the academia, industrial R&D, government and standards laboratories.

5. ADMISSION REQUIREMENT/SELECTION PROCESS

5.1 ADMISSION REQUIREMENTS

The minimum admission requirement of the ACE-FUELS MSc programmes is a Second-Class Honors degree (Upper Division) in a relevant Science or Engineering discipline from a Nigerian university, or an equivalent qualification from Universities outside Nigeria.

5.2 SELECTION PROCESS

The selection process is mainly based on submission of the required application documents and fulfillment of the general application requirements. Applicants who fulfill these requirements will scheduled for computer-based aptitude tests and interviews (either face to face or via Skype or phone). Applicants are rated using a scoring system based on the following criteria:

S/N	CRITERIA	SCORE
1	Research excellence	40
2	Motivation	15
3	Enthusiasm	10
4	Ability to take initiative & independency	20
5	Communication ability	15
	TOTAL	**100**

Candidates who score up to 60 points will be considered for admission into the programme. There are no restrictions based on age, gender, religion, nationality, ethnicity, disability or political orientation of the candidates.

Deadlines

Nomination and selection of MSc candidates take place only after the application deadline. Applicants will be notified of their application status no later than four (4) weeks after the application deadline. Candidates whose initial submissions meet the requirements will be invited for the phone interview and shall be informed of their final admission status within two (2) weeks.

Appeal & Redress

Unsuccessful candidates who believe they were unjustly evaluated due to discrimination based on gender, religion, age, ethnicity, nationality, disability, as well as procedural errors or other ethical issues, can appeal within two (2) weeks of receiving notification of their application status. An appeal committee will consider all such appeals within one (1) month.

6. COURSE OUTLINE/COURSE CONTENT

6.1 MSc FUTURE ENERGIES

PREAMBLE

Even though hydrocarbons fuels remain abundant and relatively cheap in many aspects, concerns over their finite nature and environmental impact are compelling the global efforts to implement policies to accelerate transition to cleaner energy sources. With the energy and environmental landscape changing rapidly, investments are also being made in research to understand and attain the next steps. There is no doubt that science, technology and innovation (STI) will play a fundamental and critical role in this challenging transition to the clean energies of the future. Unfortunately, Nigeria and other Sub-Saharan African countries seem to lack sufficient skilled human resources as well as technological, educational, physical and economic infrastructures to effectively adapt STI for efficient exploitation of the abundant clean energy resources in the region.

The ACE-FUELS Future Energies programme provides exceptional multidisciplinary training and research opportunities that will develop energy technologies of the future, integrate them into today's infrastructure, and examine their possible consequences for our society, economy, and environment. Renewable energies have become the fastest growing industry in the world. It is also our goal to as well develop solutions for challenges presented by current energy systems, particularly as regards cleaner hydrocarbon production. Thus, students completing this course will have a firm, broad-based knowledge and skills to fill a growing education, skills and information gap in the field of clean energy and their high-level applications within the sub region.

PROGRAMME OUTCOMES

At the end of this postgraduate programme in Future Energies, the graduates should be able to:

1. Understand the Basic Energy Concepts, technologies and contemporary energy challenges and acquire knowledge for possible solutions to sustainable clean energy usage.
2. Develop and demonstrate broad-based expertise in renewable energy technologies, including identification, design, fabrication, characterization and utilization of clean energy technologies in diverse fields.
3. Demonstrate competence in responsible conduct of research, ability to critically analyze data as well as carry out design and manage research projects independently.
4. Develop effective oral and written skills.
5. Demonstrate ability to identify and respond to key innovation demands by recognizing and exploiting relevant sources of information for innovation.
6. Understand and appreciate the importance of technological innovation to business, stakeholders and the wider economy and society
7. Develop strategies and practices to manage the concerns and risks associated with widespread utilization of renewable energy devices.

A. MANDATORY MODULE

S/N	COURSE CODE	COURSE TITLE	L	T	P	UNITS
1	FEM 801	Energy/Environmental Policy & Management	2	1	0	3
2	FEM 803	Future Energy Systems I	2	1	0	3
3	FEM 805	Future Energy Systems II	2	1	0	3
4	FEM 807	Future Energy Systems III	2	1	0	3
5	FEM 809	Local Solutions for Energy Access	2	1	0	3
6	REM 801	Research Methods & Innovation	2	1	0	3
7	MGT 805	Entrepreneurship	2	0	0	2
TOTAL			20			

(1) FUTURE ENERGY SYSTEMS (I, II, III)

This suite of courses forms the foundation of the Future Energies programme. It will provide course participants with an overview of Basic Energy Concepts, including the most significant renewable energy resources, concepts, technologies and challenges to overcome climate change and other sustainable development goals and an insight into the possible solutions to sustainable energy usage. Course participants will be able to recognize, understand and evaluate the different renewable energy resources available today and in the future, including their advantages and disadvantages.

FEM 803: FUTURE ENERGY SYSTEMS I

- Solar energy technologies
- Wind energy technologies
- Biomass energy technologies

Solar Energy Technologies

This course deals with the renewable energy systems which directly exploit the solar radiation received by the earth viz. solar photovoltaics (PV), solar thermal technologies. The course describes the fundamental mechanisms of solar energy conversion on solar cells, including the principles, manufacturing technologies, efficiencies, advantages and limitations of various PV cells. The optical and thermal parameters for solar thermal technologies are also considered with the basic heat transfer and thermodynamics principles that apply and the approaches for generating electrical power. The exploitation of these renewable energy systems in both large-scale power plants and in the urban, built infrastructure is considered. Topics include: Solar resource and solar radiation (the sun, solar radiation, solar spectral distribution, solar constant, solar insolation and position of the sun w.r.t surfaces on earth, solar time, AM 1.5 and irradiance, measurement of terrestrial solar radiation etc.). Advantages and disadvantages of solar energy. Photoelectric effect and concept of photons. Interaction of light with matter (absorptivity, reflectivity, transmittivity, emissivity etc). Principles of operation of PV cells; Manufacturing technologies of crystalline and thin film PV cells. Heat transfer and principles of solar thermal systems. Introduction to Solar collectors, Passive and active solar thermal systems, Solar drying, Solar distillation, solar cookers. The concepts of stand-alone and bulk solar thermal power generation systems

Wind Energy Technologies

This course deals with the harvesting of energy from wind. It addresses the availability of the resources, the types of systems and machines, their capabilities and limitations, the processes of setting up such systems, and their associated costs and environmental impacts. Wind energy, its potentials and its application to

power generation. Advantages and disadvantages of wind energy. Wind resource and wind power; Wind power fundamentals, Wind generation, Wind power estimation. Wind turbine technology. History of wind power harnessing – windmills (wind machines in antiquity, Islamic civilization windmills, Medieval European windmills, Aegean & Mediterranean windmills, Dutch & European windmills, The American windmills). Overview of wind turbine components (Aerodynamic rotor, transmission system, generator, power electronics interface, control system).

Biomass Energy Technologies

The course considers the technical issues, economic feasibility and sustainability of bio-energy production in the African context. The focus of the course is in the integration of technical, economic and sustainability considerations into project development, to find practical, innovative, sustainable solutions for bio-energy production. The course will involve the development of a conceptual understanding of the conversion technologies for bio-energy and biofuels production, including biodiesel, biogas, ethanol, combustion, pyrolysis, gasification and electricity generation. Topics include: Biomass as a renewable energy source (Historical development & potential of bioenergy, biomass resources, Biomass properties, environmental impact of bioenergy, Economics of bioenergy). Biomass production and conversion: Photosynthesis (Basic concept of photosynthesis, light reaction for the photochemical oxidation of water, dark reaction for the synthesis of sugars, efficiency of photosynthesis). Biomass production (Natural factors, biomass yield, fossil input for biomass cultivation & harnessing, biomass logistics, environmental impacts of biomass cultivation, Economics of biomass production, major terrestrial biomass crops, aquatic biomass). Biomass conversion processes (Thermochemical conversion processes, biochemical conversion processes, chemical conversion processes). Utilization of biomass energy (Biofuels, electric power generation, heat production, chemical biorefinery). Advantages and disadvantages of biomass energy.

FEM 805: FUTURE ENERGY SYSTEMS II

- Hydropower technologies
- Geothermal technologies
- Ocean energy

Hydropower Technologies

Hydropower as renewable energy technology and its development: Components of Hydropower facilities. Classification of Hydroelectric power plants. Advantages and disadvantages of Hydropower. Hydrology and Hydraulics; Hydrological cycle; Hydrographs/ flow-duration curves. Hydraulic turbines: Basic principle, Turbine types and sizes; Degree of reaction, Turbine performance & selection. Applications of Hydropower.

Geothermal Technologies

Geology of geothermal regions: The Earth and its atmosphere; Active geothermal regions; Model of a hydrothermal geothermal resource, Other types of geothermal resources (Hot dry rock, geopressure, magma energy, deep hydrothermal). Exploration strategies and techniques: Objectives of an exploration programme; Phases of an exploration programme (literature survey, airborne survey, geologic survey, hydrologic survey, geochemical survey, geophysical survey). Applications of geothermal energy: Electricity generation; Industrial applications. Advantages and disadvantages of geothermal energy.

Ocean Energy/Marine Energy

The earth's oceans are huge sources of renewable energy. This course highlights different ocean energy resources and applicable conversion technologies. Ocean resource assessment and measurement strategies will be addressed. Topics include: The idea of renewable energy from the ocean. Ocean activities: Waves, ocean currents, tides, salinity, temperature gradients. Tidal energy and technologies for exploitation of tidal energy: Tidal devices; turbine types, oscillating hydrofoils etc. Advantages and disadvantages of ocean energy.

FEM 807: FUTURE ENERGY SYSTEMS III

- Hybrid systems/energy mix
- Hydrogen and Green Hydrogen
- Renewable Energy storage systems
- Clean hydrocarbon/Carbon capture technologies

Hybrid Systems/Energy Mix

This course introduces established categories of hybrid systems and their application potentials, as well as provides insights in the fields of energy saving and smart utilization. Topics include: Hybrid power generation systems. Combined wind-solar systems. Hybrid thermal energy systems; combined solar-thermal and geothermal systems, Hybrid wind-diesel systems, PV-diesel systems and wind-PV-diesel systems etc. Techno-economic feasibility for energy saving systems. Main energy storage technologies. Environmental-social benefits of hybrid energy systems. New technologies for hybrid power systems. Energy and cost savings with hybrid power systems. Cogeneration systems

Hydrogen and Green Hydrogen

This module provides an initial understanding of hydrogen as an energy source, including the different techniques for commercial production and utilization of hydrogen. The students will understudy the theories and mechanisms of electrochemical production of hydrogen via water electrolysis/water splitting, including types of electrolysis and electrolyzers. The students will be introduced to the concept of electrochemical series and the interplay between electrochemical series and electrolytic processes.

Renewable Energy Storage

This course describes the need for renewable energy storage, as well as concepts and technologies used for storing energy from different sources. The course also highlights the technical and other considerations that guide energy storage options and sizes of grid connected and off-grid systems. Topics include: Energy storage technologies: Electrochemical storage systems (Lead-acid battery, lithium-ion battery, liquid metal battery, nickel-based battery, flow batteries). Mechanical storage systems (Pumped hydro storage system, flywheel storage system, compressed air storage). Thermal storage systems (Hot water storage, molten salt storage, latent heat storage). Electrical storage systems (Supercapacitors, superconducting magnetic energy storage). Hydrogen energy storage technology (Electrolysis with cryogenic storage). Multiple technologies for the storage of energy generated by wind power and other renewable sources. Introduction to the ProGeo system for storing electrical energy as methane chemical energy: an overview - Generating and storing energy in the ProGeo system - Research and development of model plants.

