AAMI
Advancing Safety in Medical Technology

Core Competencies for The Biomedical Equipment Technician (BMET)

A Guide for Curriculum Development in Academic Institutions

First Edition, 2013

About AAMI

AAMI, the Association for the Advancement of Medical Instrumentation, is a diverse community of more than 7,000 healthcare technology professionals united by one important mission—supporting the healthcare community in the development, management, and use of safe and effective medical technology. Founded in 1967, AAMI fulfills its mission through education, certification, publications, and standards development.

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- Student Website: www.aami.org/student
- Promotion of the Field: www.IamHTM.com

AAMI's Vision for the Healthcare Technology Management Professional
Biomedical Equipment Technician/Technologist
(AAMI's 2011 Future Forum)

HTM professionals will be fully integrated members of the healthcare delivery team and will have significant influence in the management of all healthcare technology. In addition, the career path will be better defined, with a supportive educational infrastructure.

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Project Manager

Robert Stiefel, MS, CCE	RHS Biomedical Engineering Consulting, LLC

Advisory Committee

Steven Yelton, PE *(Chair)*	Cincinnati State Technical and Community College
Roger Bowles, EdD	Texas State Technical College
Leanne Cordisco[1]	GE Healthcare
Barbara Christe, PhD	Indiana University–Purdue University Indianapolis (IUPUI)
John Noblitt, MA, Ed, CBET	Caldwell Community College and Technical Institute
Christopher Nowak, CBET	Universal Health Services, Inc.
William Phillips, PhD	DeVry University

Development Committee

Steve Bezanson	ITT Technical Institute
Roger Bowles, EdD, CBET	Texas State Technical College
Terry Bracewell, CBET, CIT, AAS	Bracewell's BMET Training
Barbara Christe, PhD	Indiana University–Purdue University Indianapolis (IUPUI)
J. Tobey Clark, CCE	University of Vermont
Theodore Cohen, CCE	UC Davis Medical Center
Anthony Epifane, CBET, CET, MBA	Carl Storz Endoscopy-America, Inc.
Kurt Finke, CCE	United States Department of Veterans Affairs
Dave Francoeur, CBET	CREST Services
Jeffrey Kabachinski, MS-T, MCNE	ARAMARK Healthcare Technologies
Chad Kennedy, PhD	DeVry University
D. Courtney Nanney, CCE	Catholic Health Initiatives
John Noblitt, MA, Ed, CBET	Caldwell Community College and Technical Institute
Christopher Nowak, CBET	Universal Health Services, Inc.
Faaruwq Muhammad, PMP	United States Department of Defense
Royce Shipley, CBET	Johns Hopkins Hospital
Paul Svatik, CBET-R *(Retired)*	Owens Community College
Hayden Tucker CBET, BSIT	Alcon Labs
Rajeswari Veeramallu, MS	Medvance Institute
Steven Yelton, PE	Cincinnati State Technical and Community College

AAMI Staff

Leah C. Lough, MBA	Joseph Bremner
Steve Campbell	Iman Hannon
Patrick Bernat	Ruth Moyer, graphic design

[1] 2010–2012.

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Introduction

Preface

The intent of *Core Competencies for the Biomedical Equipment Technician (BMET): A Guide for Curriculum Development in Academic Institutions* is to provide academic institutions/schools[2] that offer Biomedical Equipment Technician (BMET) programs with the following:

1. a standard set of competencies that graduates of Biomedical Equipment Technician (BMET) programs (certificate, diploma, or degree) are expected to possess upon program completion; and

2. recommended topics that a program curriculum should include in order for BMET students to learn and possess the core competencies identified in this Guide.

The competencies and topics in this Guide are relevant to BMETs entering the workforce, and the topics reflect the knowledge and skills that BMETs are expected to perform successfully in entry level positions regardless of the employment organizations, e.g., hospitals, clinics, independent service organizations, military, and manufacturers. This Guide may also assist schools in preparing their graduates for professional certification, e.g., AAMI/International Certification Commission's (ICC) certification exams.[3]

Competencies and topics were developed and agreed upon by an AAMI committee of experts from academia, hospitals, independent service organizations, device manufacturers, employer institutions, the U.S. Department of Defense, and the U.S. Veterans Administration. This Guide will also serve these and other organizations by assessing the preparedness of entry level BMET professionals to perform the responsibilities expected of them in a complex medical technology environment.

It is important to note that biomedical equipment technology is continuously changing, and the body of knowledge that BMETs acquire starts in the academic setting and continues throughout a BMET professional's career. The core competencies described in this Guide were developed and written to illustrate the skills and knowledge that BMETs will apply in the healthcare field for many years to come. However, it is essential for all academic institutions to stress the importance of continuing and lifelong learning to their BMET students.

[2] To find a list of BMET academic institutions/schools, go to www.aami.org/student/education.html.

[3] Certified Biomedical Equipment Technician (CBET); Certified Laboratory Equipment Specialist (CLES); Certified Radiology Equipment Specialist (CRES). A "Handbook for Applicants" is available from AAMI at www.aami.org/certification/).

This Guide does not describe a required curriculum by an accrediting organization, agency, or institution.[4] It also does not describe a recommended teaching method. Specific courses, curricula, educational material, for example,. that already or will incorporate and adopt the recommended topics in this Guide are left up to the school. In fact, some material at one school may be integrated into a comprehensive course, while it may be taught in separate courses at another school. For example, math, physics, and chemistry could be taught as separate subjects or taught in a combined course. In addition, this report does not recommend or describe testing or assessment methods. That, too, is left up to the school.

[4] Accrediting agencies are private educational associations and conduct peer evaluation of educational institutions and programs. Accrediting agencies can, in turn, be accredited by the U.S. Department of Education (USDE), the Council for Higher Education Accreditation (CHEA), or both.

Introduction

Development Progression of *Core Competencies for the Biomedical Equipment Technician (BMET): A Guide for Curriculum Development in Academic Institutions*

In 2007, the Medical Engineers & Technicians Association (META) Education Committee recommended a comprehensive list of outcomes for BMET education programs (see Figure 1).

In 2009, AAMI created the Educators Roundtable at the request of academicians and healthcare organizations concerned about the state and future of BMET education.

In 2010, the AAMI Educators Roundtable agreed that a set of core competencies and recommended curricular topics should be created so that BMET schools and/or programs had guidance for preparing their graduates to enter the workforce. A Core Curriculum Committee (CCC) was formed to oversee the development of expected BMET core competencies and recommended topics. It was intended that BMET schools that adopt or incorporate the CCC's recommended topics into their curricula could be assured their graduates would have an appropriate education to fulfill the responsibilities required of most entry-level BMET positions. Likewise, employers who are recruiting for entry-level BMET positions could be assured that graduates of such schools have an appropriate educational preparation.

From 2010–2012, the CCC and a Development Committee, led by an independent expert project manager, completed the first draft of core competencies and topics based on a comprehensive analysis of program descriptions, syllabi, curricula, course descriptions, job descriptions, and the AAMI/ICC certification program outline.[5]

In 2011, AAMI held its first *Future Forum* meeting and recommended "Healthcare Technology Management" as the official name of the field responsible for managing the selection, maintenance, and safe and effective use of medical equipment and systems.[6]

In 2012, a Role Delineation Task Force was created and the Professional Testing Company, Inc. (PTI), an independent provider of assessment, evaluation, and certification services, conducted a role delineation study.

In 2013, the results of the role delineation study validated the findings and analyses of the project manager, the CCC, and the Development Committee.

In 2013, the first edition, *Core Competencies for the Biomedical Equipment Technician (BMET): A Guide for Curriculum Development in Academic Institutions*, was published.

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[5] See "Accreditation/Certification" tab in this guide for the 2012 AAMI/ICC exam outline.

[6] AAMI Future Forum www.aami.org/news/2011/052311.futureforum.html.

META Outcomes

1. Demonstrate knowledge and skills in the function of the electrical and computer components of medical equipment. Demonstrate knowledge of biological signals.
2. Demonstrate knowledge of hospital organization and structure and the role of a BMET in a healthcare organization.
3. Demonstrate a working medical vocabulary and ability to communicate as part of the healthcare team. Demonstrate knowledge of basic human anatomy and physiology.
4. Demonstrate knowledge of clinical safety requirements, regulations, and standards as related to medical equipment technology and patient privacy. Identify the organizations responsible for these codes and standards.
5. Demonstrate competence in the clinical environment through internship or practical experience including performing preventive maintenance and repairs.
6. Identify key components of effective clinical customer service.
7. Use mathematics, science and emerging BMET tools to solve problems and demonstrate solutions.
8. Function as a member of a team to complete a task in a timely manner. Demonstrate ability to organize work done by team members.
9. Identify, analyze and integrate the technical equipment requirements with the needs of medical staff and patients.
10. Demonstrate professional oral and written business communication skills appropriate in a clinical environment.
11. Demonstrate skills for life-long learning by locating, evaluating, and applying relevant information using external resources such as the Internet, data books, trade publications, and library resources.
12. Demonstrate knowledge of professional ethical behavior and the requirements of the clinical setting.
13. Demonstrate a respect for diversity. Recognize contemporary professional, societal, and global issues.
14. Demonstrate quality, timeliness, and ability to complete increasingly complex assignments.

Figure 1. Medical Engineers & Technicians Association's (META)[7] recommendations for Outcomes for BMET Programs
(Reprinted with permission from META)

[7] META www.mymeta.org.

The Profession

The Profession

BMETs and the Healthcare Technology Management Profession

Healthcare technology management (HTM) is the official name of the professional field responsible for managing the selection, maintenance, and safe and effective use of medical equipment and systems.[8] The field includes biomedical equipment technicians, clinical engineers, imaging equipment specialists, laboratory equipment specialists, and others who protect patient safety and reduce healthcare costs related to technology.

BMET Definition

A **Biomedical Equipment Technician**, also referred to as a **Biomedical Engineering Technician/ Technologist (BMET)** or **Biomedical Equipment/Engineering Specialist (BES or BMES)**, is typically an electro-mechanical technician who ensures that medical equipment is well-maintained, properly configured, and safely functional. In hospital or clinical environments BMETs often work with Clinical Engineers,[9] although as in most technical fields there is a professional and legal distinction between engineers and engineering technicians.

BMET Career Ladder

At the time of the release of the first edition of this Guide, AAMI is in the process of developing a practical career roadmap for healthcare technology management (HTM) professionals that will serve as a resource for HTM professionals to use from the beginning of their careers to the end to sharpen their skills, plan for the future, and achieve leadership positions. Moreover, the roadmap would establish a clear definition of what an HTM leader is, giving professionals a tangible professional goal on which to focus. The project will also include a plan to help healthcare organizations identify and cultivate future HTM leaders.

Professional Certifications

Many BMETs pursue professional certification, such as satisfying certain education requirements and passing an examination from the International Certification Commission (ICC) and the AAMI to become a certified biomedical equipment technician (CBET). There are three other certifications BMETs can obtain: AAMI/ICC Certified Radiology Equipment Specialist (CRES) that specializes more specifically in diagnostic imaging, radiological, and nuclear medicine equipment;

[8] AAMI's 2011 Future Forum www.aami.org/news/2011/052311.futureforum.html.

[9] A Clinical Engineer is a professional who supports and advances patient care by applying engineering and managerial skills to healthcare technology, American College of Clinical Engineering, (ACCE) 1992. See www.accenet.org/downloads/reference/Whats_a_Clinical_Engineer.pdf for additional information.

