Terms of References for Trainers of Master's program in Biomedical Engineering

I. BACKGROUND AND JUSTIFICATION

Biomedical Engineering is one of the key areas on which the East African Community Regional Centre of Excellence in Biomedical Engineering, E-Health, Rehabilitation and Mobility Sciences (CEBE) is focusing. The CEBE aims to increase the knowledge and skills of Biomedical Engineering workforce in Rwanda and other East African countries for enhanced capacity for Healthcare Technology Systems management, which is currently quite limited. It is expected that with the built capacity, the technical personnel will be able to design, develop, repair, maintain, troubleshoot and calibrate medical equipment and evaluate healthcare equipment systems in the health facilities. The outcome of this endeavour will be an improved healthcare service delivery.

2. Overall Goal of the Master of Science in Biomedical Engineering programme

The purpose of this MSc. in Biomedical Engineering programmeis to strengthen the knowledge and skills in Rwanda and in the Region for the development and management of Medical equipment systems and applications in collaboration with different partners such as MoH and RBC.

3. **The specific objectives** of the e-health capacity building trainings are as follows:

3.1 Design teaching materials and upload them on the e-learning platform of the University of Rwanda. For any or all of the following five selected e-health short courses

- Biomedical measurements technology
- Advanced Embedded System Applications
- Biomaterials & Tissue Engineering
- Biomechanics and Biorobotics
- Medical Imaging Systems
- Medical Image Processing
- Healthcare Technology Management (HTM)
- Medical Device Development
- Orthopedic and mobility devices Engineering
- BioMEMS Design and Applications

3.2 Deliver any of the modules as mentioned above and detailed in Annex 1.

ANNEX 1: PROFESSIONAL COURSES TO BE DELIVERED

Modules and Objectives	Content	Requirements of the trainer
Biomedical measurements technology		
The aim of this module is to enable biomedical engineering students to acquire knowledge and skills on how instruments work in health facilities and recognize their limitations. Eventually, the biomedical engineering students will be able to develop an understanding of the measurement principles of medical instrumentation, including biochemical sensors, bio-potential amplifiers, bioelectrical signals (ECG, EEG), measurement of respiratory function, cardiac variables, blood pressure, blood flow as well as medical and laboratory devices.	**Unit 1: Sensor, Transducers, Electrodes and Amplifiers:** Bio-signals sensors and transducers, Bio-signals amplification, electrode for bio-signals **Unit 2: Bio-potential recording** ECG, EEG, EMG, PCG, EOG-lead system and recording methods, typical waveforms, frequency spectrum, abnormal waveforms, evoked response **Unit 3: Impendence techniques** Bipolar and tetra polar circuits, detection of physiological activities using impendence techniques, GSR., cardiac output, neural activities, respiratory activity, impedance plethysmography-resistance and capacitance type. **Unit 4: Non-Electrical parameters and respiratory measurements** Respiration, heart rate, temperature, blood pressure, O_2, CO_2 measurements, Spiro meter, BMR apparatus **Unit 5: Bio-Chemical measurements and blood cell counting** EM and ultrasonic blood flow meters indicator dilution method, Thermodilution method, Manual and Automatic Counting of RBC, WBC and Platelets-Auto analyzer, pH, pCO2,pO2, pHCO3 electrophoresis, colorimeter, spectrophotometer, flame photometer. Automated Biochemical analysis System, Chromatography **Unit 6: Virtual Instrumentation with LabVIEW** Introduction to LabVIEW, data acquisition-analysis tools and applications in the virtual instrumentation-Different application of virtual instrumentation	PhD in Biomedical engineering, bioengineering, Neural Engineering with expertise in bio-medical sensors and data acquisition technology, bio-signal processing, recording and analyzes. Having minimum 3 years work experience in Biomedical measurement technology. Having a grade of Associate Professor and above is an added value.
Advanced Embedded System Applications		
This module provides students with the advanced skills for studying the other courses of the program such as "product design and development". It forms advanced skills in embedded systems design. Those skills are essential in designing digital control units for consumer electronics, industrial automation, telecommunication systems and others. This Module includes lectures, laboratory work and an individual project.	**Unit 1: Embedded systems design** Embedded System Project Management, ESD and Co-design issues in System development Process, Design cycle in the development phase for an embedded system, Use of the target system or its emulator and In-circuit emulator, Use of software tools for development of an ES. **Unit 2**: **8051 Microcontroller** Microprocessor V/s Micro-controller, 8051 Microcontroller: General architecture; Memory organization; I/O pins, ports & circuits; Counters and Timers; Serial data input/output; Interrupts. Addressing Modes, Instruction set: Data Move Operations, Logical Operations, Arithmetic Operations, Jump and Call Subroutine, Advanced Instructions. Interfacing External Memory,	PhD in Computer Science, Electronics Engineering, having minimum 3 years work experience in Advanced Embedded System Design and Applications. Having a grade of Associate Professor and above is an added value.