Carbon capture & sequestration

Introduction to Carbon capture & sequestration. Coal characteristics and combustion, power plants, engines, fundamentals of combustion, gas turbines, pollution. GHG emissions, GHG emissions reduction measures, Clean Development Mechanism (CDM). Fossil fuel power generation, power plants, power plant technologies. Membrane technology in the production of clean and renewable power. CO_2 capture technologies 1 - general overview. CO_2 capture technologies 2 - chemical and physical processes. Membranes for CO_2 capture and hydrogen production. Electrochemical reduction of CO_2 to fuels. Overview of market potential and technical barriers for membranes - Market potential and technical barriers for membranes for CO_2 capture and hydrogen production

FEM 809: LOCAL SOLUTIONS FOR ENERGY ACCESS

Overview of the National Energy System (including grid system, DES and interconnections) and RE resources, Distributed Renewable Energy Systems (Technical). Design Principles, Components (incl. storage), Options and Cost for DREs. Distributed Renewable Energy System Trends. Energy End-Users in Off-Grid Settings. Socio-Economic and Cultural Factors within Communities. Methods and tools for Community Engagement. Socio-Economic and Cultural Enablers and Barriers. DRE Business Models. Business Model Canvas as a tool

for understanding business models. Supply Chains in the DRE sector. Productive Use of Energy (PUE). Financing for DRE Companies. Financing for DRE Projects. Financial Risks for the DRE Sector. Energy Access, Development, and Climate Change Nexus, significance of DRE systems in energy transition and SDG7. National Energy Policies. National Regulations in the DRE Sector. Environmental Impact Assessment. Renewable Energy Technologies and the Environment. Product Life Cycles. Circular Economy Opportunities.

FEM 801: ENERGY/ENVIRONMENTAL POLICY & MANAGEMENT

Socioeconomic (sustainability) aspects determining the selection of conventional and alternative fuel balance for energy generation. Renewable energy economics and financing (national, regional, international). Economic considerations (provision of fuel, revenue generation, project design & facility construction) and Financing considerations (institutional framework, financing approaches & sources, contracts & risk allocation). Financing and investment opportunities in renewable energy implementation. Environmental policy and practices (e.g. conservation, renewable energy, pollution prevention, recycling). Environmental regulations for renewable energy. Environmental Impact Assessment, Environmental Evaluation, Monitoring and Compliance. Environmental Management systems and the Total management systems including the ISO 9001 and 14000 standards series. Environmental impacts of diverse energy sources (solar, wind, biomass, geothermal, ocean etc) including beneficial and adverse impacts. Big data analytics for energy and environmental management.

REM 801: RESEARCH METHODS & INNOVATION (3 Units)

Fundamental concepts of scientific research. Concepts underlying peer-reviewed research. Referencing: Evaluating the relevance and impact of sources. Conducting literature reviews, evaluating published findings. Using research productivity tools (statistical, referencing, research design etc). Research conceptualization and design. Writing research proposals. Authoring and publishing high-impact articles. Communication and presentation skills. Intellectual Property (IP) development, evaluation, and strategy. Strategy and innovation concepts with a focus on research and technology commercialization. Business strategy frameworks, financial analysis, strategic marketing, operations management, business models, project management, business law, and entrepreneurship.

B. MODULE OF SPECIALIZATION

There are five (5) areas of specialization in the MSc Future Energies programme:

1. SOLAR ENERGY SPECIALIZATION

S/N	CODE	COURSE TITLE	L	T	P	UNITS
1	FEM 802	Solar thermal conversion systems and application	3	0	0	3
2	FEM 804	Photovoltaic solar energy conversion	3	0	0	3
3	FEM 806	Advanced photovoltaic systems	3	0	0	3
4	800L	ELECTIVE COURSE	2	0	0	2
5	800L	ELECTIVE COURSE	2	0	0	2
6	800L	ELECTIVE COURSE	2	0	0	2
TOTAL			**15**			

FEM 802: SOLAR THERMAL CONVERSION SYSTEMS AND APPLICATION

Solar radiation: Nature and measurement. Solar collection and thermal conversion. Solar collectors (flat-plate collectors, evacuated-tube collectors, concentrating collectors, Fresnel lens concentrators, heliostats). Solar thermal systems applications – Active & passive (heating – water& space; cooling & dehumidification; drying & distillation). Thermal energy storage. Economics of solar systems

FEM 804: PHOTOVOLTAIC SOLAR ENERGY CONVERSION

Types of solar cell/Generations of solar cells. First generation solar cells (crystalline Si, GaAs, Polycrystalline silicon solar cells). Second generation solar cells (Thin film solar cells – amorphous Si, microcrystalline Si, CdTe, $CuInSe_2$, $Cu(InGa)Se_2$, $Cu2ZnSnS_4$). Third generation solar cells (Nanocrystalline-based solar cells, polymer-based solar cells, dye-sensitized solar cells, concentrator solar cells, Tandem solar cells). Fourth generation solar cells (Hybrid or organic-inorganic solar cells). Next generation solar cells (Graded bandgap solar cells, Perovskite-based solar cells, Quantum dot solar cells, intermediate band solar cells, solar cells with up & down conversion, nano-structured solar cells e.g. with carbon nanotubes, grapheme etc.). Differences between solar cells, modules and panels (sizes and Efficiencies). Application of solar cell/modules/panels. Very low power application (such as in wrist watches, mobile phone, small torchlight, radios etc). Medium power application (such as in solar-operated cars, Street lighting, water pumping, household appliances etc). High Power and very high-power applications (as in stand-alone and grid-tied solar power plants). PV Economics: Cost of production, Cost of PV energy/Payback time, Feed-in tariff, Levelized cost etc.

FEM 806: ADVANCED PHOTOVOLTAIC SYSTEMS

Solar resource & irradiation data sources. Different solar PV technologies. Photo-voltaic panel: electrical characteristics, maximum power point, influence of shading & diffuse irradiation, etc. Photo-voltaic array: impact of positioning & tracking, string design and DC cable sizing, etc. Connection to the distribution grid: power electronics basics, earthing and circuit-breaker design, system sizing, AC cable sizing, South African regulations & standards. Financial viability: understanding tariffs, payback, etc.

2. BIOENERGY SPECIALIZATION

S/N	CODE	COURSE TITLE	L	T	P	UNITS
1	FEM 812	Bioenergy systems	3	0	0	3
2	FEM 814	Biofuels	3	0	0	3
3	FEM 816	Bio-energy & biotechnology	3	0	0	3
4	800L	ELECTIVE COURSE	2	0	0	2
5	800L	ELECTIVE COURSE	2	0	0	2
6	800L	ELECTIVE COURSE	2	0	0	2
TOTAL			**15**			

FEM 812: BIOENERGY SYSTEMS

Thermal power plants, heat energy and heat production (Biomass-based power & heat generation, biomass combustion power systems, biomass gasification power systems, biomass-fueled internal combustion engines & gas turbines, polygeneration of electricity, heat & chemicals, biomass boilers & heating systems). Biomass-based fuel cell systems (overview, biomass integrated gasification-solid oxide fuel cell systems, biomass integrated gasification-proton exchange membrane fuel cell systems, fuel cell systems fed with liquid biofuels, including ethanol, glycerol, butanol etc). Biorefineries (overview, energy inputs to basic biorefinery steps, biorefinery feedstock).

FEM 814: BIOFUELS

Biodiesel, bioethanol, methanol, biogas (Chemistry, feedstock, production process, uses). Fischer-Tropsch fuels (Overview, coal-to-liquid processes, gas–to-liquid processes, biomas-to-liquid processes). Thermochemical ethanol (Process chemistry, catalysts for ethanol synthesis, process design, energy, environmental & economic aspects). Dimethyl ether (DME) (Process chemistry, DME as energy carrier, production technology, DME from fossil fuels, DME from biomass, energy, environmental and economic aspects). Hydrogen (chemistry of hydrogen production, uses, storage, production methods, hydrogen from fossil fuels, hydrogen from water splitting, hydrogen from biomass gasification, hydrogen from electrochemical reforming of biofuels, biological hydrogen production, future hydrogen production

processes, energy, environmental and economic aspects). Substituted natural gas (SNG) (Chemistry of methanation, natural gas as energy carrier, SNG production technology, SNG from coal, SNG from biomass gasification, energy, environmental and economic aspects).

FEM 816: BIO-ENERGY & BIOTECHNOLOGY

Biomass chemistry. Biomass for modern biotechnology applications. Biofuel suitability and feasibility of different applications. Advanced modern methods for biomass treatment and handling. Complex thermal biomass conversion (gasification, pyrolysis, liquefaction). Principles of biochemical biomass conversion. Environmental impact of biomass production and use. Bio-based fuel additives. Lignin conversion and levulinic acid and furfural conversion. Industrial Microbiology and biotechnology: Types and methods of optimization of products- substrate level, physiological level, genetic level. Process optimization, selection of appropriate substrates, computer aided optimization-Modelling and simulation for product optimization using Design expert software, Minitab, Sigma Plot, Ms Excel etc. metabolic and genetic engineering for improved yield. Genetically Modified Organisms, Merits and demerits.

3. CLEAN HYDROCARBON ENERGY SPECIALIZATION

S/N	CODE	COURSE TITLE	L	T	P	UNITS
1	FEM 822	Introduction to membrane technology	3	0	0	3
2	FEM 824	Carbon capture & sequestration technologies	3	0	0	3
3	FEM 826	Membrane technologies for renewable energy applications	3	0	0	3
4	800L	ELECTIVE COURSE	2	0	0	2
5	800L	ELECTIVE COURSE	2	0	0	2
6	800L	ELECTIVE COURSE	2	0	0	2
TOTAL			15			

FEM 822: INTRODUCTION TO MEMBRANE TECHNOLOGY

Introduction – General Principles of Membrane Technology. Membrane Process – Overview of Membrane Process Unit operations. Membrane Materials and structure. Membrane Manufacturing techniques. Process Design – Membrane Module configurations and system design arrangement. Principles, Design and Application of Membrane Unit Processes. Reverse Osmosis, Ultrafiltration, Microfiltration, Dialysis, Electro dialysis, pervaporation, Gas Permeation, Liquid Membrane Process &Novel Membrane separation. membrane technology in the production of clean and renewable power; Overview of market potential and technical barriers for membranes

FEM 824: CARBON CAPTURE & SEQUESTRATION TECHNOLOGIES

Membranes for CO_2 capture and hydrogen production. Metal-organic frameworks as molecular gas cylinders for CO_2 capture. CO_2 capture technologies 3 – absorption. CO_2 capture technologies 4 – adsorption. CO_2 capture technologies 5 - membranes, cryogenic, looping cycles. CO_2 conditioning. CO_2 transport; different ways of CO_2 transport, CO_2 properties under transport conditions, impurities present in CO_2 streams from different generation/capture systems, effects of impurities on CO_2 compression and transport, risks associated with CO_2 transport. Market potential and technical barriers for membranes for CO_2 capture and hydrogen production.