AAMI/ICC Certified Laboratory Equipment Specialist (CLES) that covers the abundance of equipment found in the many different kinds of laboratory environments; and the Biomedical Electronics Technician certification (BMD) from the Electronics Technician Association (ETA) after first obtaining the Associate Electronics Technician certification (CET). In most cases, carrying the title of "CBET" is highly encouraged but not mandatory and is respected within the technical community.

See "AAMI/ICC Certification" for more information.

The Profession

BMET Employment

Employment Market

According to the U.S. Department of Labor, the job growth outlook for BMETs for the current decade is 31%, making it one of the fastest growing jobs in the country.[10]

Places of Employment

BMETs work in a hospital's Biomedical or Clinical Engineering or HTM Department but can also find employment with a third-party independent service organization (ISO), an original equipment manufacturer (OEM), durable medical equipment provider, or many other healthcare organizations. BMETs working for an OEM or ISO are often called Field Service Engineers (FSE).

General Responsibilities

BMETs install, inspect, maintain, repair, calibrate, modify, and design biomedical equipment and support systems to adhere to medical standards and guidelines. BMETs are involved in the total management of healthcare technology—from repairs and scheduled maintenance to capital asset planning, project management, budgeting and personnel management, designing interfaces and integrating medical systems, training end-users to utilize medical technology, and evaluating new devices for acquisition. BMETs educate and advise staff and other agencies on theory of operation, physiological principles, safe clinical application of biomedical equipment, and maintaining the facility's patient care and medical staff equipment.

BMETs cover a vast array of different fields and devices. However, in many cases there is a separation of responsibilities, whereby other (more specific) specialists focus on certain kinds of medical instruments—e.g., an Imaging Repair Specialist works on medical imaging equipment.

Regulatory Responsibilities

BMETs must comply with safety regulations, and most biomedical systems must have documentation to show that they were managed, tested, delivered, and used according to a planned, approved process that increases the quality and safety of diagnostics and therapeutic equipment and reduces the risk of harm to patients and staff.

[10] See www.bls.gov/ooh/installation-maintenance-and-repair/medical-equipment-repairers.htm.

In the United States, the work performed by BMETs must comply with various regulations and standards. Clinical devices and technologies are generally governed by the U.S. Food and Drug Administration (FDA); National Fire Protection Agency (NFPA), particularly NFPA 99 and chapter 7, NFPA 70, Life Safety Code 101; or the Code of Federal Regulations (CFR) 21. There are also accrediting bodies, such as The Joint Commission (TJC) or Accreditation Association for Ambulatory Health Care standards. Other countries typically have their own mechanisms for regulation.

Job Tasks and Qualifications

In the development of this Guide, job descriptions were obtained from BMET employers, including hospitals, independent service organizations (ISO), and medical equipment manufacturers—the major categories of employers of entry-level BMETs. The following job task activities and qualifications were most common throughout the descriptions.

Most Common Job Task Activities

- Troubleshoot and repair general/low-risk clinical equipment
- Calibrate equipment
- Order parts per policies and procedures
- Perform scheduled maintenance and safety testing
- Assure inspections performed in accordance with requirements and standards
- Use specialized test equipment and tools
- Document actions and results
- Know/comply with departmental policies and procedures
- Participate in performance and quality improvement activities
- Perform in a manner consistent with mission
- Perform incoming inspections and setup
- Assist with projects such as installation, relocation of equipment

Most Common Job Qualifications

- Education
- Experience
- Knowledge of electronics
- Competent and professional with oral and written communications
- Safety
- Teamwork
- Customer service

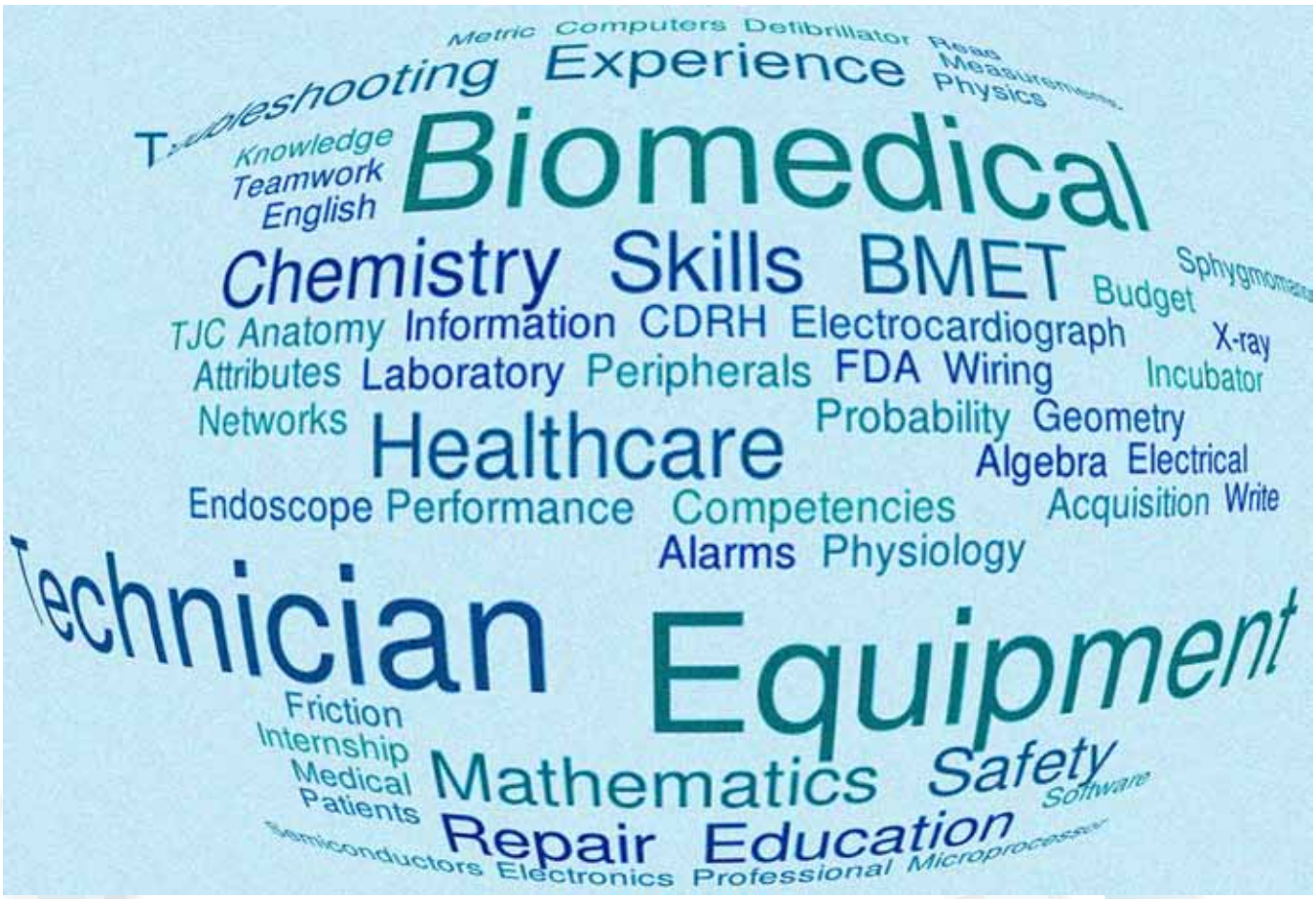
The Profession

BMET Education in the Military

All members of the military entering the BMET career field receive comprehensive technical training. Prior to 1998, Army and Navy BMETs received training at the United States Army Equipment and Optical School (USAMEOS) at Fitzsimons Army Medical Center (FAMC) in Aurora, Colorado. Only after a July 1995 Base Realignment Closure Commission decided to close FAMC did the Army and Navy merge with the Air Force, conducting training at the DoD Biomedical Equipment Technician Training School.

This school has a partnership with Aims Community College where students receive 81 quarter credits (from the Community College of the Air Force) toward an Associate of Applied Science (A.A.S.) Degree with an emphasis in Biomedical Electronics Technology. In addition to the credits acquired from DoD BMET Training School, a minimum of 24 credits must be completed through Aims Community College to receive a degree.

As of August 4, 2010, the U.S. Military moved the BMET training to San Antonio, Texas as a part of their new base realignment plan. Members of all three forces remain in rigorous, tri-service training for 10 months prior to returning to their individual services. The training is held at Fort Sam Houston and is a part of the Military Education and Training Campus.



Core Competencies

Core Competencies

Functional and Personal Core Competencies

BMET core competencies have two primary objectives and should be first among program outcomes to be adopted by a school.

1. Graduates should be fully prepared for employment in the field of biomedical equipment technology.

2. Graduates should be prepared to pass the AAMI/ICC CBET Certification Exam.

These two objectives lead to two categories of ten (10) core competencies:

1. **functional competencies**—the technical competencies associated with the performance of BMETs; and

2. **personal competencies**—the individual attributes required of successful BMETs.

The knowledge and skills in the functional competency category provide the foundation essential to the BMET profession.

The knowledge and skills in the personal competency category prepare a BMET to offer value-added performance for a successful and productive career and support the concept of continuous professional education and experience.

Organization of this Guide

This Guide is organized according to seven (7) *main* categories of **Functional Competencies** and three (3) *main* categories of **Personal Competencies**:

Functional Competencies	Personal Competencies
I. Biomedical Equipment Technology	VIII. English
II. Electronics	IX. Professional skills
III. Information technology	X. Practical experience—Internship/Laboratory
IV. Anatomy and physiology	
V. Mathematics	
VI. Physics	
VII. Chemistry	

Stated **Objectives** follow the descriptions. The Objectives specifically encompass the abilities and/or "competencies" that a BMET graduate must possess within the main Functional and Personal Competency categories prior to entering the job market.

Recommended **Educational topics** for a BMET program curriculum are divided between the ten main Functional and Personal Competency categories. Within a few of these main categories, **sub-categories** are included for convenience of organization.

Educational topics are considered *key* to the fulfillment of program outcomes and therefore fundamental to a BMET core curriculum. These topics are specific items of instruction that should be covered within the context of the main Personal and Functional Competency categories. These topics contribute to the entire body of knowledge and are included in the separate courses of the curriculum. (See figure 2.)

Functional Competency Main Category

Core Competency I: Biomedical Equipment Technology (BMET)

An interdisciplinary field encompassing healthcare technology management, including the maintenance and support, planning and acquisition, installation and training, modification and design of medical equipment and systems according to standards and guidelines.

Objectives

1. The ability to understand the design, purpose, and performance of medical equipment.
2. The ability to apply this understanding to the needs of healthcare technology management, such as maintenance, repair, and user assistance for medical equipment.

Educational Topics

Subcategory

A. Basic Concepts

Educational Topics

Biomedical equipment technology definition, scope
BMET employers
Medical and electronics terminology
Hospital organization

[More continues]

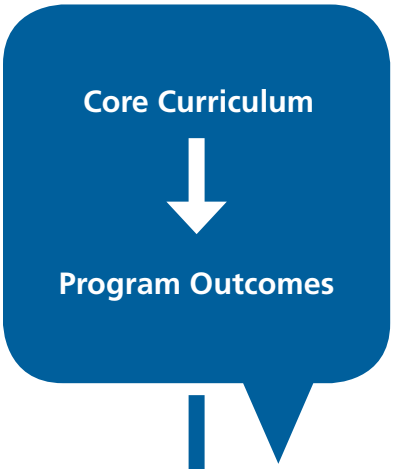
Figure 2. Example of Educational main and sub-topics for each Competency category

Progression of BMET Education

The core curriculum is the minimum necessary body of knowledge required of all BMET students and is based upon desired learning or program outcomes or goals. The Curriculum and the Outcomes are considered the foundation of the BMET Education Program.