Modules and Objectives	Content	Requirements of the trainer
	Keyboard and Display Devices: LED,7-segment LED display, LCD. **Unit 3: PIC MICROCONTROLLER** CPU, ALU, Data Movement, The Program Counter and Stack, Reset, Interrupts, Architecture Differences, Mid-Range instruction Set, Power Input and Decoupling, Reset, Watchdog Timer, System Clock/Oscillators, Configuration Registers, Sleep , Hardware and File Registers, Parallel Input Output, Interrupts, Prescaler, The OPTION Register , Mid-Range Built-In EEPROM Flash Access, TMR1 andTMR2 Serial I/0, Analog I/0, Parallel Slave Port (PSP), External Memory Connections, In-Circuit Serial Programming (ISCP). **Unit 4: Programming with PIC** Assembly Language Programming, Hex File Format, Code-Protect Features, Programming, PIC Emulators. Estimating Application Power Requirements, Reset, Interfacing to External Devices, LEDs, Switch Bounce, Matrix Keypads, LCDs, Analog I/O, Relays and Solenoids, DC and Stepper Motors, Servo Control Serial Interfaces. **Unit 5: Arm Processor Fundamentals** Registers, State and Instruction Sets, Pipeline, Memory Management, Introduction to the ARM Instruction Set	
Biomaterials & Tissue Engineering		
The module provides advanced knowledge of the relevant background science, theory, practice and materials required to fabricate permanent implants to replace tissue function, and other orthopedic and mobility devices. This course also teaches biological processes that occur during human tissue contact with artificial surfaces, how to critically read and review the literature on tissue engineering, how to anticipate biocompatibility issues with a variety of implant devices students may later encounter, current approaches directed toward the engineering of cell-based replacements for various tissue types.	**Units 1. Principles of tissue engineering** • Cell biology towards developing novel "tissue engineered" materials. • Molecular biology towards developing novel "tissue engineered" materials. • Materials science towards developing novel "tissue engineered" materials. **Unit 2: Cellular and Molecular Tissue Engineering.** • How a cell moves, reacts and maintains viability and function based on its surroundings, • how to engineer materials, tissue grafts and implants to integrate with the body, • bodily reactions and the biocompatibility of tissue engineered devices such as immune-reactivity and blood coagulation **Unit 3: Biomaterials** • Application of materials (Composites, metals, ceramics, thermoplastic materials, thermosetting materials) in the physiological environment. • Host reaction, testing and degradation of biomaterials in biological environments (e.g. blood – material interaction). • The regulatory, ethical and legal aspects of fielding biomaterials.	PhD in Biomedical Engineering, Bioengineering, Polymer Engineering, Material science, Having 3 year work in bio-materials, Molecular Biology, Biochemistry. Having a grade of Associate Professor and above is an added value.

Modules and Objectives	Content	Requirements of the trainer
Biomechanics and Biorobotics		
This module is designed to build and advance the principles of biomechanics and introduce the concept of performance analysis within a medical rehabilitation context. Utilizing biomechanics to create evidence-based intervention strategies to optimize rehabilitation. Introduction to Computer Aided Design theory and application using the software. Under this module, the methods of control of a robot and telemanipulation are studied. Computer simulations, MATLAB are used to explore biomimetic autonomous robots. This is a studio-based course with hands-on exercises with small robots and actuators.	Unit 1 Biomechanics 1. Introduction to Biomechanics. Nomenclature. 2. Kinematics 2.1 Basic concepts 2.2 Coordinates: the position of bodies; independent vs dependent coordinates; global vs relative coordinates 2.3 Modelling with 2D natural coordinates: rigid body constraints; joint constraints; relative coordinate constraints. 2.4 Modelling with 3D natural coordinates: rigid body constraints; joint constraints; relative coordinate constraints. 2.5 Human body models: human forearm. 2.6 Kinematic problems: assembly, position, velocity and acceleration problems; DOF. 3. Kinetics 4. Anthropometry 4.1 Methods and techniques. 4.2 Anatomical landmarks and ISB recommendations. 5. Practical work: motion reconstruction of a limb Unit 2: Biorobotics 1. Introduction to Mechatronic and Biomechatronic Devices: 1.1. Technological roots 1.2 Classification 1.3 Basic Terminology in Robotics 2. Mechatronic Assistive Devices for Surgery: 2.1 Computed Aided Surgery 2.2 Minimally Invasive Surgery 2.3 Robotic Devices in Surgery 2.4 Teleoperation in Surgery 3. Surgery Simulators 3.1 Education and Training 3.2 Planning 3.3 Virtual/Augmented Reality 3.4 Introduction to Haptics 4. Rehabilitation and Health Care Robotics 4.1 Bionics 4.2 Exoskeletons 5. Robot Mathematical Modelling and Control 5.1 Coordinate Frames and Homogeneous Transformation	PhD in Biomechanics, Bio robotics with minimum of 3 years work experience in Biomechanics, Bio robotics. Having a grade of Associate Professor and above is an added value.