FEM 826: MEMBRANE TECHNOLOGIES FOR RENEWABLE ENERGY APPLICATIONS

Introduction - Membrane applications in solar hydrogen production - Solar water electrolysis - Thermochemical water-splitting cycles - Solar membrane steam reforming. Membrane technologies for solar-hydrogen production. Membranes for biofuels production & processing. Membrane processes for biofuel separation, Membrane materials and fabrication, Membrane operations for gas and vapour separation. Membrane reactors for biofuels treatment. Membrane bioreactors Ceramic membrane preparation and applications.

4. GEOTHERMAL ENERGY SPECIALIZATION

S/N	CODE	COURSE TITLE	L	T	P	UNITS
1	FEM 832	Geothermal reservoir engineering	3	0	0	3
2	FEM 834	Advanced geothermal drilling/completion technology	3	0	0	3
3	FEM 836	Geothermal production/power plants	3	0	0	3
4	800L	ELECTIVE COURSE	2	0	0	2
5	800L	ELECTIVE COURSE	2	0	0	2
6	800L	ELECTIVE COURSE	2	0	0	2
TOTAL			**15**			

FEM 862 - GEOTHERMAL RESERVOIR ENGINEERING

Geothermal reservoir types. Concepts of geothermal systems. Mathematical foundations of single and multi- phase flow in porous media. Analytical and numerical methods. Phase behavior. Well productivity index. Recovery factor. Simulation. Well Stimulation and engineered geothermal systems. Field Examples.

FEM 864 - ADVANCED GEOTHERMAL DRILLING/COMPLETION TECHNOLOGY

Drilling Concepts (Drilling the Limit, etc.). Drilling Optimization. Drilling Performance Analysis. Drill string Dynamics. Drilling Problems (Risk Analysis, Solutions). Under-Balanced Drilling. New Developments in Drilling Operations. Blow Out. Geothermal Drilling Technology. Well Design and Well Construction. Offshore Drilling (Well Design and Special Consideration). HPHT Wells, Horizontal and Extended Reach Wells, Multilaterals. Completion & Well Intervention. Case Studies.

FEM 866 - GEOTHERMAL PRODUCTION/POWER PLANTS

Introduction to integrated production systems. Review of reservoir inflow characterization. Single-phase and multi-phase flow modelling in wells. Flow assurance issues. Surface facilities. Production monitoring and optimization. Integrated field management. Geothermal power generating systems: single-flash steam plants; double-flash; steam plants; dry-steam plans; binary cycle power plants; advanced and hybrid systems. Field examples. Geothermal heat use without involving a power plant or a heat pump. Geothermal heat pumps. Use of spent fluids from geothermal power plants for direct use applications in so-called "cascaded" operation.

5. HYDROGEN ENERGY SPECIALIZATION

S/N	CODE	COURSE TITLE	L	T	P	UNITS
1	FEM 842	Hydrogen Production and Utilization Processes	3	0	0	3
2	FEM 844	Electrolyzers and Fuel Cell Technology	3	0	0	3
3	FEM 846	Hydrogen Economy	3	0	0	3
4	800L	ELECTIVE COURSE	2	0	0	2
5	800L	ELECTIVE COURSE	2	0	0	2
6	800L	ELECTIVE COURSE	2	0	0	2
TOTAL			**15**			

FEM 842: HYDROGEN PRODUCTION AND UTILIZATION PROCESSES

Hydrogen energy. Hydrogen production, storage, transport and distribution systems. Hydrogen production methods (steam-methane reforming, electrolysis, thermochemical cycles, photoelectrochemical hydrogen production, biological processes, etc), the hydrogen rainbow (gray, blue, green hydrogen, etc). R&D goals for hydrogen production. Technical and economic comparison of different production methods and global status, cost analysis. Hydrogen separation and purification. Hydrogen storage, physical-based storage (compressed gas, cryo/cold compressed, liquid hydrogen), material-based storage (adsorbents, metal

hydrides, etc), novel materials for hydrogen storage. Tank types and designs for compressed hydrogen and liquid state hydrogen. Hydrogen storage challenges, R&D goals, technical targets for hydrogen storage, hydrogen storage materials database. Hydrogen utilization in energy, power generation, transportation, buildings, industry. Safety, regulations, codes and standards for hydrogen.

FEM 844: ELECTROLYZERS AND FUEL CELL TECHNOLOGY

Components of electrolytic cells and electrolyzers, configuration of electrolyzer stacks, different electrolyzer technologies (PEM, AEL, SOE, etc). Water splitting reaction mechanisms, electrodes and electrocatalysts for water splitting, challenges, R&D goals, technical targets. Introduction to fuel cell technology, structure and working of fuel cells, parts of a fuel cell, fuel cell systems, types of fuel cells (PEMFC, DMFC, AEFC, SOFC, regenerative FC, etc), their advantages and applications. Efficiency and performance and associated losses in fuel cells, R&D goals, technical targets. Transportation and stationary applications of fuel cells. Microbial fuel cells. Thermodynamic analysis of fuel cells.

FEM 846: HYDROGEN ECONOMY

Definition and basic principles of hydrogen economy. Hydrogen economy and technology roadmap. Global overview of the market potential for hydrogen. Importance of hydrogen economy. Challenges of hydrogen economy. Hydrogen value chains. Design and operation of hydrogen supply chains. Clean energy and hydrogen economy. Transition pathways for hydrogen energy. Energy transition pathways for green hydrogen in Sub Saharan Africa. The future of hydrogen (opportunities and challenges). Skilling the green hydrogen economy.

6.2 MSc ELECTROCHEMICAL TECHNOLOGY

PREAMBLE

Electrochemical technology represents another important multidisciplinary area linking up the chemical, physical, biological and materials sciences and plays a vital role in several modern technological processes in diverse fields including manufacturing, new materials development, corrosion protection, environmental remediation, energy storage and conversion. Electrochemical technologies are indeed becoming increasingly important with increasing global focus on clean and sustainable energy and the associated need for clean energy storage options. This postgraduate programme focuses on two broad areas of specialization: Electrochemical Energy and Environmental Electrochemistry and equips students with cutting-edge knowledge and skills in research, development, innovations. The Electrochemical Technology programme, like other ACE-FUELS programmes, takes an immersive approach to learning both the principles and practices of electrochemical technology with much of the material based around examples and practical exercises. Students completing this course will have a firm, broad-based grasp of the current practices and directions in this exciting area and will have the knowledge and skills to apply develop new applications that better benefit humanity.

PROGRAMME OUTCOMES

At the end of this postgraduate programme the graduates should:

1. Develop and demonstrate broad-based expertise in electrochemical technology, including its applications in diverse contexts.
2. Demonstrate competence in responsible conduct of research, as well as ability to critically analyze data as well as design and manage research projects independently.
3. Develop effective oral and written skills.

4. Demonstrate ability to identify and respond to key innovation dilemmas by recognizing and exploiting relevant sources of information for innovation.
5. Understand and appreciate the importance of technological innovation to business, stakeholders and the wider economy and society
6. Be effectively prepared for professional employment and entrepreneurship.

A. MANDATORY MODULE

S/N	CODE	COURSE TITLE	L	T	P	UNITS
1	ETM 811	Fundamental Electrochemistry	2	1	0	3
2	ETM 813	Materials for Electrochemical Technology	2	1	0	3
3	ETM 815	Electrochemical Energy Storage	2	1	0	3
4	ETM 817	Electrochemical Principles and Methods	2	1	0	3
5	REM 801	Research Methods & Innovation	2	1	0	3
6	MGT 805	Entrepreneurship	2	0	0	2
TOTAL			17			

ETM 811: FUNDAMENTAL ELECTROCHEMISTRY (3 Units)

Electrodes and cell reactions. Electrolytic and galvanic cells. Thermodynamics of electrochemical reactions. Electrode kinetics. Current-voltage features of charge-transfer reactions. Interfaces, Interphases, Electrical double layers: Theory & Models and electrode processes. The electrode/solution interface at equilibrium. Polarization electrodics. Transport, activation and ohmic overpotential. Butler-Volmer equation. Mass transfer processes in electrochemistry – flux equation involving diffusion, migration and convection (dilute solution theory and concentrated solution). Applications of electrochemical principles: Electrochemical description of biological cells; electrophysiology, action potentials, cardiac fibrillation and defibrillation. Electrochemistry in environmental monitoring and remediation. Electrochemical basis of corrosion and corrosion control: Corrosion cell. Kinetics of corrosion reactions: Polarization curves, mixed potential theory, passivity, effect of mass transfer. Quantitative estimation of corrosion rates. Electrokinetic Phenomena. Electrochemical remediation for pollution control. Electrochemical synthesis of oxidizing agents (ozone, hydrogen peroxide, chlorine and hypochlorite and chlorine dioxide) and electrochemical oxidation of organic contaminants.

ETM 813: MATERIALS FOR ELECTROCHEMICAL TECHNOLOGY (3 Units)

Solid state electrochemistry. Defect chemistry. Solid state ionics. Solid and polymer ionic conductors. Electrochemistry of mixed ionic-electronic conductors. Solid state redox reactions. Electrochemical energy materials. Electrolytes and electrode materials for rechargeable and non-rechargeable batteries, electrochemical capacitors, fuel cells and electrolytic cells. Efficiency of electrode materials. Effect of microstructure on electrode material performance. Charge and mass transfer considerations. Importance of carbon science and technology. Characterization of carbon materials used in electrochemical technology. Active carbon, carbon black, fullerenes, and graphene. Carbon electrodes for Li-ion batteries, supercapacitors and fuel cells. Ionic liquids: Introduction, properties, synthesis, functionalities, applications. Electroplating and electrodeposition, magnetic thin films, metal refining and conductive polymers.

ETM 815: ELECTROCHEMICAL ENERGY STORAGE (3 Units)

Electrochemical devices and their basic principles of operation: Batteries, fuel cells, capacitors and supercapacitors; photovoltaic cells and photoelectrochemical cells, superconductors. Energy storage technologies: Electrochemical storage systems (Lead-acid battery, lithium-ion battery, liquid metal battery, nickel-based batteries, flow batteries). Electrical storage systems (Supercapacitors, superconducting magnetic energy storage). Hydrogen energy storage technology (Electrolysis with cryogenic storage). Metal-organic frameworks as molecular gas cylinders for hydrogen. Safety in hydrogen handling. Superconductors and superconducting magnetic energy storage.

ETM 817: ELECTROCHEMICAL PRINCIPLES AND METHODS (3 Units)

The solid-electrolyte interface. The electric double layer and electrochemical capacitors. Interfacial electrochemistry. Mass transfer in electrochemical systems. Electrocatalysts and electrochemical reactors. Semiconductor electrochemistry Semiconductor/electrolyte interface. Principles of electrochemical sensors. Safety procedures for work at FUTO laboratories. Analytical accounting nomenclature: Accuracy, Precision, Resolution, Error propagation etc. Overview of standard equipment used in electrochemistry (potentiostats, counter and reference electrodes, electrochemical cells etc). Design of electrochemical reactors. Experimental techniques for kinetic and/or thermodynamic parameters: Cyclic voltammetry, current time and current-potential characteristics, rotating disc electrodes, chronoamperometry, digital simulation of electrochemical processes. Survey of electrochemical processes and power sources. The general principles, theoretical and practical, of some materials characterization techniques (SEM, XRD, FTIR).