Program outcomes are fulfilled by desired core competencies, and individual topics within an educational program are the building blocks for core competencies. (See Figure 3.)

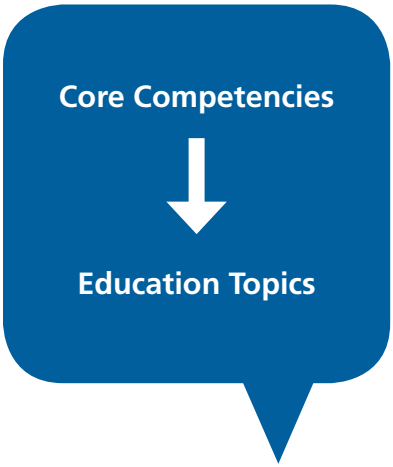
Note that this approach to organizing educational concepts and/or material does not dictate specific "courses" that should be offered in an educational BMET program. That is still up to the school, allowing for flexibility in teaching methods and learning styles.



The minimum necessary education required is the **core curriculum**

The goals of the core curriculum are its **program outcomes**

Components of the educational program



The objectives of the program outcomes are the knowledge and skills imparted by the **core competencies**

The basic concepts of education in the core competencies are **education topics**

Components of a BMET program described in this Guide

Figure 3. The progression of a BMET education program

Core Competencies

I. Biomedical Equipment Technology

Biomedical Equipment Technology is an interdisciplinary field encompassing healthcare technology management, including the maintenance and support, planning and acquisition, installation and training, modification and design of medical equipment and systems according to standards and guidelines.

Objectives

1. To understand the design, purpose, and performance of medical equipment.
2. To apply this understanding to the needs of healthcare technology management, such as maintenance, repair, and user assistance for medical equipment.

Educational Topics

A. Basic Concepts

Biomedical equipment technology definition, scope
BMET employers
Medical and electronics terminology
Hospital organization
Hospital departments and divisions
Hospital care areas
Clinical engineering (CE) department organization
Facilities
Environment of care
BMET functions and responsibilities
BMET professionalism and ethics
Customer relations
Professional organizations
Field service representatives
BMET specialists
Medical equipment/healthcare technology management
Administrative functions
Management and supervision
Equipment control
Healthcare technology life cycle
Equipment acquisition
Computerized maintenance management system (CMMS)
Safety Codes and Regulations
The Joint Commission accreditation standards
Center for Devices and Radiological Health
Occupational Safety & Health Administration (OSHA)
National Fire Protection Association (NFPA)
National Electrical Code (NEC/NFPA 70)
American National Standards Institute (ANSI)
U.S. Food and Drug Administration (FDA)
ECRI Institute
Local, regional, and national professional organizations
Patient safety
Electrical safety
Fire safety
Radiation safety
Power cords
Electrical wiring
Grounding

Electrical receptacles
Electrical shock
Leakage current
Ground fault circuit interrupter
Isolated power
Line isolation monitor
Inspections on and preventive maintenance:
Inspection and preventive maintenance software
Risk factors, assessment
Troubleshooting
Repair
Biological hazards
Infection control
Universal Protections
Material safety data sheet (MSDS)
Mercury spill containment
Medical Gasses and hazards of compressed gasses
Hazard and recall communications
Professional registration
BMET-related PowerPoint presentations

B. Medical Specialties

Anesthesia
Gynecology
Obstetrics
Ophthalmologist
Respiratory therapy
Intensive/coronary care units
Operating rooms
Endoscopy
Cardiac catheterization laboratory
Radiology
Clinical laboratory
Cytology

C. Medical Equipment

Measurement
Signal
Noise
Signal processing and analysis
Fourier analysis
Physiologic parameters
Sensor
Transducer
Battery-operated equipment
Electromagnetic interference
Temperature measurement
Pressure and force transducer
Motion transducer
Flow transducer
Optical transducer
Electrochemical transducer
Biopotential transducer
Biopotential amplifier
Signal isolation
Electrical noise filtering
Defibrillation protection circuit
Display
Sphygmomanometer
Stethoscope
Electrocardiograph
ECG leads and electrodes
Exercise electrocardiography
Electroencephalograph
Electromyograph
Defibrillator
External pacemaker
Infusion pump
Patient controlled analgesic pump
Feeding pump
Syringe pump
Electrocardiograph monitor
Physiologic monitor
Central station monitor
Invasive (direct) blood pressure monitor
Non-invasive blood pressure (NIBP) monitor
Doppler ultrasound unit
Pulse oximeter
Respiration monitor
Apnea monitor
Volume monitor
End tidal CO_2 monitor
Oxygen analyzer
Cardiac output monitor
Alarms
Physiologic monitor network
Telemetry
Ambulatory (Holter) recording
Bispectral index (BIS) monitor
Life support equipment
Intra-aortic balloon pump
Heart-lung machine
Cell saver
Ventricular assist device
Extracorporeal membrane oxygenator
Respiratory therapy equipment

Bag-valve-mask resuscitator
Suction devices
Pressure regulator
Suction/pressure pump
Dental compressor unit
Dental operating system
Dental ultrasonic prophylaxis unit
Ventilator
Spirometer
Pulmonary function analyzer
Fetal monitor
Neonatal monitor
Sequential compression device (SCD)
Blood/fluid warmer
Hypo-hyperthermia unit
Physical therapy equipment
Continuous passive motion (CPM) unit
Traction unit
Muscle stimulator
Therapeutic ultrasound machine
Transcutaneous electrical nerve stimulator (TENS) unit
Intensive care bed
Infant incubator
Infant transport incubator
Infant radiant warmer
Phototherapy device
Dialysis machine
Anesthesia machine
Anesthetic gas monitor
Electrosurgical unit
Smoke evacuator
Laser
Minimally invasive surgery
Surgical robot
Optics
Ophthalmoscope
Otoscope
Slit lamp
Electro-optics
Microscope
Surgical microscope
Endoscope
Cystoscope
Video
Sterilizer
Clinical Laboratory
Analysis equipment
Organization of the lab
Regulatory agencies
Laboratory safety
pH/blood gas analyzer
Clinical chemistry analyzer
Cell counter
Centrifuge
Hematology analyzer
Colorimeter
Spectrophotometer
Flame photometer
Utility equipment
Ion selective electrode
Co-oximeter
Dosimetry
Electromagnetic radiation
Ionizing radiation
Atom and electron shells
Photons
Inverse square law
Electromagnetic spectrum
X-ray
X-ray regulations
X-ray unit high voltage generator
X-ray unit controls
X-ray tube: anode, cathode, induction motor, cathode and filament currents
Film processor
Mobile x-ray
Fluoroscopy
Dental panoramic x-ray
Digital x-ray
Plate reader
Diagnostic ultrasound machine
Acoustic waves
Electromagnetic waves
Properties of sound in human tissue
Manufacturers of diagnostic ultrasound machines
Clinical uses of diagnostic ultrasound
Propagation of ultrasound waves
Acoustic impedance, reflection, refraction, intensity, attenuation
Diagnostic ultrasound machine modes of operation
Controls of diagnostic ultrasound machine
Transducers used with diagnostic ultrasound
Doppler theory
Axial and lateral resolution of ultrasound
Ultrasound scanner
Scan converter

Quality assurance procedure for ultrasound
Problems with and troubleshooting ultrasound
Nuclear medicine/gamma camera
Computed tomography (CT)
Positron emission tomography
Magnetic resonance imaging (MRI)
Radiation therapy
Computer applications in imaging
Medical network standards, DICOM, HL7
Picture archiving and communication system (PACS)
Power distribution system
Environmental control unit
Oxygen storage and generation system

D. Test Equipment and Procedures

Electrical safety analyzer
Electrical safety testing
Electrosurgical unit analyzer
Electrosurgical unit inspection
Medical ultrasound analyzer
Physiologic monitor inspection
Non-invasive blood pressure (NIBP) monitor analyzer
NIBP inspection
Invasive blood pressure inspection
Cardiac output monitor inspection
Pulse oximeter testing
Electrocardiograph simulator/analyzer
Electrocardiogram (ECG) testing
Telemetry inspection
Fetal monitor inspection
Infusion pump analyzer
Infusion pump inspection
Infant incubator inspection
Infant radiant warmer inspection
Defibrillator analyzer
Defibrillator testing
External pacemaker inspection
Heart-lung machine maintenance
Ventilator inspection and maintenance
Anesthesia machine maintenance
Gas analyzer
Pressure meter
Flowmeter
X-ray unit testing
Centrifuge preventive maintenance
Microscope maintenance
Water bath inspection
Slide stainer inspection
Water bath operation and maintenance
Laboratory incubator operation and maintenance
Slide stainer operation and maintenance
Diluter operation and maintenance
Cell counter inspection
Colorimeter operation and maintenance
Spectrophotometer operation and maintenance

E. Troubleshooting and Repair

Hospital grade plug
Schematic, wiring diagram
Circuit extraction
Relay troubleshooting
Ventilator operation and troubleshooting
Compressor operation and repair
Alternating pressure pump operation and troubleshooting
Heating pad pump operation and troubleshooting
Oxygen concentrator operation and troubleshooting
Low-volume suction machine operation and troubleshooting
Electrocardiograph operation and troubleshooting
Defibrillator troubleshooting
Physiologic monitor troubleshooting
NIBP troubleshooting
Invasive blood pressure troubleshooting
Pulse oximeter operation and troubleshooting
Infusion pump operation and troubleshooting
Fetal monitor operation and troubleshooting
Electrosurgical unit operation and troubleshooting
Sterilizer operation and troubleshooting
Diagnostic ultrasound troubleshooting
Dental x-ray operation and troubleshooting
X-ray unit operation and troubleshooting
Blood gas analyzer operation and troubleshooting
Centrifuge operation and troubleshooting
Centrifuge repair

Core Competencies

II. Electronics

The field of electronics deals with active and passive electrical components, and with analog and digital electrical circuits that involve such components. Electronics is used in information processing, telecommunications, and signal processing. Today, most electronic devices use semiconductor components to perform electron control.

Objectives

1. To understand the principles of electronic components, circuits, and instruments.
2. To apply this understanding to troubleshooting and repairing of electronic equipment.