Modules and Objectives	Content	Requirements of the trainer
	5.2 Kinematics of Manipulators 6. Practical work: robot modeling using Matlab	
Medical Imaging Systems		

Modules and Objectives	Content	Requirements of the trainer
The aim of this module is to provide the students with a solid understanding of all the major medical imaging techniques employed in modern hospitals, including x-ray imaging, computed tomography, magnetic resonance imaging, ultrasound, nuclear isotope imaging. Each technique will be presented in the context of the underlying clinical requirements. Students need to learn what physical principles are involved, and what properties of tissues the corresponding medical images show.	**Unit 1: Principles of x-rays** Production of x rays, continuous and line spectra, factors determining the x-ray emission, Efficiency of x-ray production, sources of radiation. Radiation units - detection and measurements of x-rays. **Unit 2: Interaction of radiation with matter** Effects of x-rays Instrumentation, basics of Radiation Protection in Diagnostic Radiology, radiotherapy & nuclear medicine, radiation accidents. **Unit 3: Various components of radiographic systems** X-ray generator, HT circuit & KV control Electrical circuit for X-ray unit, Filament circuit and mA control, Safety devices, X-ray tubes for various medical applications, rating charts of X-ray tubes. **Unit 4: Exposure switching and control of exposure time.** X-ray films and its processing, properties of X-ray films, intensifying & fluorescent screens, Fluoroscopy systems, Direct and indirect fluoroscopy, Image intensifier & TV chain for fluoroscopy, Basics of digital radiography & digital subtraction angiography. **Unit 5: Computed Tomography** Principles of sectional imaging, scanner configuration, data acquisition system, image formation principles, CT generations. **Unit 6: Magnetic Resonance Imaging (MRI)** Physics of MRI, MRI sequences, effects of magnetic fields. Image acquisition, Radiofrequency transmitter, RF power amplifier, design and principles of coils, MRI Fourier reconstruction, MRI instrumentation – magnets – gradient system -Functional MRI - Application of MRI **Unit 7: Ultrasound (US)** Characteristic impedance, wavelength, frequency and velocity of propagation, Absorption, beam width, resolution, generation and detection. US system-HV Pulse generator, transmitter circuit position encoder circuit, Time Gain Compensation (TGC), digital scan converter and types transducers and construction. Principles of image formation - principles of A-mode, B-mode and M-mode displays - Doppler Ultrasound and Color flow mapping- 3D and 4D ultrasound and its applications. **Unit 8: Radioisotope imaging** Law of radioactive decay, half-life period - production of radioisotopes for medical use, rectilinear scanners, linear scanners - SPECT – PET and Gamma camera. Physics of thermography imaging systems - Pyroelectric vidicon camera – clinical thermography.	PhD degree in Biomedical Engineering, Electronics Engineering, with a minimum of 3 years work experience in medical imaging systems. Having a grade of Associate Professor and above is an added value.