REM 801: RESEARCH METHODS & INNOVATION (3 Units)

Fundamental concepts of scientific research. Concepts underlying peer-reviewed research. Referencing: Evaluating the relevance and impact of sources. Conducting literature reviews, evaluating published findings. Using research productivity tools (statistical, referencing, research design etc). Research conceptualization and design. Writing research proposals. Authoring and publishing high-impact articles. Communication and presentation skills. Intellectual Property (IP) development, evaluation, and strategy. Strategy and innovation concepts with a focus on Research translation and technology commercialization. Business strategy frameworks, financial analysis, strategic marketing, operations management, business models, project management, business law, and Entrepreneurship.

B. MODULE OF SPECIALIZATION

There are two (2) areas of specialization in the MSc Electrochemical Technology Programme:

1. ELECTROCHEMICAL ENERGY

Module Overview

The Electrochemical Energy specialization module is devoted to the applications of Electrochemistry in the field of Energy and introduces the basic theory for electrochemical energy conversion and storage technologies. The courses are designed to familiarize students with electrochemical methods of energy conversion and with the fundamental theory of energy storage technologies to illustrate recent trends in technology development.

Learning Outcome

Upon completion of this module, the student shall develop advanced understanding of components and features of the key electrochemical energy conversion and storage technologies work, as well as understand unique new developments in electrochemical energy storage and conversion technologies. In addition, should be very familiar with the processes involved in both lab-scale fabrication and industrial-scale assembly of electrochemical storage devices. The student would better appreciate and understand how electrochemical energy storage and conversion technologies solve real-world problems at stand-alone and grid scales.

Module Contents

S/N	CODE	COURSE TITLE	L	T	P	UNITS
1	ETM 802	Energy Applications of Electrochemistry	3	0	0	3
2	ETM 804	Electrochemical Storage Technologies	3	0	0	3
3	ETM 806	Battery Technology	3	0	0	3
4	800L	ELECTIVE COURSE	2	0	0	2
5	800L	ELECTIVE COURSE	2	0	0	2
6	800L	ELECTIVE COURSE	2	0	0	2
TOTAL			15			

ETM 822: ENERGY APPLICATIONS OF ELECTROCHEMISTRY (3 Units)

Thermodynamics of electrochemical systems. Principles of equilibrium and non-equilibrium electrochemistry, transport phenomena, electrostatics, porous electrodes. Interfacial electrochemistry. Semiconductor electrochemistry and photocatalysis. Conventional and next generation electrocatalysts and electrochemical reactors. Mixed ionic-electronic conductors. Introduction to the concept of electrochemical energy. Electric power from solar cells, principles of operation, characteristics Electrochemical energy production methods. Electrochemical production of hydrogen. Water electrolysis. Safety in hydrogen handling. Electrochemical energy conversion: Fuel cells and photoelectrochemical cells. Thermodynamic and kinetic calculations for electrolysis cells and fuel cells. Mathematical models of electrochemical energy conversion. Applications of solar cells, hydrogen and fuel cells in stationary and mobile systems. Photovoltaics – Dye sensitized solar cells and challenges.

ETM 824: ELECTROCHEMICAL STORAGE TECHNOLOGIES (3 Units)

Economical and energy analyses for the introduction of energy systems based on renewable energy resources and hydrogen. Engineering and characterization of electrochemical storage devices: Important rechargeable and non-rechargeable battery technologies; various fuel cells; solar cells, capacitors and supercapacitors; photovoltaic cells, photoelectrochemical cells, different hydrogen storage technologies, superconductors. Chemical storage using hydrogen and fuel cells. Operation and design of various electrochemical storage technologies. Energy Storage Challenge: an experimental group project to design, fabricate and characterize electrochemical storage devices, including cost/benefit analysis.

ETM 826: BATTERY TECHNOLOGY (3 Units)

Basic operating principles, materials selection criteria, design and fabrication properties and capabilities, applications areas and system aspects of batteries. Components and processes in batteries. Battery production at laboratory-scale and industrial-scale assembly (electrode, cell, module). Battery management systems. Battery characterization methods (overpotential, battery capacity, state of charge, charge/discharge cycles, state of health, impedance). Review of various battery applications: mobility, mild hybrid, plug-in-hybrid, battery electric vehicle (BEV) for cars and ships, utilities, grid storage. Life Cycle Analysis according to cost and environmental aspects; material and energy consumption, reuse, recycling. Overview of specific primary and rechargeable batteries (Lead-acid, Li-ion, NiMH, NaS, metal-air etc.), including their advantages and disadvantages, operation and safety. Focus on Li-ion battery development and safety issues (thermal runaway, short-circuiting, fire/explosion hazard).

2. ENVIRONMENTAL ELECTROCHEMISTRY

Module Description

This module provides a unique overview of the principles of electrochemical science and application of electrochemical techniques and principles in environmental science, sensors, catalysis and pollution control technologies.

Learning outcomes

Having successfully completed this Environmental Electrochemistry Module, the student should clearly understand the basic principles behind modern electrochemical methods and their applications in environmental monitoring, remediation and protection. The student should have the capacity to critically evaluate the information that can be obtained from the electrochemical techniques as applied to environmental protection and management. In addition, the student should demonstrate a systematic understanding of fundamental electrochemical science principles and ability to apply such knowledge to the solution of environmental pollution problems, as well as an awareness of issues within electrochemistry that overlap with other related subjects including environmental impact, sustainability and climate change. The student shall be able to read and critically evaluate environmental electrochemical literature as well as design, develop and deploy their own tailor-made systems and interventions.

Module Contents

S/N	CODE	COURSE TITLE	L	T	P	UNITS
1	ETM 812	Electrochemical/Electrokinetic Remediation	3	0	0	3
2	ETM 814	Electrochemical Sensors and Biosensors	3	0	0	3
3	ETM 816	Advanced Oxidation Processes	3	0	0	3
4	800L	ELECTIVE COURSE	2	0	0	2
5	800L	ELECTIVE COURSE	2	0	0	2
6	800L	ELECTIVE COURSE	2	0	0	2
TOTAL			**15**			

ETM 812: ELECTROCHEMICAL/ELECTROKINETIC REMEDIATION (3 Units)

Classification of pollutants. Environmental media and pollutant transport. Current methods for pollutant analyses. Current methods for pollutant detection and treatment. The concept of Environmental Electrochemistry. Electroanalytical techniques. Electrochemistry of inorganic and organic pollutants. Electrolysis and electrodeposition. Design of electrochemical reactors. Photoemission at metal electrodes. Electrokinetic phenomena and electrochemical remediation. Direct and indirect electrolysis of pollutants in the aqueous phase. Electroflotation, electrocoagulation and electroflocculation. Membrane-assisted Processes. Electrokinetic remediation of soils and sediments. Water disinfection: Background and principles. Electrochemical disinfection of water. Photoelectrochemical disinfection of air and water. Emerging materials for electrochemical treatment of pollutants.

ETM 814: ELECTROCHEMICAL SENSORS AND BIOSENSORS (3 Units)

Definitions and theoretical background. Sensing systems and components. Signal transducing systems; Receptor systems; Sensing systems. Analytical performance indicators (sensitivity, selectivity, accuracy, precision, response time, reversibility, repeatability). Basic concepts in electroanalytical chemistry. Electronic and electrochemical signals, signal-to-background ratio and detection limits. Electroanalysis of environmental samples. Direct voltammetric (or polarographic) determination of pollutants. Ion-selective electrodes and potentiometry. Electrochemical sensors in environmental analysis. Types of electrochemical sensors. Sensors and biosensors for inorganic and organic contaminants. Materials and membranes for sensor electrode fabrication (conducting polymers, porous membranes etc.). Functional materials for sensing systems. Development of electrochemical sensors by micro and nanofabrication techniques. Integrated sensing systems and microfluidics. Micro-electro-mechanical systems (MEMS) and Bio(MEMS). Lab-on-a-chip systems. Biochips. Micro-total-analytical systems (μTAS). Detecting systems: Conductivity detectors. Photo-assisted detection of pollutants. Electrochemical detection and enumeration of microorganisms.

ETM 816: ADVANCED OXIDATION PROCESSES (3 Units)

Fundamentals and background of advanced oxidation processes (AOPs). The role of hydroxyl radicals and their generation. Reaction kinetics and degradation mechanisms of organic pollutants by hydroxyl radicals. Effects of process parameters and scavenging media on degradation efficiency. Removal of specific pollutants in aqueous media; biodegradability enhancement and toxicity reduction. Fundamentals of UV irradiation. Absorption and bond dissociation energies. UV sources and their characteristics. UV photolysis background. Actinometry. Direct photolysis. UV light based (photochemical and photocatalytic) AOPs for water and wastewater treatment; opportunities and challenges. Modeling approach for AOPs simulation. Common oxidants and catalysts and their alternatives. Fenton reaction. Alternative catalysts for Fenton reaction. Types of homogeneous and heterogeneous Fenton and photo-Fenton processes; influencing parameters, reaction kinetics and mechanisms. Iron catalysts in heterogeneous Fenton processes; sources and supports. Ozonation; background and fundamentals, reaction kinetics and mechanisms. Application of homogeneous and heterogeneous catalytic ozonation in water treatment. Reactor configurations; batch and continuous flow systems.

6.3 MSc NANOTECHNOLOGY

PREAMBLE

The study of nanomaterials, nanoscience and nanotechnology exists at the overlap between physics, chemistry and biology and incorporates the cross-disciplinary principles and theories to design and development of new products on the nanoscale. This postgraduate programme has three possible areas of specialization: Nanophysics Specialization, Nanochemistry Specialization, Nanobiotechnology Specialization and equips students with cutting-edge knowledge and skills in research, development, innovation and application of nanotechnology in diverse fields. The course takes an immersive approach to learning both the principles and practices of nanotechnology with much of the material based around examples and practical exercises. Students completing this course will have a firm, broad-based grasp of the current practices and directions in this exciting area and will have the knowledge and skills to design new products and processes on the nano-scale.

PROGRAMME OUTCOMES

At the end of this postgraduate programme in Nanotechnology, the graduates should:

1. Develop and demonstrate broad-based expertise in nanotechnology, including identification, design, fabrication, characterization and utilization of nanomaterials in diverse fields.
2. Demonstrate competence in responsible conduct of research, as well as ability to critically analyze data as well as design and manage research projects independently.
3. Develop effective oral and written skills.
4. Demonstrate ability to identify and respond to key innovation dilemmas by recognizing and exploiting relevant sources of information for innovation.
5. Understand and appreciate the importance of technological innovation to business, stakeholders and the wider economy and society
6. Develop strategies and practices to manage the concerns and risks associated with widespread utilization of nanomaterials.