Educational Topics

A. Basic Concepts

Electrical mathematics
Units of measurement
Atomic structure of matter
Charge, current, energy, voltage
Magnetism
Conductor, insulator
Resistance
Wire jackets
Wire gauge table
Motor

B. Direct Current

Resistor
Resistor color code
Ohm's Law
Watt's Law
Resistive DC circuits
Resistive DC parallel circuit
Resistive DC series-parallel circuit
Capacitor
Inductor
Power
Energy, efficiency
Series, parallel, series-parallel circuits
Network theorems
Kirchoff's voltage law
Variable resistor
Voltage divider
Rheostat
Kirchoff's current law
Current divider
DC circuit analysis
Open and short circuit
Branch and loop current
Node voltage
Source conversion
Branch, nodal, mesh conversion
Thevenin
Superposition, Thevenin's theorem, Norton's theorem
Maximum power transfer theorem
DC power supply

C. Alternating Current

Magnetism and electromagnetism
Sinusoidal AC voltage and current
AC waveform, amplitude, frequency
Signal generator
AC circuit
Reference ground in an AC circuit
Test points in an AC circuit
Phasors
Average and RMS calculations
Impedance
Capacitor
Inductor
Reactance
Transformer
Transformer in a power supply
RC circuit
RL circuit
RLC circuit and resonance
Series, parallel, series-parallel circuits
Series resonance
Parallel resonance
Filter
Circuit theorems
Pulse response of reactive circuits
Series-parallel resonant conditions
Power and power factor
Power: apparent, reactive, real
Three-phase power system
Bode plot
Poly-phase system

D. Solid State

Semiconductors
Atomic structure of semiconductors
Electrons in each shell for Cu, Si, and Ge
Majority and minority current flow in Si and Ge
Semiconductor theory
Atomic theory
Energy levels
Crystals
Hole and electron current
N-type and p-type semiconductors
PN junction
Forward and reverse characteristics for PN junction
Model for ideal and practical diode
Diode
Diode V-I curve
Diode circuits
Series and parallel diode configurations
Half- and full-wave rectification
Bridge rectifier
Rectifier filter
DC power supply circuit
Power supply filtering
Split power supply
Semiconductor analog circuit
Clipping and clamping circuits
Special purpose diodes
Light emitting diode (LED)
Zener diode
Zener voltage regulator
Zener diode application circuit
Photodiode
Transistor theory
Transistor parameters and ratings
Bipolar junction transistor (BJT)
Current flow in BJTs
Symbols for NPN and PNP BJTs
Active, off, and saturation for BJTs
Bias
Base bias
Voltage divider bias
Collector feedback bias
Emitter feedback bias
Input/output impedance
DC load lines
PNP circuits
Transistor switch
Gain in a transistor
Bandwidth
Transistor amplifier
Single stage BJT amplifier
Voltage amplifier
Troubleshooting a BJT amplifier
Transistor AC equivalent circuits
Common-emitter amplifier
Common-collector amplifier
Common-base amplifier
Multi-stage amplifier
Noise
Fixed and voltage divider bias of BJTs
Emitter and collector feedback bias of BJTs
Design and characteristics of BJT circuit configurations
Maximum ratings for BJTs
Four primary types of biasing networks

Transistor regulated power supply
Series and pass transistor operation
Field effect transistor (FET)
Junction gate field-effect transistor (JFET)
Metal–oxide–semiconductor field-effect transistor (MOSFET)
JFET and MOSFET bias circuits
FET amplifiers
FET amplifier AC equivalent circuit
Common-source FET amplifier
Common-drain FET amplifier
Power amplifier
Class B amplifier
Class C amplifier
Push-pull amplifier
Amplifier frequency response
Decibel
Curves for BJTs, FETs, SCRs, and diodes
Compound configurations
Operational amplifier
Negative feedback
Linear operational amplifier circuits
Inverting and non-inverting amplifiers
Inverting adder
Differential amplifier
Bridge amplifier
Instrumentation amplifier
Comparator
Integrator
Differentiator
Level detector
Open loop system
Positive feedback
Active filter
High-pass, low-pass, band-pass, and notch active filters
Oscillator
Frequency response
Fourier series
Unijunction transistor (UJT)
Programmable unijunction transistor (PUT)
Build and operate UJT and PUT relaxation oscillators
Thyristor
Diac
Triac
Silicon controlled rectifier (SCR)
Switch mode power supply
Control circuit
Temperature sensor
Photodevice
Phase control with SCR and Triac
Phase-locked loop
Voltage regulator
Integrated circuit
Fixed and adjustable IC regulator
555 timer

E. Digital

Number systems
Binary number system
Digital mathematics
Transistor-transistor logic (TTL) devices
Complementary metal–oxide–semiconductor (CMOS) devices
Logic gates
Logic level
Pulse waveform
Truth tables
Timing diagrams
System clock
Circuit reduction techniques
Logic families
Digital circuits
MSI/LSI logic circuits
Boolean algebra
DeMorgan's Theorem
Karnaugh maps
Delay times
Switching times
Power dissipation
Digital circuit
Digital arithmetic circuits
Adder
Comparator
Encoder
Decoder
Multiplexers/demultiplexers
Parity circuit
Seven segment display
Edge-triggered circuitry
J-K flip-flop
Negative gate
Build and operate basic gate circuits
Combinational logic circuit
Design a combinational logic circuit
Sequential logic circuit
Latch circuit

Synchronous and asynchronous counters
Shift register
Frequency divider circuit
Switching circuit
Counter
Serial data transmission
Clock circuit
Build and operate two common clock signal source circuits
Monostable theory
Oscillator circuit
Binary input and output
Multiplexing data
Analog to digital conversion
Digital to analog conversion
Optical isolator
Semiconductor memory
Read-only memory (ROM)
Erasable programmable read-only memory (EPROM)
Programmable logic array
Bus systems

F. Telecommunications

Terminology
Signals
Spectra
Noise
Amplitude
Single side band
Transmitter, receiver
Frequency
Modulation
Angle and pulse modulation
Transmission and reception
Communications techniques
Digital and data communication
Multiplexing
Digital -to-analog and analog-to-digital conversions
Radio telemetry
Cabling
Transmission line
Antenna
Laser techniques
Fiberoptics
Television theory

G. Test Equipment

Digital meter
Oscilloscope
Power supply
High voltage probe
Function generator
Frequency counter

H. Skills

Safety
Screwdrivers
Pliers
Wrenches
Power tools
Sockets
Hand measurement tools
Hammers
Punches
Taps and dies
Component identification
Anti-static grounding
Soldering
Wire tinning
Wire joining
Desoldering
Audio/video connectors
Fasteners
Use of digital ohmmeter
Use of digital multimeter
Use of prototype board
Troubleshooting electrical faults
Use of oscilloscope
Build temperature simulator
Build DC power supply
Build connectors
Ordering parts and components from catalogs using Internet
Procedures and equipment for electrostatic discharge (ESD)
Build and operate a complex logic circuit
Digital circuit troubleshooting

Core Competencies

III. Information Technology

Information technology is the field involving the design, application, and support of computer-based information systems. Information technology (IT) uses computers and telecommunications equipment to store, retrieve, transmit, and manipulate data.

Objectives

1. The ability to understand the principles of computers, peripherals, networks, and software.
2. The ability to apply this understanding to applications with medical equipment and systems of medical equipment.

Educational Topics

A. Basic Concepts

Number systems
Microcomputer hardware
Microprocessor
Microprocessor types
Central processing unit
Power supply
Motherboard
Slots
Bus slot card
Input/output card
Drives
Hard drive types
Hard drive interfaces
Optical drive
Address
Microprocessor memory
DRAM subsystem
Microprocessor register
Clocks and timers
Machine code
Assembly code
Machine code instructions
Keyboard and mouse
Data input
Microcomputer architecture
Input/output ports
Disc subsystem
Serial and parallel ports
Input and output devices
Video
Video display hardware
Sound
Printers
Laptop
Storage devices
Disk input/output
Measuring and improving drive performance
Interface applications
Programming
Software architecture
68HC12 instruction set
Addressing modes
Subroutines
Serial data transmission
Bus structure
Read/write timing cycle
Interrupt, interrupt request (IRQ)

Memory
Direct memory access (DMA)
Virtual memory
Paging
Basic programming
Stack operations
Intermediate programming
BCD operations
Conversion subroutines
Multiplexed displays and routines
Multiplexed keyboard and routines
Virus, spyware
Computer certifications
A+ certification

B. Microprocessor Applications

Computer applications
Basic input/output system (BIOS)
Operating system
Installing, configuring, upgrading, troubleshooting operating system
DOS commands
MS-DOS
Windows XP
Windows XP installation and setup
Internet
Windows
Files and folders
File management
Word processing
Spreadsheet
Database
Electronic mail
Word
Documents
Tables
Technical reports
Importing data
HTML
Web pages
Excel
Excel: worksheets
Excel: charts
Excel: functions
Excel: solving electronic engineering problems
Excel: parts inventory
Excel: scheduling
Presentation software
PowerPoint
Project
LabView
Programming languages
Visual Basic
AutoCAD
Programmable controller
Embedded system
Program editing
Formatting
"If" statements
Loops
Text boxes, buttons, pop-ups, picture boxes
Arrays
Subroutines, functions
Accessing hardware

C. Microcomputer Maintenance

Safety procedures
Disassemble personal computer
How to build a computer
Personal computer repair tools
Hard drive organization
Hardware and software diagnostic tools
Performance analysis
System optimization
Sound card
System configuration
Backup device
Universal serial bus (USB)
Compact disc–read only memory (CD-ROM)
Hard drive maintenance
Memory layout
Mouse operation
Serial communication
Keyboard operation
Install operating system
Major components
Remove/replace hardware
Error code
Preventive maintenance
Power supply problems
Media types
Partition hard drive
Microcomputer troubleshooting
Power-on-self-test
Format hard drive
Customer relations
Security
Password

D. Networks

Network
Network terminology
Network topology
Network standards
Network cable types
Network cabling
Network connectors
Network operating system
Network address
Cisco network
Open systems interconnection (OSI) model
802 networking model
Baseband and broadband
Signal transmission
Cables and connectors
Network cabling
Network adapter
Local area network (LAN)
Wide area network (WAN)
Remote connectivity
Ethernet network
Ethernet switching
Token ring network
Connecting device to network
Fiber distributed data interface (FDDI)
Asynchronous transfer mode (ATM)
Digital subscriber line (DSL)
Internet connection sharing (ICS)
Remote access
Frequency and wavelength
Serial data transmission
Synchronous/asynchronous transmission
Network components
Hub
Switch
Cisco switch
Repeater
Bridge
Router
Backbone, segment
Centralized computing environment
Client /server environment
Network protocol
Static route
Routing information protocol (RIP) route
Network traffic, load, utilization
Network gateway
Spanning tree protocol
Root switch and root port
Routing protocol
Access control list (ACL)
Packet filtering ACL
Network address translation/port address translation (NAT/PAT)
Open system interconnection protocol theory
Virtual local area network (VLAN)
Domain name system (DNS)
Dynamic host configuration protocol (DHCP)
Network support tools
Network troubleshooting
Synchronous optical network (SONET)
Client and server relationships
Crosstalk
Data frame
Network software
File sharing
File transfer protocol (FTP)
Transmission control protocol/internet protocol (TCP/IP)
Peer to peer network
Active, passive, hybrid hubs
Wireless network
Network interface controller (NIC)
Packet structure and function
Managing network accounts
Managing network performance
Avoiding data loss
Modem
Point to point protocol (PPP)
Institute of Electrical and Electronics Engineers (IEEE) standards
Media access control (MAC) address
International standard for wide-area packet-switched communications (X.25)
Virtual private network (VPN)
Router and server security
Encapsulation
Internet history
Internet protocol (IP) addressing
Internet functions
Layered model
Subnet
Number conversion
Routing
Packet forwarding
Static routing

Dynamic routing
Voice over IP (VOIP)
Carrier sense multiple access (CSMA), collision detection and avoidance
Routing information protocol (RIP)
Layer 3 switch
Variable length subnet masking (VLSM)
Classless inter-domain routing (CIDR)
Routing information protocol version 2 (RIPv2)
Enhanced interior gateway routing protocol (EIGRP)
Link-state routing protocol
Open shortest path first (OSPF) routing
Radio wave propagation
Radio frequency spectrum
Wireless advantages and disadvantages
Wireless protocol
Wireless local area network (WLAN)
Wireless signal noise
Wireless infrastructure
Wireless router
Wireless gateway
Troubleshooting transmitters and receivers
Fixed and non-fixed wireless networks
Wireless system security
Firewall
Troubleshooting wireless network
Shared wireless access protocol (SWAP)
Documentation
Simple network management protocol (SNMP)
Remote management
Monitoring and optimization
Network security and management
Fault tolerance
Analog and digital signals
Access point
Data collision
Free space optics (FSO)
Satellite fixed broadband wireless
Communications channel bandwidth and data rate
Satellite voice and data communications
Data communications techniques and theories
Low- and high-level modulation
Active and passive filters
Cellular telephone
Infrared wireless technology
Telecommunications standards
FCC rules and regulations
Wireless communication standard IEEE 802
Bluetooth wireless standard

Core Competencies

IV. Anatomy and Physiology

Anatomy and physiology are fields of biology that study the structure and the function of living systems respectively. This includes organisms, organ systems, organs, cells, and bio-molecules in a living system.