Modules and Objectives	Content	Requirements of the trainer
Medical Image Processing		
This module will describe the principles and role of digital image processing and analysis in medical imaging. It covers both the underlying theory and provides students with practical experience of these techniques applied to medical images using a computer image processing package such as Matlab.	**Unit 1: Image perception** MTF of the visual system - monochrome vision models - color vision model Image sampling and quantization - Two-dimensional sampling theory - Practical limits in sampling reconstruction. Image quantization - visual quantization. Image transforms - Two-dimensional orthogonal and unitary transforms - properties of unitary transforms – one dimensional Discrete Fourier Transformation (DFT), 2D DFT - cosine, sine Hadamard, Haar transforms, KLT, slant transforms. **Unit 2: Image enhancement** Point operations - contrast stretching - clipping and thresholding - digital negative intensity level slicing - bit extraction. Histogram modeling - histogram equalization - modification. Spatial operations - smoothing techniques. Magnification and interpolation. Transform operations. Applications in medical imaging. **Unit 3: Image filtering and restoration** Noise models. Inverse and Weiner filters –filtering using image transforms. Splines and interpolation. Maximum entropy restoration. Bayesian methods **Unit 4: Image analysis** Spatial feature extraction - transform features. Edge detection – boundary extraction, shape features image segmentation **Unit 5: Applications of Medical Image processing:** Fusion of PET and MRI for Hybrid Imaging: Hybrid PET Fusion System, PET/CT Systems, PET/MRI Systems, High-Resolution Fusion. Quantitative Medical Image Analysis. - Image reconstruction from projections CT reconstruction Radon transform-inverse radon transform back projection operator-convolution back projection- parallel beam geometry-Fan beam geometry. 2D image reconstruction techniques - Iteration and Fourier methods.	PhD in biomedical engineering, biophysics, electronics engineering with prior hands on experience in image processing software (matlab, python, openCV, C/C++), and minimum of 3 years' work experience in medical imaging processing. Having a grade of Associate Professor and above is an added value.
Healthcare Technology Management (HTM)		
This module provides to students the managerial skills at all levels of the organization process sound conceptual, technical, and interpersonal skills in order to carry out the required managerial functions of planning, organizing, staffing, directing, controlling and decision making. In addition, it provides advanced knowledge to ensure improved access, quality and use of medical equipment and	**Unit 1: Organization of the HTM system** Importance of HTM service, definitions (health technology, medical device, medical equipment, etc.), Regulatory and standardization of healthcare technology, developing policies of HTM, determining technical requirements for HTM, and how to choose an appropriate model for HTM, Organizational structure of HTM, relationship between health delivery systems and HTM, determine human resource required and responsibilities. **Unit 2. Medical equipment life cycle** Planning and Budgeting, Procurement and commissioning, Daily operation and safety, Evaluation of equipment and testing, Education and training,	PhD in Biomedical Engineering, Clinical Engineering, Electronics with a minimum of 3 years work experience teaching the Healthcare Technology Management. Having a grade of Associate Professor and above is an added value.

Modules and Objectives	Content	Requirements of the trainer
technologies.	Finance and personnel management, Implementation. **Unit 3: Medical equipment operation and hospital environment** Maintenance management, Operational management, Usage, maintenance and repair, hospital environment concept, hospital layout, computerized maintenance management systems. **Unit 4: Quality management systems for medical device** Medical equipment types**,** Market trend**,** Safety issues, Codes, standards and regulations of medical devices, Risk analysis techniques, calibration and testing	
Medical Device Development		
This course will examine the multidimensional aspects of medical device development and manufacturing and provide students with the entrepreneurship skills necessary to understand how devices are developed and brought to market. Students will specifically learn how to assess a device's clinical effectiveness, to evaluate its core function/technology, and to identify the appropriate path and requirements to obtain regulatory clearance/approval.	**Unit 1. Design requirements** Market Evaluation analysis, Risk management analysis **Unit 2. Design process** Design History file –in depth, Prototype development and simulation, Device documentation (intellectual properties/registration), Design control **Unit 3. Regulatory environment** Premarket administration: Manufacturing/import Business Licence, pro-manufacturing import registration, Good Manufacturing Practices (pre and post): Inspection premarket safety/post market administration **Unit 4. Medical device clinical Evaluation** Critically assess the requirements for clinical evaluations and investigations of medical devices and in-vitro diagnostic medical devices, Interpret the relevant commission, Explain how clinical evaluation forms part of the design and risk management processes and distinguish between the different methods of carrying out a clinical evaluation including their costs and benefits.	PhD in Electronics Engineering, Biomedical engineering , Mechanical Engineering with a minimum of 3 years work experience in the development of medical devices. Having a grade of Associate Professor and above is an added value.
Orthopedic and mobility devices Engineering		
A critical objective of this module is the preparation of design, development procedures and project presentations on prosthetic, orthotic and mobility devices, modelling and simulation applied to the biomechanics of musculoskeletal system and prosthetic/orthotics, and design of medical devices used in rehabilitation engineering.	**Unit 1**: **Design and development of prosthetic, orthotic and mobility devices** • Design of orthopaedic devices using softwares such as ProEngineer. • Methods for orthopaedic devices development with the use of 3D printers. • Wheelchair design • Mobility aids such as walking frames, crutches and others **Unit 2: Design and development of Orthopaedic Implants.** • Modeling techniques for the design of hip, knee, and spine implants. • Kinematics and surgical protocols, • Assemblies and FEA analysis of implants, • Analysis of the deformations, fatigue, and optimization of orthopaedic	PhD degree Biomechanical engineering. Having a minimum of 3 years work experience in design and development of orthopedic, prosthetic and other mobility related devices. Having a grade of Associate Professor and above is an added value.