A. MANDATORY MODULE

S/N	CODE	COURSE TITLE	L	T	P	UNITS
1	NTM 801	Nanostructure and Characterization	2	1	0	3
2	NTM 803	Nanomaterials Characterization and Applications	2	1	0	3
3	NTM 805	Cross-Disciplinary Nanoscience	2	1	0	3
4	NTM 807	Environmental, Health, Social Impacts of Nanotechnology	2	1	0	3
5	REM 801	Research Methods & Innovation	2	1	0	3
6	MGT 805	Entrepreneurship	2	0	0	2
TOTAL			**15**			

NTM 801: NANOSTRUCTURE AND CHARACTERIZATION (3 Units)

Basics and Scale of Nanotechnology: History, nature and development of nanoscience. Scientific revolutions. Time and length scale in structures. Issues of scale in relation to nanotechnology. Properties at nanoscale (optical, mechanical, electronic and magnetic). Classification of nanomaterials: Classification based on dimensionality (1-D, 2-D, 3-D). Quantum Dots, wells and wires: Carbon-based nano materials (buckyballs, nanotubes, graphene). Metal-based nano materials (nanogold, nanosilver and metal oxides). Nanofluids. Nanocomposites. Nanopolymers. Nanoglasses. Nano ceramics. Biological nanomaterials. Nanosynthesis/Fabrication of Nanostructures: *Chemical Methods*: Metal Nanocrystals by Reduction. Solvothermal Synthesis. Photochemical Synthesis. Sonochemical Routes. Physical vapour deposition (PVD), chemical vapour deposition (CVD) and atomic layer deposition (ALD). Superlattices/quantum wells. *Physical Methods:* Ball Milling. Electrodeposition. Spray Pyrolysis. Flame Pyrolysis. DC/RF Magnetron Sputtering. Molecular Beam Epitaxy (MBE). Nanofluid preparation methods: Sonification. *Nanofabrication:* Self-assembly. Patterning and lithography. Molecular imprinting methodologies and applications. Photolithography and its limitation-Electron-beam lithography (EBL)- Nanoimprint – Soft lithography patterning. Important design factors at the nanoscale. Nucleation and deposition of nanostructures. Functionalization of nanomaterials.

NTM 803: NANOMATERIALS CHARACTERIZATION AND APPLICATIONS (3 Units)

Ellipsometry/ Quartz crystal microbalance, Atomic force microscopy (AFM) and scanning microscopes, Scanning tunneling microscopy (SEM)/Scanning electron microscopy (SEM)/ transmission electron microscopy (TEM), Surface Fourier Transform Infrared (FTIR) spectroscopy, Confocal Raman imaging. Nanomaterials Applications*:* Current and future applications of nanostructured materials. Molecular electronics and printed electronics. Nanoelectronics. Polymers with special architecture. Liquid crystalline systems. Nanofluids. Linear and nonlinear optical and electro-optical properties. Chemical and biosensors. Materials protection and corrosion control. Environmental protection and pollution control. Nanomedicine and Nanobiotechnology. Energy conversion and energy storage. Catalysis. Nanocomposites. Big data analytics for predicting materials design and use.

NTM 805: CROSS-DISCIPLINARY NANOSCIENCE (3 Units)

Nanomaterials: ceramics, glasses, polymers, fullerenes, graphene, carbon nanotubes, polymeric and inorganic nanostructures, metal oxides, nano-powders, nanocomposites, nano-alloys and quantum dots. Structural properties in nanochemistry: chemical crystallography (introduction to bonding, crystal structures and properties), reactivities of nanostructured materials, physical and chemical properties, processing nanostructured materials. Quantum mechanics: The fundamentals of nanophysics. The quantum nature and construction of atoms, molecules and nanoparticles. Structural properties in nanophysics. Crystallography of nanostructured materials, physical and chemical properties of nanoparticles and interfaces, processing of nanostructured materials. Biological chemistry: Bonds, acids and bases, chemical reactions, enzymes. Macromolecules: Carbohydrates, lipids, proteins, nucleic acids. Cells and house-keeping functions: Cell structure and metabolic processes.

NTM 807: ENVIRONMENTAL, HEALTH, SOCIAL IMPACTS OF NANOTECHNOLOGY (3 Units)
Nanomaterials and Environmental Impact: Fields of application of nanomaterials (electronics, environment, energy, communication, health, everyday life) Environmental fate, behavior and transport (in air, water bodies and soil). Bio-availability, consumer exposure, environmental exposure-assessment. Bio-accumulation and biomagnification. Life cycle assessment. Nanomaterials and Health Risks: Nanomaterials hazards identification and characterization. Nanotoxicology and ecotoxicology. Exposure risks and health-risk assessment; cancer and non-cancer risks. Detoxification and bioactivation pathways; surface modification; biopersistence; quantum dots and cellular imagining; biomedical applications of nanomaterials. Preventive measures: development and implementation of regulations and industry best practices on use of nanomaterials. Ethical issues associated with nanotechnology and its applications. Social perception of nanotechnologies: Improvement in standards of living versus ethical, health, and environmental concerns.

REM 801: RESEARCH METHODS & INNOVATION (3 Units)
Fundamental concepts of scientific research. Concepts underlying peer-reviewed research. Referencing: Evaluating the relevance and impact of sources. Conducting literature reviews, evaluating published findings. Using research productivity tools (statistical, referencing, research design etc). Research conceptualization and design. Writing research proposals. Authoring and publishing high-impact articles. Communication and presentation skills. Intellectual Property (IP) development, evaluation, and strategy. Strategy and innovation concepts with a focus on Research translation and technology commercialization. Business strategy frameworks, financial analysis, strategic marketing, operations management, business models, project management, business law, and Entrepreneurship.

B. MODULE OF SPECIALIZATION

There are three (3) areas of specialization in the MSc Nanotechnology programme:

1. NANOPHYSICS SPECIALIZATION

S/N	CODE	COURSE TITLE	L	T	P	UNITS
1	NTM 802	Micro and nano fabrication	3	0	0	3
2	NTM 804	Quantum nanostructures	3	0	0	3
3	NTM 806	Solid state physics and optoelectronics	3	0	0	3
4	800L	ELECTIVE COURSE	2	0	0	2
5	800L	ELECTIVE COURSE	2	0	0	2
6	800L	ELECTIVE COURSE	2	0	0	2
TOTAL			**15**			

NTM 802: MICRO AND NANO FABRICATION (3 Units)
Crystal Growth, Wafer Preparation, Epitaxy and Oxidation: Basic steps in IC fabrication. Electronic grade silicon. Crystal plane and orientation. Defects in the lattice. Crystal growth. Silicon shaping and processing. Vapour and liquid phase epitaxy, Epitaxial Evaluation. Growth mechanism. Thin oxides. Oxidation Techniques and systems. Lithography, Wet and Dry Etching: Mask Making. Optical lithography, Electron lithography, X-ray lithography, Ion lithography. Plasma properties. Feature size control and Anisotropy Etch mechanism. Lift off Techniques. Plasma reactor. Introduction to Atom Lithography based on metastable atoms beam (MAB) and self-assembled monolayer structures (SAMs), on Si substrates. Exposure to MAB. Arrays of Si (111), (110) and (100) microstructures. Deposition, Diffusion, Ion Implantation: Deposition processes: Physical vapour deposition, Sputtering, Polysilicon, Plasma assisted deposition. Models of diffusion in solids: Atomic diffusion mechanism. Device and MOS Circuit Fabrication: Isolation, p-n junction isolation, self-alignment, local oxidation. Trench techniques: Planarization, Chemical, mechanical polishing, Metallization and Gettering, Basic MOS device considerations.

NTM 804: QUANTUM NANOSTRUCTURES (3 Units)

Basic Quantum Modelling; Density of States; Nucleation and Growth of Nanoparticles; Quantum Dots & Nanoparticles; Quantum Dot devices; Quantized Conductance; Quantum Computing; Assembly of Nanoparticles; Nanotubes and Nanowires; and Single Molecule Magnets. Selected nanomaterials: Quantum Confined Materials: Inorganic quantum confined structures. Manifestation of quantum confinement. Quantum confined stark effect. Dielectric confinement effect, superlattices. Core shell quantum dots, quantum wells. Quantum confined structures as Lasing media. Organic Quantum confined structures. Photonic Crystals: Important features of photonic crystals. Dielectric mirrors and interference filters. photonic crystal laser. Photonic crystal fibers (PCFs). Photonic crystal sensing. Nanophotonic Fabrication**:** Adiabatic nanofabrication, Nonadiabatic nanofabrications: near field optical CVD and near field photolithography. Self-assembling method via optical near field interactions. Regulating the size and position of nanoparticles using size dependent resonance – Size controlled, position controlled and separation-controlled alignment of nanoparticles.

NTM 806: SOLID STATE PHYSICS AND OPTOELECTRONICS (3 Units)

Crystal Structures: Brillouin Zones and elementary diffraction. Metals and the Free electron model. Band theory of solids. Semiconductors and devices p-n junctions, transistors, LEDs. Magnetism. Superconductivity and devices. Finite solids and nanostructures. Wave nature of Light. Waveguides, Optical fibres. Photodetectors and Image sensors. Polarization and non-linear optics. Nanotechnology in Electrical and Electronics Industry: Advantages of nano electrical and electronic devices. Integrated Circuits. Lasers. Micro and Nano Electromechanical systems. Sensors, Actuators, Optical switches, Bio-MEMS. Diodes and Nano-wire Transistors. Data memory. Lighting and Displays. Organic electroluminescent displays. Quantum optical devices. Batteries. Fuel cells. Photo-voltaic cells. Electric double layer capacitors. Lead-free solder. Nanoparticle coatings for electrical products.

2. NANOCHEMISTRY SPECIALIZATION

S/N	CODE	COURSE TITLE	L	T	P	UNITS
1	NTM 812	Advanced nano and organic synthesis	3	0	0	3
2	NTM 814	Structure and properties of nanomaterials	3	0	0	3
3	NTM 816	Soft nanomaterials and nanocomposite materials	3	0	0	3
4	800L	ELECTIVE COURSE	2	0	0	2
5	800L	ELECTIVE COURSE	2	0	0	2
6	800L	ELECTIVE COURSE	2	0	0	2
TOTAL			**15**			

NTM 812: ADVANCED NANO AND ORGANIC SYNTHESIS (3 Units)

Organic Synthesis: Oxidation and reduction methods, stereochemistry and products from hydride and dissolving-metal reductions. Synthetic organic applications of phosphorus, silicon, titanium, copper, palladium and ruthenium. Chemistry of heterocycles. Mechanisms of molecular rearrangements involving carbo-cations, electron deficient nitrogen and oxygen species, and of carbonyl compounds. Experimental and instrumental methods and techniques of organic chemistry. Nano Synthesis methods: Electrosynthesis, chemical, thermal and microwave synthesis. Thin Film Deposition Methods. Thermal chemical vapor deposition (CVD), catalytic synthesis and plasma synthesis. Tuning nanoparticles sizes, shapes and dimensionality by appropriate choice of the chemical precursors and/or of the reaction's conditions. Properties of nanomaterials: Chemical, electrochemical, spectroscopic, microscopic, mechanical, electrical and optical properties of materials. Synthetic nanomaterials: Ceramics, glasses, polymers, fullerenes,

nanotubes, graphenes, carbon nanotubes, metal oxides and catalysts (PGMs etc), nanocrystals, nanocomposites, nano-alloys, quantum dots, zeolites, metal-organic frameworks.