Objectives

1. To understand the structures and functions of the human body.
2. To apply this understanding to the interaction of medical equipment with the human body.

Educational Topics

Word roots, prefixes, and suffixes
Definitions, terminology
Human body
Body cavities
Symptoms
Diagnoses
Treatments
Atoms, molecules, compounds, polymers
Chemistry of the human body
Role of water in the body
Ingestion, digestion, absorption, excretion
Metabolism
Adenosine triphosphate (ATP)
DNA
RNA
Cell
Nucleus, cilia, lysome
Tissue
Connective tissue
Biological membranes
Epithelial membrane
Tumor
Organ
System
Organism
Abnormal conditions
Infection, infectious disease
Metabolic disorder
Immune disorder
Meningitis, hydrocephalus, encephalitis, cerebrovascular accident
Centers for Disease Control and Prevention (CDC)
Bacteria, virus, fungus
Anaerobic, aerobic, streptococci, staphylococci
Pasteurization, sterilization, disinfection, antisepsis, antibiotic, media
Immunity
Blood
Circulation, respiration
Oxygen and carbon dioxide transport
Blood testing
Hepatitis
Diffusion, semi-permeable, osmosis, filtration, isotonic, hemolysis
Biomedical measurements
Action potential
Biopotentials
Physiologic parameters
Homeostasis
Vital signs
Hypothermia, hyperthermia

Respiration
Positive and negative feedback systems
Respiratory system
Cardiovascular system
Auscultation
Blood pressure
Hypertension
Heart
Heart chambers and valves
Cardiac cycle
Cardiac conduction system
Coronary circulation system
Heart rate and arrhythmia
Cardiovascular measurements
Electrocardiogram
Cardiac output
Blood vessels
Gastrointestinal system
Bone
Skeletal system
Muscle
Musculoskeletal system
Brain
Nervous system
Neuron, afferent and efferent
Nerve impulse, neurotransmitter
Electroencephalogram
Autonomic nervous system
Eye
Ear
Renal/urinary system
Urinalysis
Renal testing
Endocrine system
Exocrine system
Reproductive system
Lymphatic system
Skin
Balance
Growth and development

Core Competencies

V. Mathematics

Mathematics is the study of numbers and their relationships. Mathematics is an essential tool in the study and application of many other fields, including science, engineering, and economics.

Objectives

1. To understand mathematical concepts up to the level of calculus.
2. To apply this understanding to applications in biomedical equipment technology, electronics, information technology, physics, and chemistry.

Educational Topics

Whole numbers
Prime number
Fractions
Decimal numbers
Percent
Metric system
Metric measures
Metric prefixes
Binary number system
Octal number system
Hexadecimal number system
Other units systems
Exponential notation
Engineering notation
Scientific notation
Scientific calculation
Unit conversion
Converting between number systems
Sets
Set operations
Algebra
Factoring
Equation
Ratio
Proportion
Isolating the variable
Powers
Roots
Exponent
Radical
Logarithm
Linear equation
Formula evaluation and rearrangement
Simplifying algebraic expressions
Inequality
Absolute value equation
Function
Linear function
Equations of a line
Non-linear function
Composite function
Inverse function
Polynomial function
Rational function
Exponential function
Logarithmic function
Systems of equations
Linear systems of equations in two variables
Nonlinear systems of equations in two variables
Matrices
Determinants
Geometry

Measurement
Graphing
Circle, bar, and line graphs
Rectangular coordinate system
Graphing linear equations with two variables
Vector addition
Quadratic equation
Simultaneous equation
Exponential equation
Logarithmic equation
Complex number
Angles
Radians and degrees
Right triangle trigonometry
Oblique triangle trigonometry
Trigonometric functions
Graphs of trigonometric functions
Inverse trigonometric functions
Analytic trigonometry
Trigonometric equation
Trigonometric identity
Vectors in two-dimensional plane
Trigonometric form of complex number
Product and quotient of complex numbers
Powers and roots of complex numbers
Equations with complex solutions
Polar coordinates
Variation
Graphing trigonometric functions
Analytic geometry
Lines and conic sections
Estimation
Probability
Statistics
Rate of change
Integration
Area
Volume
Financial management

Core Competencies

VI. Physics

Physics is a field of science involving the study of matter and energy and their interactions.

Objectives

1. To understand the principles of physics.
2. To apply this understanding to applications in biomedical equipment technology, electronics, and information technology.

Educational Topics

Measurement
Metric abbreviations
Vector quantities
Matter
Motion
Force
Motion on incline
Trajectory motion
Acceleration
Gravity
Newton's Laws of motion
Friction
Field forces
Work
Energy
Power
Circular motion
Force addition by scaling and complement methods
Concurrent and non-concurrent equilibrium
Impulse
Momentum
Collision
Mechanical energy
Heat
Thermodynamics
Thermal energy
Specific heat capacity
Latent heat
Heat transfer methods
Ideal gas laws
Electric force
Electric field
Electric potential and capacitance
Current and resistance
Series and parallel circuits
Magnetism
Electromagnetic induction
Electromagnetic radiation
Waves
Light
Optics
Reflection
Refraction
Interference
Diffraction
Geometrical optics
Physical optics
Spectra
Color
Photometry
Basic forces in physics
Special theory of relativity
Photoelectric effect
Compton effect
Quantum mechanics
Cosmology
Atomic and nuclear physics
Mechanics
Hydraulics
Pneumatics
Motor applications

Core Competencies

VII. Chemistry

Chemistry is a field of science that involves the composition, structure, properties, and reactions of matter. Chemistry is concerned with atoms and their interactions with other atoms and various forms of energy.

Objectives

1. To understand the principles of chemistry.
2. To apply this understanding to applications in biomedical equipment technology, and anatomy and physiology.

Educational Topics

Measurements
Mass
Temperature measurement
Temperature conversion
Atoms
Elements
Periodic table
Chemical formula, equation
Compounds
Energy
Structure and properties of matter
States of matter
Gases, Liquids, and Solids
Combined gas law
Ideal gas law
Law of partial pressures
Mixtures, solutions, solvents, solutes, and suspensions
Specific gravity
Density
Chemical bonding
Ionic bond
Covalent bond
Chemical reactions
Chemical equilibrium
Acids, bases, pH
Electrolyte
Ion, cation, anion
Isotope
Titration

Core Competencies

VIII. English

The field of English involves the study and use of the English language, including grammar, vocabulary, composition, and literature.

Objectives

1. To understand vocabulary and grammar, and to be able to read, write, and present.
2. To apply this understanding and ability to communicate with people involved with healthcare technology management (e.g., clinicians, administrators, manufacturers, and vendors).

Educational Topics

Grammar
Planning and drafting
Thesis statement
Writing essays
Theme
Writing skills
Outline, notes
Organization, transition, integrating sources
Reviewing
Revision
Metacommentary
Diction
Tone
Style
Paragraphs
Sentences
Subject and verb agreement
Coordination and subordination
Reflective essay
Technical writing
Research techniques
Citation
Critical reading
Logical reasoning
Textual analysis
Narration
Description
Critique
Argument
Journal
Research paper
Audience analysis
Documents for reference or instruction
Integrating visuals with text

Core Competencies

IX. Professional Skills

Professional skills include the practical abilities that help employees succeed as practitioners in their careers. This material supplements the theoretical aspects of the curriculum and teaches skills applicable to the professional world. Professional skills are necessary for effective participation in a profession.

Objectives

1. To understand interpersonal relationships (e.g., communications, customer service, professional organizations) necessary for success in the workplace.
2. To apply this understanding to jobs in healthcare technology management.

Educational Topics

A. Philosophy

Logical fallacies
Deductive and inductive reasoning
Argument evaluation and construction
Thinking critically about the media
Science and pseudoscience

B. Psychology

Research methods
Biology of behavior
Learning
Cognition (memory, thought, and language)
Job analysis and evaluation
Employee selection
Evaluating employee performance
Group behavior
Employee motivation
Employee satisfaction and commitment
Organizational communication
Stress management

C. Technology Careers

Goals
Time management
Budget
Personal attributes
Safety
Critical thinking
Academic integrity
Working with data
Data-driven decision making
Documentation
Communication
Engineering communication
Electronic communication
Presentation skills
Public speaking
Career exploration
Engineering careers
Job search
Resume

Job application
Interviewing techniques
Job application follow-up
Job performance skills
Working relations
Professionalism
Professional ethics
Ethical and social responsibilities in the workplace
Whistleblowing
Diversity
Diversity in the workplace
Bias in the workplace
Workplace problem solving
Teams, teamwork, and self-monitoring
Design and teamwork
Quality, quality improvement

D. Practicum/Internship to Include

Hospital and department organization
Employee orientation
BMET department experience
Clinical engineering department meeting
Chemical safety
Biological safety
Codes and standards
The Joint Commission
American Association of Blood Banks
National Fire Protection Association/
NFPA-99 Health Facilities Code
U.S. Food and Drug Administration
Safe Medication Devices Act (SMDA)
Occupational Safety & Health Administration (OSHA)
X-ray tester/scope meter
Infusion pump tester
Multi-parameter patient simulator
Anesthetic gas analyzer
CO_2/O_2 analyzer
Medical equipment function
Inspection and preventive maintenance
Servicing medical equipment
Equipment maintenance documentation
Medical equipment use
Medical equipment cycle—acquisition to disposal
Infection control/Sterile procedures
Operating cost/budgeting
Problem solving
Interpersonal skill development
Professional development
Write paper on experience
Research project

Core Competencies

X. Practical Experience—Internship/Laboratory

Laboratory and/or internship education involving use of biomedical equipment; applied healthcare technology management education, as opposed to theoretical; the BMET program advisory committee reviews and advises on content at least annually.

Objectives

1. To understand how to operate and maintain biomedical equipment.
2. To apply this understanding and ability to actual biomedical equipment, either in a laboratory or in a hospital.
3. To apply education with real-life, hands-on experience in an actual work environment.
4. To practice a variety of healthcare technology management responsibilities including the following:
   a. equipment safety;
   b. inspection and maintenance procedures;
   c. troubleshooting and repair;
   d. acceptance testing/incoming inspection;
   e. documentation; and
   f. equipment evaluation.