Modules and Objectives	Content	Requirements of the trainer
	implants	
BioMEMS Design and Applications		
The emphasis of this module will be on applications and design of **M**icro **E**lectro-**M**echanical **S**ystems (MEMS) devices for Biomedical and related applications. MEMS fabrication techniques and processes are covered. Membranes and cantilevers used for sensing and actuation and how geometry affects their sensitivity and structural response will be studied. The course will conclude with an introduction to microfluidics and its application to biotechnology.	**Unit 1:** Introduction to MEMS (Micro Electrical Mechanical Systems) technology, Micro-fabrication **Unit2:** Mechanical Transducers: Cantilevers, membranes, spring constants, measuring deflections (Mach-Zehnder spectrometer), static, dynamic (frequency shift), stress, strain, Electrostatics, pull-in, piezoelectric (PZT) **Unit 3:** Chemical and biological transducers, ISFET (Ion Sensitive Field Effect Transistors) Microfluidics and Biotechnology, soft lithography **Unit 4:** Microflows, shear, pressure, flow rate, single and two phase flows, mixing, separation, surface tension, microdrops, Electrophoresis (DNA, proteins, cells), electro-osmotic flow, micropumps. Introduction to ANSYS, Using ANSYS for structure and fluid MEMS problems, ANSYS, Project.	PhD in Biomechanics, nanotechnology, microfluidic systems, mechanical engineering with a focus on biosensors, micro fluidic devices. Having a minimum of 3 years work experience, Having a grade of Associate Professor and above is an added value.

General Requirements

- Demonstrated experience as a lead for a minimum of three similar projects including design, develop, implement and evaluate ehealth systems.
- Strong data analysis expertise, including software and knowledge of significance testing and high level statistical analysis
- Previous experience working in Rwanda (or similar context) highly desirable
- Cultural sensitivity and strong inter-personal skills essential;
- Demonstrated facilitation and training skills required
- Management, planning, coordination, organization, and facilitation skills
- Flexibility and complete availability for the duration of the assignment
- Spoken and written fluency in English is a requirement; spoken and written French is an advantage
- Flexibility, tenacity and results-oriented approach essential for success.
- Experience of working in low resources settings

II. DESIGN OF TEACHING MATERIALS AND MODE OF COURSES DELIVERY

The training consultant will employ rigorous and varied methods of training and research to achieve this task. The mode of delivery shall ensure that there is transfer of skills to the trainees for sustainability purposes. The trainees should demonstrate the capacity to be future designers, developers, implementers, users and evaluators of e-health systems in Rwanda and the Region.

III. RESPONSIBILITIES

The consultant is expected to undertake the following tasks based on the CEBE approved objectives and content of the short courses:

1. Design teaching materials for the following short courses;

- Biomedical measurements technology
- Advanced Embedded System Applications
- Biomaterials & Tissue Engineering
- Biomechanics and Biorobotics
- Medical Imaging Systems
- Medical Image Processing
- Healthcare Technology Management (HTM)
- Medical Device Development
- Orthopedic and mobility devices Engineering
- BioMEMS Design and Applications

2. Deliver the modules mentioned above in collaboration with University of Rwanda lecturers

4. PERIOD OF PERFORMANCE

For each training, the start and the end date will be agreed upon between CEBE and the consultant. The consulting services will start from the date the contract is signed till the end of the agreed period for service provision.

5. REPORTING REQUIREMENTS

A detailed work plan with clear deliverables and milestones must be submitted within 2 weeks of the contract agreement. The consultant will be requested to report the progress and performance according to the contract. The final report for the whole assignment will be given as stipulated in the contract.

6. SKILLS TRANSFER

The consultant will be an experienced expert in e-health like in the design, development, implementation and evaluation of e-health innovations, and therefore will be required to transfer skills during the period of execution of the assigned tasks.