NTM 814: STRUCTURE AND PROPERTIES OF NANOMATERIALS (3 Units)

Solids, Surfaces & Interfaces: Electronic structures from atoms to the solid state; crystalline and non-crystalline solids; surface modification reactions. Interfaces and interface structure. Chemical, electrochemical and biological interfaces. Interfacial reactions, adsorption, catalysis. Nanoscale structure formation/surface patterning. Capillary phenomena and molecular self-assembly. Catalytic, electrical, optical, and magnetic properties of nanomaterials. Basic quantum chemistry: orbitals; band structures, density of states; Nanomaterials and Interfaces: Tailored Interfaces and Switchable Surfaces; Nanocomposites; Sol-Gel Materials and Mesoporous Structures; Organic-Inorganic Hybrids; Copolymeric Membranes; Dendrimers and Polyhedral Oligomeric Silsesquioxane Nanostructures; Molecular Amplification; Core-Shell Materials; and Nanotube Devices. Nanocatalysts: Smart materials. Heterogenous nanostructures and composites – semiconductor nanocatalysts (TiO_2, ZnO) and doped semiconductors. Nanoparticles for water purification-Photocatalytic mechanism, general pathways and kinetics. Magnetic Nanoparticles Nanoscale carbon for contaminant separation Nanostructures for Molecular recognition (Quantum dots, Nanorods, Nanotubes). Molecular Encapsulation and its applications. Nanoporous zeolites. Self-assembled Nanoreactors.

NTM 816: SOFT NANOMATERIALS AND NANOCOMPOSITE MATERIALS (3 Units)

Polymer Chemistry: Basic definitions and polymer nomenclature, molecular weight averages and distributions, constitutional and configurational isomerism, rubber elasticity, step-growth and free-radical chain-growth polymerizations, emulsion polymerization. Macromolecules: Applications of macromolecules in nanotechnology. Block copolymers and self-assembled polymerization. Micelles and colloids. Dendrimers and molecular brushes. Supramolecular polymers, polymeric blends and macromolecular nanocomposites. Polymer templates. Applications in the manufacturing of nanostructured materials and nanoscale devices. Surface functionalization: Interfacial electrochemistry; Polymer adsorption; Langmuir-Blodgett layers; layer-by-layer assemblies; Chemical grafting on gold; Silanization; Radical grafting; Conductive polymers; Micro patterning. Nanocomposites: Structure-property relationships of nanocomposites, incorporation of different nanophases into polymeric matrixes for functional materials fabrication, surface energy control, dispersion methods, techniques for nanocomposite materials characterization. Influence of dispersed (organic or mineral) elements on; the chemical nature and morphologies of nanocomposite materials. Common nanocomposites (polymer-clay nanocomposites etc). Critical issues in synthesis, fabrication, processing, and characterization of nanocomposites. Challenges in manufacturing low cost real-life components for industrial applications; commercial success stories, future directions.

3. NANOBIOTECHNOLOGY SPECIALIZATION

S/N	CODE	COURSE TITLE	L	T	P	UNITS
1	NTM 822	Fundamentals of bionanotechnology	3	0	0	3
2	NTM 824	Biomaterials and tissue engineering	3	0	0	3
3	NTM 826	Nanoscale biosystems	3	0	0	3
4	800L	ELECTIVE COURSE	2	0	0	2
5	800L	ELECTIVE COURSE	2	0	0	2
6	800L	ELECTIVE COURSE	2	0	0	2
TOTAL			**15**			

NTM 822: FUNDAMENTALS OF BIONANOTECHNOLOGY (3 Units)

Development of nanobiotechnology – Timelines and progress. Biomolecules and biomaterials. Biological performance of materials. Structure of natural materials. Biomolecules and biomaterials as bases for inorganic structures. Inorganic replicas of biometerials. Nanostructured materials in biotechnology. Biointerface structure and characterization. Surface derivatization and characterization. Molecular prints of

biomolecules. manufacturing process for producing nanoparticles in the biotechnology and pharmaceutical industries. Nanoscale biomaterials used for medical and drug delivery devices. Bioconjugates; Immobilization techniques

NTM 824: BIOMATERIALS AND TISSUE ENGINEERING: (3 Units)
Overview of implantable biomaterials: Definition, Timelines and progress. Different types of biomaterials (metals, ceramics, synthetic polymers, and biopolymers). Tissues structure and organization (vascular wall, cartilage, bone) Enzyme reactors based on nanostructured materials. Tissue engineering and regenerative medicine: Tissues structure and organization (vascular wall, cartilage, bone). Materials in Medicine; Biomineralization and Biomimetic Approaches; Thin films, grafts and coatings; Host Reaction to Biomaterials and Artificial Organs. Nanomaterials in bone substitutes and dentistry. Implants and Prosthesis. Reconstructive Intervention and Surgery. Nanorobotics in Surgery Engineering. Drug delivery. Therapeutic applications. Nanoscale biomaterials for medical and drug delivery devices. Gene technology and high throughput systems. Stem cell and precursor cell-based therapies

NTM 826: NANOSCALE BIOSYSTEMS (3 Units)
An introduction to the chemistry of amino acids, carbohydrates, lipids and nucleic acids. Protein and enzyme structure and function. An introduction to cell biochemistry. Self-assembly of peptides and proteins. Self-organizing systems. Synthesis, assembling and encapsulation of nanoparticles. Isolation/ purification and characterization of nanoparticles. Molecular modeling and simulation. Biointerfaces, nanoscale patterning, micro and nano-topography. Biomembranes, biomimetics, biochips, bioseparation, biosensors, molecular recognition elements in nanosensing. Biomicroelectromechanical systems (BioMEMS). Biomedical applications of nanomaterial devices. Nanomedicine: Diagnostics (colorimetric, fluorometric, biosensors, surface Plasmon resonance), Disease diagnostics based on molecular changes. Nanopharmacology. Therapeutics, Imaging. Physiological response to nanomaterials. Systematic and cellular immunological responses to different nanomaterials.

6.4 MSc CORROSION TECHNOLOGY

PREAMBLE
Corrosion is a phenomenon of great importance because of its disastrous effects on the economy, safety, energy consumption and environment. The oil and gas industry in Nigeria for instance loses up to $765 Million USD yearly to corrosion, with profound environmental degradation due to products spillage. This postgraduate programme in Corrosion Technology provides unique and comprehensive training on the theory and practice of corrosion and corrosion control interventions in varied environments. By means of an innovative blended-learning approach involving classroom teaching and practical hands-on sessions, the students will receive fundamental training on corrosion appreciation and monitoring as well as diagnosing corrosion problems and choosing appropriate corrosion control technologies to solve diverse corrosion-associated problems. The ACE-FUELS Corrosion Technology programme provides an exceptional opportunity for bright students from Nigeria and Sub Saharan Africa to develop and diversify their skill set and ultimately enhance their employability across a broad spectrum of national, regional and multinational companies.

PROGRAMME OUTCOMES
At the end of the programme in Corrosion Technology, the graduates should:

1. Develop and demonstrate broad-based expertise in the theory and practice of corrosion monitoring, assessment and control as well as deployment of corrosion protection interventions in diverse fields.
2. Demonstrate competence in responsible conduct of research, as well as ability to critically analyze data as well as design and manage research projects independently.
3. Develop effective oral and written skills.
4. Demonstrate ability to identify and respond to key innovation dilemmas by recognizing and exploiting relevant sources of information for innovation.
5. Understand and appreciate the importance of technological innovation to business, stakeholders and the wider economy and society
6. Develop strategies and practices to manage corrosion and its associated consequences and risks.

A. MANDATORY MODULE

S/N	CODE	COURSE TITLE	L	T	P	UNITS
1	CTM 801	Corrosion Basics	2	1	0	3
2	CTM 803	Selected Corrosion Control Techniques	2	1	0	3
3	CTM 805	Corrosion in the Energy Sector	2	1	0	3
4	CTM 807	Corrosion and Environmental Management	2	1	0	3
5	REM 801	Research Methods & Innovation	2	1	0	3
6	MGT 805	Entrepreneurship	2	0	0	2
TOTAL			**15**			

CTM 801: CORROSION BASICS (3 Units)

The Corrosion Phenomenon: Definition of corrosion. Electrochemistry of corrosion. Corrosion in different environments. Factors that influence rate of corrosion. Uniform and galvanic corrosion, Localized (Pitting and crevice) corrosion, Galvanic corrosion, De-alloying, Passivation, Electrochemical and semiconducting properties of passive films. Metallurgical Aspects: Introduction to Metallurgy. The microstructure of common metals/alloys. Defects in metals (grain boundaries, inclusions, etc). Effect of microstructure and metallurgical factors on corrosion behavior of materials. Corrosion Monitoring Techniques: Classical methods (gravimetric, gasometric, thermometric); Electrochemical methods (polarization, impedance, noise, voltammetry); Surface imaging techniques (microscopy, scanning probe techniques); Surface analysis (XPS, EDX, FTIR,); Pourbaix Diagram (Potential - pH Diagram), Evans diagram. Basic Corrosion Mechanisms: Corrosion of iron and steel. Corrosion of aluminium alloys. Corrosion of magnesium alloys. Corrosion in different environments: Acidic solution, salt water, alkaline solution, atmosphere, Microbial influenced corrosion, high temperature oxidation.

CTM 803: SELECTED CORROSION CONTROL TECHNIQUES (3 Units)

Materials Selection and Design: The Importance of Design in Corrosion Prevention. Compatibility of Materials and Environments. Materials Selection for Corrosion Control (Metals, Alloys, Nonmetals, Composites). Recent advances in corrosion resistant materials. Corrosion Inhibitors: Corrosion Inhibition (Theory and Practice). Fields of application of corrosion inhibitors. Environmentally friendly corrosion inhibitors. Corrosion Inhibition mechanisms and models. Protective Coatings: Overview of Protective coating systems. Organic coatings, Metallic coatings, Ceramics coatings, Nanocomposite coatings, Functional coatings. Surface preparation and coating application techniques. Coating failures: causes and prevention.

CTM 805: CORROSION IN THE ENERGY SECTOR (3 Units)

Corrosion in oil and gas industry: The corrosion challenge in oil and gas industry in Nigeria and abroad. Corrosion of oil/gas facilities (upstream and downstream). Factors that influence corrosion in oil and gas

sector. Common aggressive environments in oil and gas industry: Pipelines and subsoil environments, drilling fluids, offshore environment, refineries, storage facilities, microbial influenced corrosion, CO_2 and H_2S Corrosion. Corrosion mitigation techniques in oil and gas: Corrosion inhibitors, anticorrosion and antifouling coatings, biocides, cathodic protection systems. Corrosion in renewable energy systems: Degradation of energy infrastructure in extreme environmental conditions. Pollution-related pollution. Materials selection for extreme environments. Coatings for extreme environments. Efficient corrosion monitoring and control. Corrosion behavior solar panels, and support structures. Developing more corrosion resistant and long-lasting PV panels. Enhanced durability and reliability of PV systems. Corrosion risks to renewable energy systems and consequences. Corrosion in turbines and power plants: High temperature corrosion in turbines and power plants. Alloys and coatings for improved high temperature corrosion resistance. Role of oxide scales in high temperature corrosion. Structure and composition of effective oxide scales.