Educational Topics

Student responsibilities in a working environment written and explained
Employee orientation to department and organization
Policies and procedures of department and organization
Organizational chart of department and organization
Evaluation of student by supervisor
Recording and reporting experience working as a BMET
Hands-on experience in the department
Hands-on experience in representative areas served by department
Hands-on experience in different organizations—hospital, ISO, manufacturer
Attention to detail

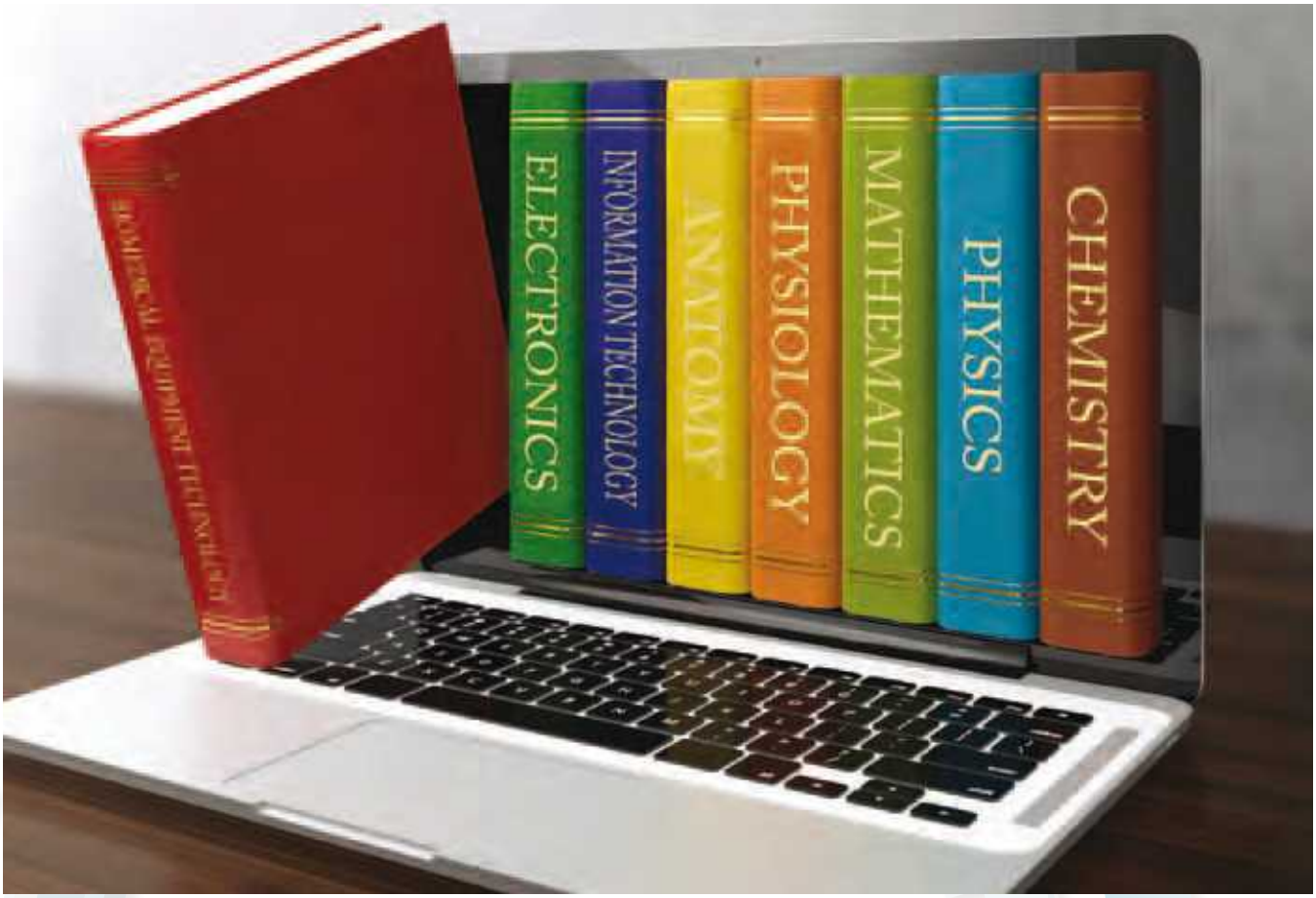
Reliability
Verbal communication
Ability to accept criticism
Demeanor
Professional behavior in the workplace
Personal grooming
Collaboration
Initiative
Self-improvement
Adaptability
Attention to patient and personal safety
Safe and proper use of biomedical equipment
Safe and proper use of biomedical test equipment
Inspection of and maintenance of biomedical equipment
Troubleshoot problems with biomedical equipment
Equipment inventory and control
Computerized maintenance management system (CMMS)
Attendance at department meetings

Note regarding laboratory courses:

Obtaining representative samples of modern medical equipment for laboratory courses has always been a challenge for BMET schools. Modern medical equipment is an expensive, moving target, and budgets are limited and donations are usually limited to out-of-date, retired equipment. Nevertheless, schools, with assistance from their advisory committees, must determine the types of equipment that are most critical to their students' laboratory experience, and strive to obtain it by negotiating for donations or discounts with manufacturers and vendors.

Note regarding internships:

Placing students in internship positions can be challenging due to the scarce number of potential internship sites in the vicinity. BMET schools have taken various approaches to establishing internships. One approach is to have only limited (or no) internships and instead develop very strong laboratory courses to provide practical experience. Another approach is cast a wider net to internship sites regionally or nationally, beyond the immediate locale of the BMET school. Although somewhat inconvenient, a paid internship could provide the BMET intern with resources for temporary housing and living expenses.



Resources for BMET Educational Programs

Resources for BMET Educational Programs

The following textbooks, workbooks, and tools/supplies are suggested resources only and not inclusive of all resources that may be used by BMET schools.

Textbooks

Biomedical Equipment Technology

Basic Laboratory Methods for Biotechnology
Seidman, Lisa A.; Moore, Cynthia J.
ISBN 0-13-795535-9

Biomedical Device Technology—Principles and Design
Chan, Anthony
Charles C. Thomas, 2008, ISBN 978-0-398-07699-3

Biomedical Instrumentation, Technology and Applications
Khandpur, R.S.
McGraw Hill, 2005, ISBN 0-07-144-784-9

BMET Study Guide: Preparing for Certification and Sharpening Your Skills
AAMI, 2012

Clinical Engineering Handbook
Dyro, Joseph
Academic Press, 2004, ISBN 978-0122265709

Clinical Engineering Principles and Practices
Webster and Cook
Prentice Hall, 1979

Electrocardiography for Health Care Personnel, 3rd ed.
Booth, Kathryn; O'Brien, Thomas
MacGraw Hill, 2012

Introduction to Biomedical Equipment Technology
Carr & Brown
Prentice Hall, 2001, ISBN 0-13849431-2

Introduction to Biomedical Instrumentation: The Technology of Patient Care
Christe, Barbara
Cambridge University Press, 2009

Medical Equipment Management Manual
Stiefel, Robert H.
AAMI, 2009, ISBN 1-57020-350-4

NFPA 99 Health Care Facilities
National Fire Protection Association, 2012

NFPA 99 Health Care Facilities Code Handbook
National Fire Protection Association, 2012

Principles of Biomedical Instrumentation and Measurement
Aston, R.
Merrill Publishing Co., Columbus, OH, 1990

Radiographic Science for Technologists: Physics, Biology, and Protection, 10th ed.
Bushong, Stewart C.
Mosby, 2009, ISBN 0323064140

Recommended practice for a medical equipment management program, ANSI/AAMI EQ56:2013
AAMI, 2013, ISBN 1-57020-483-7

Safety in Healthcare Facilities
Cram, Nicolas; Holder, Selby
TSTC, 2007

Tech Careers: Biomedical Equipment Technicians
Bowles, Roger
ISBN 978-1-934302-29-3

Ultrasound Physics and Technology: How, Why, and When
Gibbs, Vivien; Cole, David; Sassano, Antonio
Elsevier, 2009, ISBN 978-0-7020-3041-3

Electronics

Circuit Analysis—Theory and Practice
Robbins, Allan; Miller, Wilhelm C.

Digital Fundamentals
Floyd, Thomas L.
Prentice Hall, ISBN 9780132359238

Digital Systems, 10th ed.
Tocci, Ronald J.
Prentice Hall

Digital Systems Principles and Applications
Tocci, Ronald J.; Widmer, Neal S.
Prentice-Hall, 2009, ISBN 97801131725799

Drafting for Electronics, 3rd ed.
Lamit and Lloyd
Prentice Hall

Electrical Machines, Drives, and Power systems, 6th ed.
Wildi, T.
Prentice Hall

Electronic Devices and Circuit Theory, 10th ed.
Boylestad, Robert; Naqshelsky, Louis
Prentice-Hall, 2009

Electronic Devices—Conventional Flow Version
Floyd, Thomas L.
Prentice Hall, ISBN 0131140809

Electronic Devices—Electron Flow Version
Floyd, Thomas L.
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Tools/Supplies

Arduino Experimentation Kit, ARDX, v1.0

Digital/analog trainer, RSR Electronics pn P01PAD234A

Digital multimeter

Electronics component kit

Electronics tool kit

Graphing calculator

Logic probe kit, Elenco Electronics model LP-525K

LabVolt MindSight System

MS Excel

MS Word

Removable storage device

Scientific calculator

Accreditation

Accreditation

Accreditation of institutions of higher learning is intended to ensure the quality of the education provided. There are a variety of types of accreditation, including national or regional, and institutional or programmatic. There are over 7,000 colleges and universities and more than 20,000 programs accredited by 19 institutional accrediting agencies and 61 programmatic accreditors (Eaton, JS.).

Accrediting agencies are private educational associations that conduct peer evaluations of educational institutions and programs. Accreditation agencies do not specify curricula or competencies. Accrediting agencies can, in turn, be accredited by the U.S. Department of Education (USDE), the Council for Higher Education Accreditation (CHEA), or both. Institutions of higher learning that are accredited by an agency that is recognized by the U.S. Secretary of Education can participate in federal financial assistance programs administered by the U.S. Department of Education.

ABET and The Association of Technology, Management, and Applied Engineering (ATMAE) are national accreditation agencies that accredit programs in applied science, computing, engineering, and engineering technology. Most of the agencies that accredit institutions that provide BMET education programs are regional and accredit the entire institution—not individual programs.

Regional accreditation agencies include:

- Middle States Association of Colleges and Schools
- New England Association of Schools and Colleges
- New York State Board of Regents
- North Central Association of Colleges and Schools
- Northwest Commission on Colleges and Universities
- Oklahoma Board of Career and Technology Education
- Oklahoma State Regents for Higher Education
- Pennsylvania State Board of Vocational Education
- Puerto Rico State Agency for the Approval of Public Postsecondary Vocational, Technical Institutions and Programs
- Southern Association of Colleges and Schools
- Western Association—Community and Junior Colleges
- Western Association—Senior Colleges and Universities

It is beyond the scope of this Guide to discuss the accreditation criteria for BMET educational programs or their schools. However, the ABET criteria may serve as an example. The ABET program criteria for bioengineering technology (and similarly named programs) are more general than the specific topics included in our BMET topics list. Their criteria are available on ABET's website at www.abet.org/accreditation-criteria-policies-documents (see Figure 4).

ABET Accreditation Criteria for Bioengineering Technology and Similarly Named Programs

Lead Society: Biomedical Engineering Society

Cooperating Societies: American Ceramic Society, American Institute of Chemical Engineers, American Society of Agricultural and Biological Engineers, American Society of Mechanical Engineers, Institute of Electrical and Electronics Engineers

Applicability: These program criteria apply to engineering technology programs that include bioengineering, biomedical engineering, medical electronics, biomedical equipment and similar modifiers in their titles.

Objective: An accreditable program in Bioengineering Technology will prepare graduates with the technical skills necessary to enter careers in the design, application, installation, operation and/or maintenance of biomedical equipment. Graduates of associate degree programs typically have strengths in the building, testing, operation, and maintenance of existing biomedical equipment or systems, whereas baccalaureate degree graduates are well prepared for development and implementation of biomedical equipment or systems.