CTM 807: CORROSION AND ENVIRONMENTAL MANAGEMENT (3 Units)

Structured Framework for Corrosion Management. Corrosion Management Policy and Strategy Corrosion management systems and features of successful corrosion management systems. Corrosion Management Planning & Implementation. Big Data Analytics for corrosion prediction and management. Corrosion Risk Assessment. Risk Based Inspection. Risk based corrosion management system. Identification of corrosion threats. HACCP programs for corrosion. Lifecycle cost analysis. Corrosion control strategies. Corrosion monitoring and inspection. Review of programme performance. Proactive and Reactive Measurement of Performance Corrosion modeling and lifetime prediction. Environmental, Social and Economic Impact of Corrosion: Economic consequences: Loss of efficiency, Product contamination, Depletion of resources. Social impacts: Safety concerns, Health concern. Environmental impact: Environmental monitoring (soil, water, groundwater, sediment, ecology) of locations with corroding structures. Environmental assessment of corrosion control interventions. Life cycle impact assessment of corrosion control interventions.

REM 801: RESEARCH METHODS & INNOVATION (3 Units)

Fundamental concepts of scientific research. Concepts underlying peer-reviewed research. Referencing: Evaluating the relevance and impact of sources. Conducting literature reviews, evaluating published findings. Using research productivity tools (statistical, referencing, research design etc). Research conceptualization and design. Writing research proposals. Authoring and publishing high-impact articles. Communication and presentation skills. Intellectual Property (IP) development, evaluation, and strategy. Strategy and innovation concepts with a focus on research and technology commercialization. Business strategy frameworks, financial analysis, strategic marketing, operations management, business models, project management, business law, and entrepreneurship.

B. MODULE OF SPECIALIZATION

The Module of specialization in the MSc Corrosion Technology programme comprises five (5) core courses, from which the student can choose any three (3), in addition to any three (3) elective courses, to achieve the required 15 Units:

S/N	CODE	COURSE TITLE	L	T	P	UNITS
1	CTM 802	Anticorrosion coatings technology	3	0	0	3
2	CTM 804	Corrosion inhibition/inhibitors	3	0	0	3
3	CTM 806	Microbial induced corrosion	3	0	0	3
4	CTM 808	Cathodic protection	3	0	0	3
5	CTM 810	Corrosion in reinforced concrete	3	0	0	3
4	800L	ELECTIVE COURSE	2	0	0	2
5	800L	ELECTIVE COURSE	2	0	0	2
6	800L	ELECTIVE COURSE	2	0	0	2
TOTAL			**15**			

CTM 802: ANTICORROSION COATINGS TECHNOLOGY (3 Units)

Introduction to paints, coatings and anticorrosion coatings. Coating system components and their functions (pigment, binder and solvent). Coating properties: Rheological properties, optical properties, adhesion, mechanical properties and chemical properties. Primers, intermediate coats, top coat and their functions. Corrosion inhibiting primers. Mechanisms of anticorrosion action. Barrier and special functions of coatings. Surface Coating defects. Coating Application: Surface Preparation Techniques: Mechanical methods (Sand blasting and Flame clearing). Conversion Coatings and Pretreatment Chemicals. Paint Application Techniques: (Brushing, dipping, spraying, electrodeposition, vacuum impregnation etc). Functional Coatings: Self-healing/Smart Coatings, Superhydrophobic Coatings

CTM 804: CORROSION INHIBITION/INHIBITORS (3 Units)

Corrosion control by chemical treatment. Classification of corrosion inhibitors. Corrosion inhibition mechanisms. Benign and harmful corrosion inhibitors. Critical concentrations and corrosion inhibition efficiency. Fields of application of corrosion inhibitors. Corrosion inhibitors for different environments (acidic, alkaline, salt water, CO_2, concrete, simulated body fluids). Corrosion inhibitors for iron/steel, aluminium, copper, magnesium. Environmentally friendly corrosion inhibitors. Biomass corrosion inhibitors. Corrosion inhibited coatings for iron/steel and magnesium alloys. Selectivity and specificity of action of corrosion inhibitors. Techniques for predicting and monitoring corrosion inhibition performance. Computational modeling of corrosion inhibitor performance.

CTM 806: MICROBIAL INDUCED CORROSION (3 Units)

Description of microbiologically influenced corrosion (MIC). Bacterial transport, attachments and general mechanism. Role of aerobic and anaerobic microorganisms. MIC and biofilms. MIC failure analysis. General classification of bacteria in MIC. Common Microorganisms Associated with MIC. Sulfate Reducing Bacteria (SRB). Mechanisms and models of SRB corrosion. Sulphur-Oxidizing Bacteria (SOB) and acid-producing bacteria (APB). Iron-Oxidizing Bacteria (IOB). MIC evaluation and assessment: Chemical analysis using biosensors; Fiber-optic microprobe; Electric field mapping; DNA probes; Scanning electron microscope; Atomic force microscope; Oxygen microelectrodes; Corrosion sensors; Electrochemical measurements. MIC prevention and control: MIC prevention is cheaper than control. Maintaining sterile environment. Appropriate design, Environmental control. Complete drainage and dry storage. Chemical/biological treatment using oxidizing or non-oxidizing biocides, Biocides for different applications.

CTM 808: CATHODIC PROTECTION (3 Units)

History of Cathodic Protection; theory and practice. Practical Parameters in cathodic protection: Structure potentials, Current density requirements. Cathodic Protection and Coatings. Cathodic Protection of Underground Pipelines and Storage Tanks: Cathodic protection of terrestrial pipeline transportation systems. Cathodic Protection of buried pipelines. Cathodic Protection of Storage Tanks. Modeling and Prediction of Pipeline Corrosion, Sacrificial Anodes, Cathodic Protection: Methods of Applying Cathodic Protection. Galvanic Anode Systems. Applications of Galvanic Anode Systems. Advantages of Galvanic Anode Systems. Limitations of Galvanic Anode Systems. Anode Selection criteria. Specifications of Galvanic Anode Systems

CTM 810: CORROSION IN REINFORCED CONCRETE (3 Units)

Processes in Concrete Corrosion: Corrosion reactions and mechanisms. Composition and properties of concrete. The nature of concrete environment. Forms of corrosion associated with concrete. Corrosion of steel in concrete: Conditions for initiation and propagation. Factors that control corrosion rates in concrete. Effect of aggressive species like chloride, carbon dioxide, sulphate, and moisture. Testing and Monitoring Concrete Corrosion: Corrosion rate measurement, Half-cell potential survey, pH measurement, Corrosion sensors for concrete structures. Corrosion control in reinforced Concrete: Natural protectivity/resistivity of concrete. Concrete quality porosity, permeability, depth of cover, water/cement ratio, and chloride content.

Corrosion inhibitors and additives. Membranes and sealers. Epoxy coating. Galvanizing. Cathodic protection. Choosing appropriate corrosion control interventions.

6.5 GENERAL ELECTIVE COURSES

S/N	COURSE CODE	COURSE TITLE	L	T	P	UNITS
1	CHM 824	Electrochemical Applications	2	0	0	2
2	ETM 801	Basic Electrochemistry	2	0	0	2
3	PTE 824	Introduction to Polymer Science	2	0	0	2
4	NTM 832	Nanotechnology for Energy Applications	2	0	0	2
5	NTM 834	Computational Modeling & Simulation Methods	2	0	0	2
6	MGT 801	Project Management Basics	2	0	0	2
7	MGT 803	Change Management	2	0	0	2
8	MGT 805	Entrepreneurship	2	0	0	2
9	EVM 801	Climate Change	2	0	0	2
10	CHM 864	Statistical Thermodynamics	2	0	0	2
11	CHM 868	Applied Spectroscopy and Electrochemistry	2	0	0	2
12	FEM 842	Smart Grid Technology Overview	2	0	0	2
13	FEM 844	Fuels and Combustion	2	0	0	2
14	FEM 846	Renewable Energy Finance and Management	2	0	0	2
15	FEM 852	Finite Element Methods	2	0	0	2
16	FEM 854	Exergy Analysis	2	0	0	2
17	FEM 856	Rock Mechanics	2	0	0	2
18	FEM 858	Mini-grids: Planning and Design	2	0	0	2
19	FEM 852	Appliances for off-grid communities	2	0	0	2

CHM 624: ELECTROCHEMICAL APPLICATIONS (2 Units)

Electrochemical material evaluation principles for the choice of electrodes and electrochemical systems. Electroanalysis, Desalination, Demineralization, Electrodecantation and Electrofloatation as separation techniques in electrochemical industries. Polarography at rotating disc electrodes as an electroanalytical technique. Electrometallurgy and electro-refining in mineral processing. Electrosynthesis of key industrial chemicals: chlorine, sodium hydroxide, hydrogen peroxide, sodium perchlorate, aluminum, adiponitrile (used for making nylon-66) etc

ETM 801: BASIC ELECTROCHEMISTRY (2 Units)

Electrodes and cell reactions. Electrode kinetics. Interfaces, Interphases, Electrical double layers and electrode processes. Butler-Volmer equation. The electrode/solution interface at equilibrium. Polarization electrodics. Some technological aspects of electrodics.

PTE 824: INTRODUCTION TO POLYMER SCIENCE (2 Units)

Introduction to polymer science. Polymer synthesis: Step-growth polymerization, chain growth polymerization and controlled free radical polymerization. Molecular weight and molecular weight distribution. Mechanical property relationships: Visco-elastic properties and thermo-mechanical properties of polymers. Polymer morphology: Intermolecular forces, crystalline and amorphous phases, cross linking. Copolymers: Homopolymer, graft, alternating and random copolymers. Polymer density. Mechanical properties: Strain, stress, toughness, modulus. Polymer gels. Thermal properties: Melting point, glass transition temperature, degradation, crystallization. Hydrophobic and hydrophilic properties. Electrical

properties. Polymer characterization: Thermal gravimetric analysis (TGA), differential thermal analysis (DTA), differential scanning calorimetry (DSC), scanning electron microscopy (SEM) atomic force microscopy (AFM)Fourier transform infrared spectroscopy (FTIR), dielectric strength, surface resistivity.

NTM 832: NANOTECHNOLOGY FOR ENERGY APPLICATIONS (2 Units)
Introduction to Nano scale materials & nanotechnologies: synthesis, characterization, functionalization of nanomaterials: some applications and challenges. Energies and nanomaterials: Introduction; context and challenges dealing with energy; energy and power; production, storage, distribution (smart grids) and use of energy; some illustrations. Nanomaterials for solar energy applications: Semiconductors, Interaction of light with matter, solar cells basics. First to third generation solar cells, nanocrystalline-based solar cells, emerging thin film photovoltaic: organic solar cells, hybrid solar cells. Solar cooling and heating. Nanotechnology for bioenergy and biofuels production. Carbon-based nanomaterials in biofuel cells. Nanomaterials as heterogeneous catalysts in biorefineries for biomass conversion. Nanomaterials for energy storage applications. Nanoscale electrode materials.

NTM 834: COMPUTATIONAL MODELING & SIMULATION METHODS (2 Units)
Theory and application of computational methods for simulation of molecular properties and spectra as well as structural and bulk properties of matter. Ab Initio methods, Density Functional Theory methods, Hybrid Quantum / Classical methods. Energy functions and force fields, geometry optimization, normal mode analysis, and reaction--path techniques at the molecular level, and an introduction to the simulation of static and dynamic properties of organic and inorganic substances, chemical reactions and molecular spectroscopies via both Monte Carlo and molecular dynamics (MD) methodologies. Simulation laboratory exercises are compulsory to enable each student acquire skills for modern computational simulation software and complete the computational project in order to pass the course. The student will be able to derive, analyze, and utilize the computational software for molecular mechanics methods, ab initio methods, density functional theory methods, simulating molecular properties and thermodynamics properties, molecular reactions dynamics.