Outcomes:

Graduates of associate degree programs must demonstrate knowledge and hands-on competence appropriate to the goals of the program in the following:

a. the application of circuit analysis and design, analog and digital electronics, microcomputers, bioengineering systems, and safety in the building, testing, operation, and maintenance of biomedical equipment; and

b. the applications of physics, chemistry, and biological sciences to building, testing, operation, and maintenance of biomedical equipment in a rigorous mathematical environment at or above the level of algebra and trigonometry;

In addition to the above, graduates of baccalaureate degree programs must demonstrate the following:

a. the ability to analyze, design, and implement bioengineering systems;

b. the ability to utilize statistics/probability, transform methods, discrete mathematics, or applied differential equations in support of bioengineering systems; and

c. an understanding of the clinical application of biomedical equipment.

Figure 4. ABET Accreditation Criteria

Accreditation

AAMI/ICC Certification

The International Certification Commission for Clinical Engineering and Biomedical Technology (ICC), through AAMI, certifies biomedical equipment technicians (CBET), radiology equipment specialists (CRES), and laboratory equipment specialists (CLES).

The AAMI/ICC Certification for the Biomedical Equipment Technician (BMET) is a formal recognition by the International Certification Commission for Clinical Engineering and Biomedical Technology for individuals that have demonstrated excellence in theoretical as well as practical knowledge of the principles of biomedical equipment technology.

Certification gives formal recognition of an individual's theoretical and practical knowledge of biomedical equipment technology. Information about certification and the current "Handbook for Applicants" is available from AAMI (see www.aami.org/certification). The handbook explains the application for testing and the exam itself. See Figure 5 for a list of the topics included in the 2012 edition of the handbook.

Applicants must have an appropriate combination of education and experience. One such combination is an associate's degree in biomedical equipment technology and two years of full-time BMET experience. However, applicants can also be eligible for candidate status by completing their educational requirement. Then, upon completion of the experience requirement, they can receive full certification.

I. **Anatomy and Physiology** *(Approximately 12%)*
- A. Systems
  - 1. Respiratory
  - 2. Gastrointestinal
  - 3. Nervous
  - 4. Circulatory
  - 5. Musculoskeletal
  - 6. Endocrine
- B. Organs
  - 1. Heart
  - 2. Lungs
  - 3. Liver
  - 4. Kidneys
  - 5. Brain
  - 6. Gallbladder
  - 7. Pancreas
  - 8. Other
- C. Blood
  - 1. Components
  - 2. Metabolism
- D. Terminology

II. **Public (employee, patient, visitor) Safety in The Healthcare Facility** *(Approximately 15%)*
- A. Electrical
  - 1. Microshock/Electrical Safety Testing
  - 2. Other
- B. Chemical
  - 1. Material Safety Data Sheet
  - 2. Other
- C. Radiation Hazards
  - 1. Light Spectrum
  - 2. Types of Rays
- D. Biological
  - 1. Standard Precautions
  - 2. Other
- E. Fire
  - 1. Class
  - 2. Fire Extinguishers
- F. Codes and Standards
  - 1. Credentialing and Certification
    - a. Joint Commission Comprehensive Accreditation Manual
    - b. AABB
    - c. American College of Radiology

Figure 5. List of topics in 2013 CBET Examination

Please refer to the most recent version of the handbook, available at www.aami.org/certification.

2. NFPA 99
   a. Gas and Vacuum Systems
   b. Electrical Systems
3. FDA
   a. SMDA
   b. Other
4. OSHA
5. Other (NEC, ANSI, FCC, etc.)

III. Fundamentals of Electricity and Electronics *(Approximately 13%)*

A. Transducers
B. Calculations and Conversions
   1. Hex/Decimal/Binary
   2. Other
C. Circuits and Components
   1. Active Devices
      a. Solid-State Devices
         1. Analog
         2. Digital
      b. Other (CRTs, X-Ray tubes, Photomultipliers, etc.)
   2. Power Supplies
   3. Passive Devices
D. Power Distribution and Storage Systems
   1. Transformers
   2. Distribution
   3. Batteries
   4. UPS/Line Conditioning
E. Terminology

IV. Healthcare Technology Function and Operation *(Approximately 25%)*

A. Monitoring Systems (ECG, EEG, Blood Pressure, Pulse Oximetry, Fetal Monitor)
B. Portable Equipment (Infusion Devices, Syringe Pumps, PCA Pumps, Hypo Hyperthermia)
C. Life Support Equipment (Defibrillators, Anesthesia Machines, Critical Care Ventilators, Balloon Pumps)
D. Therapeutic Equipment (Infant Warmers, Ultrasound Therapy)
E. Laboratory Equipment (Centrifuges, Water Baths, Analyzers)
F. Diagnostic Imaging (Ultrasound, Radiographic/Fluoroscopy)
G. Operating Room (Electro Surgical Generators, Video Carts, Lasers, Tourniquets, Sterilizers, Warmers)
H. Test Equipment (Electrical Safety, Defibrillator, Electro Surgical, Physiologic Simulators, Oscilloscopes, Meters)
I. Diagnostic Equipment
J. Terminology

Figure 5. List of topics in 2013 CBET Examination (continued)

V. **Healthcare Technology Problem Solving** *(Approximately 25%)*
- A. Electronic Component Level, Block Level
- B. Monitoring Systems (ECG, EEG, Blood Pressure, Pulse Oximetry, Fetal Monitor)
- C. Portable Equipment (Infusion Devices, Syringe Pumps, PCA Pumps, Hypo Hyperthermia)
- D. Life Support Equipment (Defibrillators, Hemodialysis, Anesthesia Machines, Critical Care Ventilators, Balloon Pumps)
- E. Therapeutic Equipment (Infant Warmers, Ultrasound Therapy)
- F. Laboratory Equipment (Centrifuges, Water Baths, Analyzers)
- G. Diagnostic Imaging (Ultrasound, Radiographic/Fluoroscopy)
- H. Operating Room (Electro Surgical Generators, Video Carts, Lasers, Tourniquets, Sterilizers, Warmers)
- I. Diagnostic Equipment
- J. Situational (User Error, User Training, Applications)

VI. **Healthcare Information Technology** *(Approximately 10%)*
- A. Regulatory and Safety
  1. Medical Device Data Systems (MDDS)
  2. IEC 80001 – Application of Risk Management for IT Networks
  3. Health Insurance Portability and Accountability Act (HIPAA)
  4. Digital Millennium Copyright Act (DMCA)
- B. Foundations
  1. Hardware
     - a. Topology
     - b. PCs/Laptops/Servers
     - c. Wiring/Structured Cabling/Connectors
     - d. Switches/Hubs/Routers
     - e. Wireless Communications
     - f. Other
  2. Software/Middleware/Applications
     - a. EMR/EHR
     - b. Healthcare Information Systems (PACs, LIS, RIS)
     - c. Network Protocols (IP, CCP, UDP)
     - d. Operating Systems
- C. Function and Operation
  1. Hardware
     - a. PCs, Switches, Patch Panels
     - b. Networks, Topology
     - c. Peripherals
     - d. Other

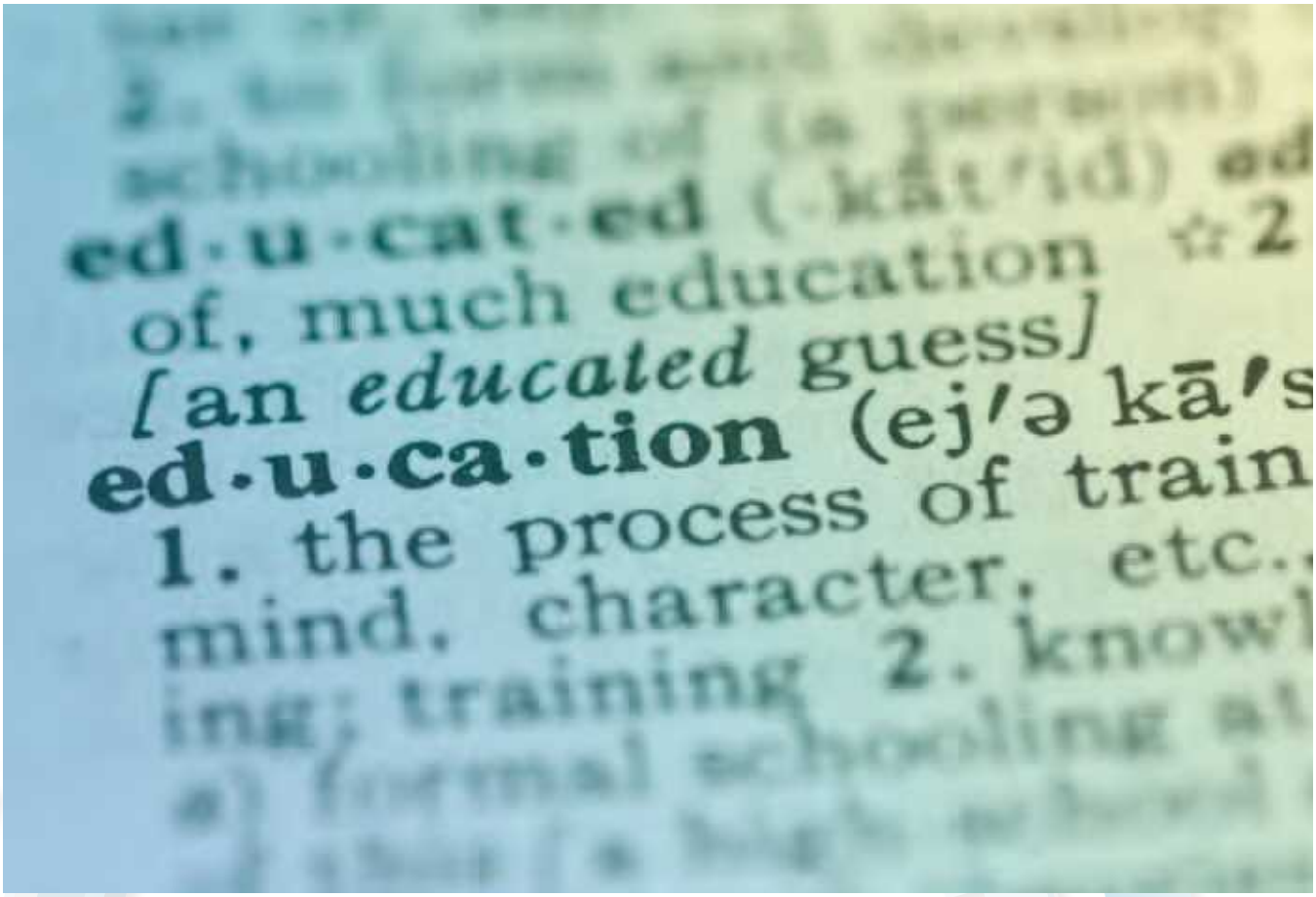
Figure 5. List of topics in 2013 CBET Examination (continued)

2. Integration
    a. Bedside Medical Device Integration (BMDI)
    b. Medical Device Integration (MDI) (Labs, Printers, etc.)
    c. Mobile Devices (Handhelds, Smart Phones, Tablets, etc.)
3. Test Equipment
    a. Cable Test Devices (Copper, Fiber)
    b. Network Test Devices
4. Security

D. Problem Solving
1. Computer Networks
2. Integration
3. PCs, Switches, Hubs

E. Terminology

Figure 5. List of topics in 2013 CBET Examination (continued)



Definitions and Acronyms

Definitions and Acronyms

AAMI Association for the Advancement of Medical Instrumentation

Accredit/Accreditation 1. To bring into credit or favor. 2. To authorize; give credentials to. 3. To believe in; take as true. 4. To certify as meeting certain set standards by regional associations. 5. To attribute. *Webster's New World Dictionary*. A process in which certification of competency, authority, or credibility is presented by an authoritative body.

ACCE American College of Clinical Engineering

ACL Access control list

ANSI American National Standards Institute

ATM Asynchronous transfer mode

ATMAE Association of Technology, Management and Applied Engineering

ATP Adenosine triphosphate

BIOS Basic input/output system

BIS Bispectral index—as in "BIS monitor"

BJT Bipolar junction transistor

BMET Biomedical Equipment Technician/ Technologist

CBET (Certified Biomedical Equipment Technician) A professional certification issued to eligible individuals upon passing the AAMI/International Certification Commission exam.

CDC Centers for Disease Control and Prevention

CD-ROM Compact disc–read only memory

CDRH Centers for Devices and Radiological Health (Division of the U.S. Food and Drug Administration)

CE Clinical Engineering

CFR Code of Federal Regulations

CHEA Council for Higher Education Accreditation

CIDR Classless inter-domain routing

CLES (Certified Laboratory Equipment Specialist) A professional certification issued to eligible individuals upon passing the AAMI/International Certification Commission exam.

CMMS Computerized maintenance management system

CMOS Complementary metal-oxide-semiconductor—as in "CMOS devices"

Competence/competent 1. Well qualified; capable; fit. 2. Sufficient; adequate. 3. Permissible or properly belonging; authorized, or fit. *Webster's New World Dictionary.*

Core competency An area of specialized expertise that is the result of harmonizing complex streams of technology and work activity." ~ C.K. Prahalad

Core competency An area of expertise that is fundamental to a particular job or function. Encarta® World English Dictionary [North American Edition] © & (P) 2009 Microsoft Corporation

Competency An observable and measurable behavior that has a definite beginning and end; can be performed within a limited amount of time; consists of two or more competency builders; and leads to a product, service, or decision.

Competency builders The skills, knowledge, and attitudes (written in measurable terms) needed to perform a given competency.

CPM Continuous passive motion—as in "CPM unit"

CRES (Certified Radiology Equipment Specialist) A professional certification issued to eligible individuals upon passing the AAMI/International Certification Commission exam.

CSMA Carrier sense multiple access

CT Computed tomography

DHCP Dynamic host configuration protocol

DMA Direct memory access

DNS Domain name system

DSL Digital subscriber line

ECG Electrocardiogram

EIGRP Enhanced interior gateway routing protocol

Entry level A position of employment that requires no previous experience, but may require some training and/or specific skills, knowledge, or attitudes.

EPROM Erasable programmable read-only memory

ESD Electrostatic discharge

ETA Electronics Technician Association

FCC Federal Communications Commission

FDDI Fiber distributed data interface

FET Field effect transistor

FSE Field service engineers

FSO Free space optics

FTP File transfer protocol

Healthcare Technology Management (HTM) The professional field responsible for managing the selection, maintenance, and safe and effective use of medical equipment and systems.

ICC (International Certification Commission) AAMI's issuing body of professional certifications.

ICS Internet connection sharing

Information technology The field involving the design, application, and support of computer-based information systems. Information technology (IT) uses computers and telecommunications equipment to store, retrieve, transmit, and manipulate data.

IP Internet protocol

IEEE Institute of Electrical and Electronics Engineers

IRQ Interrupt request

ISO Independent service organization

JFET Junction gate field-effect transistor

LAN Local area network

LED Light emitting diode

MAC Media access control—as in "MAC address"

META Medical Engineers & Technicians Association

MRI Magnetic resonance imaging

MSDS Material safety data sheet

MOSFET Metal-oxide-semiconductor-field-effect-transistor

NAT/PAT Network address translation/port address translation

NEC National Electrical Code

NIBP Non-invasive blood pressure—as in "NIBP monitors"

NIC Network interface controller

NPFA National Fire Protection Agency

OEM Original equipment manufacturer

OSPF Open shortest path first

OSHA Occupational Safety and Health Administration

PACS Picture archiving and communication system

PPP Point to point protocol

PUT Programmable unijunction transistor

RIP Routing information protocol—as in "RIP route"

ROM Read only memory

SCR Silicon controlled rectifier

SCD Sequential compression device

SMDA Safe Medication Devices Act

SONET Synchronous optical network

SNMP Simple network management protocol

SWAP Shared wireless access protocol

TCP/IP Transmission control protocol/network protocol

TENS Transcutaneous electrical nerve stimulator—as in "TENS unit"

TJC The Joint Commission

TTL Transistor-transistor logic—as in "TTL devices"

UJT Unijunction transistor

USB Universal serial bus

USDE United States Department of Education

U.S. FDA United States Food and Drug Administration

VLAN Virtual local area network

VLSM Variable length subnet masking

VOIP Voice over internet protocol

VPN Virtual private network

WAN Wide area network

WLAN Wireless local area network

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Bibliography and AAMI Online Resources

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AAMI Online Resources

AAMI Career Tools for the HTM Community	www.aami.org/careertools
AAMI Communities	www.aami.org/communities
AAMI Membership	www.aami.org/membership
AAMI Publications	www.aami.org/publications
AAMI Student Website	www.aami.org/student
BMET Schools	www.aami.org/student/education.html
Promotion of the Field	www.IamHTM.com

AAMI Programs Making a Difference

Standards—AAMI is a leading source of consensus standards and guidelines to expedite and enhance the development, management, and use of healthcare technology. More than 100 AAMI technical committees and working groups write medical device standards, recommended practices, and technical information reports on issues ranging from sterilization to dialysis and clinical alarms to electromedical equipment. E-mail: standards@aami.org.

Publications—AAMI offers several complimentary publications to keep members up to date on standards and regulations, new technologies, policy developments, and guidance. Visit www.aami.org/publications/books.

Books & CDs—AAMI's comprehensive and practical books and manuals cover a wide variety of important topics including sterilization, information technology, accreditation, human factors, healthcare technology management, quality systems, and certification. Visit www.aami.org/books.

AAMI's Annual Conference & Expo—It's the premier conference for healthcare technology management—a three-day networking and learning experience that features the best and brightest speakers discussing key issues affecting patient safety and the healthcare technology management profession. To learn more, visit www.aami.org/ac.

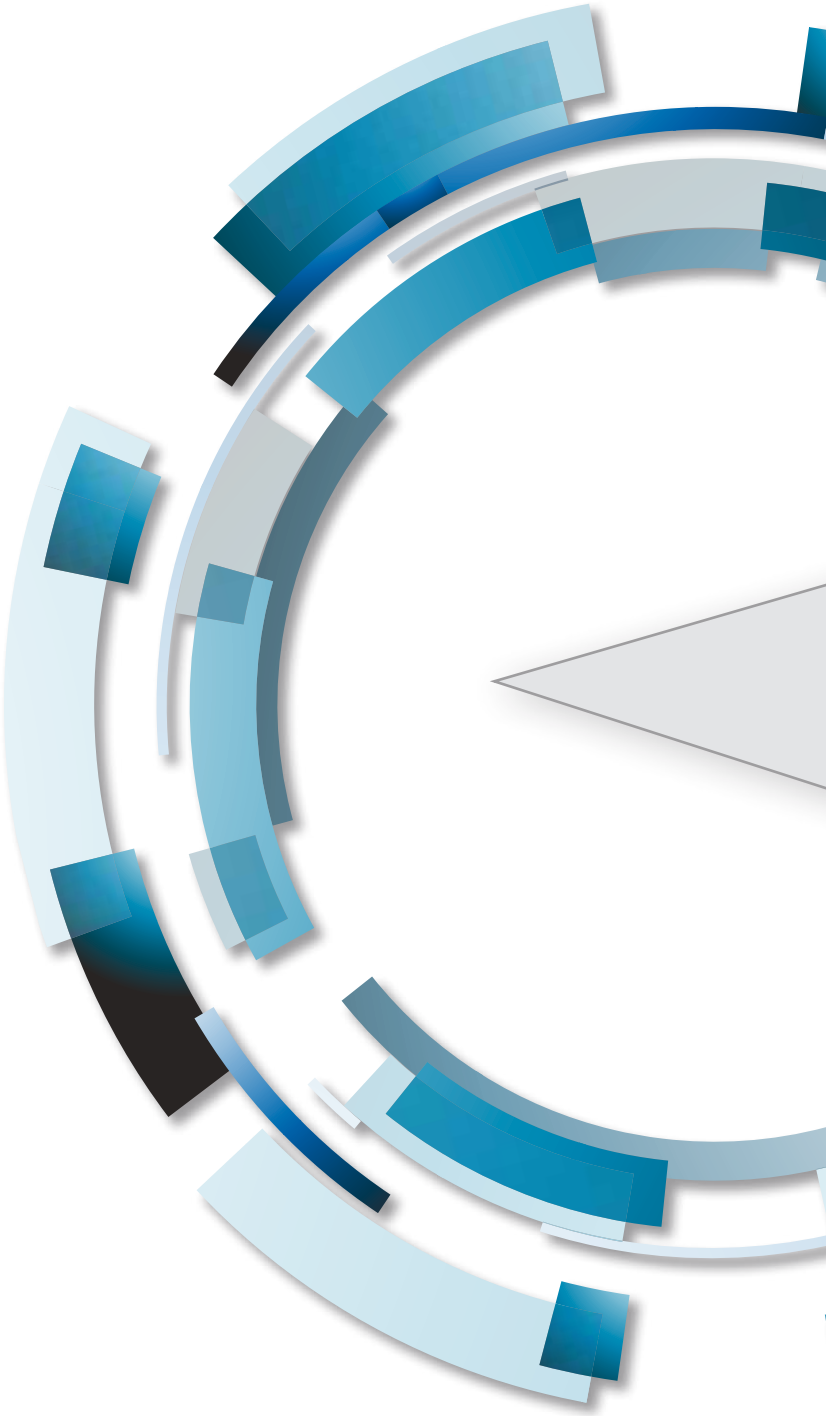
International Standards Conference—The AAMI/FDA International Conference on Medical Device Standards and Regulation is a unique annual event bringing together industry and government leaders to explore the latest developments in international standards key to global market access and regulatory compliance. To learn more, visit www.aami.org/isc.

Training Programs—AAMI provides numerous face-to-face training programs, and online courses and webinars covering critical topics such as quality systems, sterilization, clinical engineering, design control, process and software validation, risk management, documents/records, statistics, purchasing controls, human factors, benchmarking, and IT issues. To learn more, visit www.aami.org/meetings.

Certification—AAMI provides leadership in public safety through the oversight of the International Certification Commission's certification programs for biomedical equipment technicians (CBET), radiology equipment specialists (CRES), and laboratory equipment specialists (CLES). To learn more, visit www.aami.org/certification.

Benchmarking—AAMI offers two web-based benchmarking tools designed specifically to help healthcare technology management and sterile processing departments measure their practices, policies, and procedures against similar departments at other facilities. Visit www.aami.org/benchmarking.

Healthcare Technology Safety Institute (HTSI)—The AAMI Foundation's HTSI is a new community of leaders focused on a common vision, "Healthcare technology will advance patient safety and will do no harm." HTSI engages the healthcare community in multidisciplinary safety initiatives to strengthen the development, management, and use of healthcare technology for improved patient outcomes. To get involved, e-mail htsi@aami.org or visit www.aami.org/htsi.



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Advancing Safety in Medical Technology

4301 N. Fairfax Drive, Suite 301
Arlington, VA 22203-1633
Phone: +1-703-525-4890
Web: www.aami.org