MGT 801: PROJECT MANAGEMENT BASICS (2 Units)
Project design and management cycle, Project Implementation Plan (PIP), Project Development strategies, Project Monitoring, Evaluation and Learning (MEL) and sustainability. Application of Theory of change approach to Energy project. Use of designated software for development of Project Management.

MGT 803: CHANGE MANAGEMENT (2 Units)
Introduction to change concepts and theories of change management. Methodologies and processes of change management. Dimensions of change. Pre-requisite for change. Resistance to Change. Change Management Strategy & Systems. Communicating & Implementing change. Change Failure.

MGT 805: ENTREPRENEURSHIP (2 Units)
Fundamentals of starting and operating business in energy ecosystem. Dynamic role of entrepreneurship in the energy sector of the economy. Financial planning and control; Forms of ownership for startups; Strategic Marketing Planning; New Product or Service Development; Business Plan Creation; Types and theories of Innovation; Sources and Process of Innovation; Technological Entrepreneurs; Innovation Strategy & Systems; Managing Innovation and Intellectual Property; Funding Innovation and sustainable entrepreneurship.

EVM 801: CLIMATE CHANGE (2 Units)
Air pollution, global warming and climate change. Climate change modeling. Climate change mitigation. Climate change adaptation and planning. Discussions on recent technologies to combat global warming and abate climate change. Sustainable development goals. Corporate sustainability versus profitability.

CHM 864 STATISTICAL THERMODYNAMICS (2 Units)
Statistical mechanics vs. thermodynamics. Review of statistical concepts. Canonical and grand canonical ensembles. Entropy. General formulation of statistical thermodynamics. Fermi-Dirac, Bose-Einstein and Boltzmann statistics. Quantum ideal gases. Specific heat of solids. Electrons in metals and semiconductors. Radiation: the photon gas

CHM 868 APPLIED SPECTROSCOPY AND ELECTROCHEMISTRY (2 Units)
This topic introduces advanced spectroscopy and electrochemistry. Studies in the area of spectroscopy will focus on the principles of and use of NMR, IR and mass spectrometry for chemical structure determination. Studies in electrochemistry will focus on the underlying principles, important examples of electrochemical reactions and expand to the analytical uses of electrochemistry in sensor technology. A considerable focus will be on the underlying theory of each technique along with instrumentation and sample requirements.

FEM 842: SMART GRID TECHNOLOGY OVERVIEW (2 Units)
This course will provide a broad overview of all components and technologies associated with, and connected to, the new Smart Grid. The field specific knowledge to be covered would be Renewable Energy Systems and characteristics. Grid code compliance. PV components and sizing. Storage components, e.g. batteries. Microgrids and power flow. Energy storage scheduling, load-frequency control and inter-area power flow. Network dynamics &stability. Economics of SG installations. Communications technology and selection. Applicable network codes & regulations, and power system modeling and simulation software.

FEM 844: FUELS AND COMBUSTION (2 Units)
Fundamentals of fuels and combustion technologies. Conventional fuels – properties (energy density, pollutant load, costs) and uses. Advantages and disadvantages of conventional fuels. Options for alternative fuels. Conventional and novel combustion method. Impact of continued hydro-carbon fuel use, and possibilities for a more sustainable future. Fuel handling of conventional and novel fuels; relevant codes and legislation such as DSEAR/ATEX and consider implications on fuel use in industry.

FEM 846: RENEWABLE ENERGY FINANCE AND Management (2 Units)
The basic renewable energy financial metrics. Economic justification and impact of renewable energy projects. Sustainability drivers for renewable energy business. Barriers to renewable energy project implementation. Existing opportunities for renewable energy implementation. Energy Project Management. Big Data Analytics - Data Acquisition and Validation, Data Integration, Calculations and Design work, Application of supporting Software. Energy Economics. Energy Law II: Joint Operation Agreements. Drilling Contracts and related agreements for energy supply subsurface activities.

FEM 852: FINITE ELEMENT METHODS (2 Units)
The main objective of the course is to provide a practical training in technological design using finite element methods. The course aims at introducing the fundamental principles of the modelling for statics and dynamics analyses, as well as for stress analysis. Significance and importance of finite element methods in tech design. Fundamentals of finite element methods for small displacement linear elastic analysis (statics). Non-linear finite element method. Use and mastery of commercial FE software (Abaqus). Application of FE methods in modeling steady-state and transient field problems. Model development and output data analysis & interpretation.

FEM 854: EXERGY ANALYSIS (2 Units)
Sustainability & efficiency (sustainable development, sustainability methods & metrics, thermodynamic approach to sustainability of efficiency). Thermodynamic Analysis of process (Mass & energy rate balances for a steady flow process – 1st law of thermodynamics, quality of energy & materials, entropy & 2nd law of

thermodynamics, entropy production, entropy rate balance for a steady flow process, maximum work obtainable from a steady flow process). Exergy concept (Defining exergy, exergy reference environment, exergy versus energy, exergy of work & heat transfer, exergy of a stream of matter, physical exergy, chemical exergy). Exergetic evaluation of process & technologies (Exergy rate balance for a steady flow process, internal & external exergy losses, exergetic efficiency performance, Economic & Ecological aspects of exergy). Renewability of biofuels (Application of cumulative exergy consumption of biofuels production, renewability indicators).

FEM 856: ROCK MECHANICS (2 Units)

Poroelastic theory: Hooke's law for dry rock, porous rock or non-porous rock, Biot's and Skepton's Coefficient. Borehole stability: Effect of mud weight on well stability, Rupture modes around a borehole. Sand production prediction: Sand production mechanisms, Theories to predict sanding tendencies. Hydraulic fracture design: Theory and calculation of hydraulic fracture. Concepts of fracture and its measurements. Fracture orientation & azimuth, Fracture area, Numerical modeling. Reservoir engineering applications: Depletion and effective stress, Compaction drive, Reservoir compaction and compressibility, Subsidence.

MTH 862: METHODS OF APPLIED MATHEMATICS (2 Units)

First and second order differential equations in the phase plane. Linear approximations at equilibrium points. Index of a point; limit cycles; averaging, regular and singular perturbation methods. Stability and Liapunov's method. Bifurcation. Basic ideas of calculus of variations. The Euler-Lagrange equations; eigenvalue problems. Applications to second and higher order differential and partial differential equations. Rayleigh-Ritz and Galerkin methods and discrete models.

FEM 844: MINI-GRIDS: PLANNING AND DESIGN

This multi-disciplinary course aims to provide the Masters' level student with a framework for understanding the mini-grid sector, enabling the graduate to assess its challenges and to offer potential solutions. After completion of the course, the students should be able to identify the most suitable mechanisms to promote and implement clean energy mini-grids in their countries.

The course will offer the following topics, suitable for non-technical students:

- Business models: demand creation, productive use, financing
- Mini-grid systems: generation, storage, DC technology
- Regulation & policy
- Demand assessment and community engagement
- Future options - grid integration vs DRE; smart mini-grids: peer to peer democratisation, digitalization.

FEM 852: APPLIANCES FOR OFFGRID COMMUNITIES

This multi-disciplinary, non-technical course aims to provide the Masters' level student with the knowledge and skills to contribute to the off-grid appliances sector by assessing its challenges and mapping potential innovative solutions in the context of technology readiness, market opportunities and local socio-economic nuances. If situated early on in a Masters' programme, the course could open options for further research, as well as career paths or entrepreneurship opportunities in the DRE appliances sector.

7.0 STAFFING

Staff involved in the Africa Center of Excellence in Future Energies and Electrochemical Systems (ACE-FUELS) are drawn from the partner Departments in FUTO, as well as from our academic and sectoral partners:

Name	Rank
Abdulwahab, Malik N.	Professor
Achumba, Ifeyinwa E.	Professor
Alaneme, Kenneth K.	Professor
Alisi, Chinwe S.	Professor
Enenebeaku, Conrad K.	Professor
Eya, Dominic D.	Professor
Ezema, Fabian I.	Professor
Ezeonu F.C.	Professor
Madu, Chinyere A.	Professor
Nkwocha, Edmund E.	Professor
Nweke C. O.	Professor
Ogbulie, Judeanthony N.	Professor
Ogoke, Iheanyi J.	Professor
Ogueke, Chika C.	Professor
Ogueke, Nnamdi V.	Professor
Oguzie, Emeka E	Professor
Okereke, Chikwendu N.	Professor
Onyekuru, Samuel O.	Professor
Opara, Alexander I.	Professor
Orji, Chikwendu E.	Professor
Owuamanam, Clifford I.	Professor
Azeez, Taofik O.	Reader
Ibeneme, Ikechukwu S.	Reader
Ike, Innocent S.	Reader
Iwuji, Samuel C.	Reader
Lawal, H. A.	Reader
Nwachukwu, Ikenna	Reader
Ogbulie, Toochukwu E.	Reader
Ohia, Nnaemeka P.	Reader
Okeoma, Kelechi	Reader
Ujowundu, Cosmas O.	Reader
Uzoije, Atulegwu P.	Reader
Aharanwa, Bibiana C.	Senior Lecturer
Akalezi, Christogonus O.	Senior Lecturer
Amangabara, Gordon T.	Senior Lecturer
Anyiam, Chioma K.	Senior Lecturer
Arukalam, Innocent O.	Senior Lecturer
Duru Ijeoma	Senior Lecturer
Echeme, Ibeawuchi I.	Senior Lecturer

Name	Rank
Ihugba, Okezie A.	Senior Lecturer
Ikerionwu, Charles	Senior Lecturer
Joe-Uzuegbu, Chijioke	Senior Lecturer
Mbamara, Uchenna S.	Senior Lecturer
Nwanonenyi, Simeon C.	Senior Lecturer
Nwogu, Ngozi C.	Senior Lecturer
Obiukwu, Osita O.	Senior Lecturer
Oguzie, Kanayo L.	Senior Lecturer
Onojo, O. J.	Senior Lecturer
Onyeachu, Ikenna B.	Senior Lecturer
Orga, Anselem C.	Senior Lecturer
Oze, Rita	Senior Lecturer
Ugwu, Kelechi E.	Senior Lecturer
Ulaeto, Sarah B.	Senior Lecturer
Verla, Evelyn N.	Senior Lecturer
Ayogu, Ignatius I.	Lecturer 1
Chidiebere, Arinze M.	Lecturer 1
Chijioke, Chinonye F.	Lecturer 1
Etim, Ini-ibehe N.	Lecturer 1
Njoku, Chigoziri N.	Lecturer 1
Ohajianya, Anthony	Lecturer 1
Okorondu, Justin N.	Lecturer 1
Ugochukwu, K. A.	Lecturer 1
Njoku, Demian I.	Lecturer 1
Ugochukwu, K. A.	Sectoral Partner
Uba Osigwe, Kelechi	Sectoral Partner
Ozumba, Chinyere	Sectoral Partner
Nwankwo Emeka	Sectoral Partner
Nzuruba, C.	Sectoral Partner
Udensi, Emmanuel	Sectoral Partner