Biomedical Electronics Technician (BMD)

Competency Requirements

Biomedical electronics technicians are expected to obtain knowledge of the principles of modern biomedical techniques, the proper procedure in the care, handling and maintenance of biomedical equipment and to display an attitude/behavior expected of an electronics technician who works in a hospital or healthcare environment. The BMD is a journeyman level certification requiring the basic electronics competence as the pre-requisite to earn a CET, which can be achieved by earning the Associate CETa prior to or on the same day as your CETcertification examination. Once the CET has acquired these skills, abilities and knowledge, he or she will be able to enter employment in any part of the biomedical electronics field. With minimal training in areas unique to specific products, the CET should become a profitable and efficient part of the medical workforce.

Biomedical Electronics Technicians must be knowledgeable and have abilities in the following technical and human relations areas:

1.0 MEDICAL ELECTRONICS SAFETY

- 1.1 Define electrical safety
- 1.2 List the names of major organizations which publish electrical safety codes and standards
- 1.3 List responsibilities of hospital staff regarding safety
  - 1.3.1 Develop an electrical safety program for a typical hospital
- 1.4 Relate how preventive maintenance reduces electrical hazards
- 1.5 Define corrective maintenance
- 1.6 Define preventive maintenance
- 1.7 Explain the insurance and legal requirements regarding electrical safety
- 1.8 Describe medical industry safety standards
- 1.9 Explain the physiological effects of poor safety measures on the human body
- 1.10 Define leakage current
- 1.11 Explain the usefulness of A.C. line isolation systems
- 1.12 List the dangers associated with poor grounding
- 1.13 Describe required grounding of electronics equipment
- 1.14 Explain how hazards through ground faults can be reduced
- 1.15 Administer electrical safety tests on equipment
- 1.16 Explain precautions required for communicable disease (H.I.V. or TB) prevention for hospital workers
- 1.17 List precautions for working with/on ladders (ANSI ASC A14 standard)
- 1.18 List extra precautions biomed personnel must take to maintain cleanliness standards in medical facilities
- 1.19 Briefly describe the following safety code standards:
  - 1.19.1 NFPA 99 and Chapter 7, Healthcare Facilities Code
  - 1.19.2 NFPA 70®, National Electrical Code® (NEC®)
  - 1.19.3 NFPA 101®, Life Safety Code®
  - 1.19.4 CFR 21 (Code of Federal Regulations, Title 21 {FDA})
- 1.20 Describe microshock (also called cardiac shock, ventricular fibrillation)
- 1.21 Describe macroshock (also called strong current electrocution)
- 1.22 State the ground resistance limit for *existing* portable medical equipment in patient care areas
- 1.23 State the ground resistance limit for *new* portable medical equipment in patient care
- 1.24 State the chassis leakage current limit for portable medical equipment in patient care areas
- 1.25 State the lead leakage current limit for portable medical equipment in patient care areas
- 1.26 Describe the current radiation safety rules required in medical equipment use and maintenance
- 1.27 Describe the current rules for safety in the maintenance and use of medical laser equipment
- 1.28 Describe fire safety rules commonly required for medical equipment maintenance personnel
- 1.29 Describe chemical rules commonly required for medical equipment maintenance personnel

2.0 THE HUMAN NERVOUS SYSTEM

- 2.1 Explain the major functions of the nervous system
  - 2.1.1 Identify the human anatomy as it relates to the nervous system
- 2.2 List the major parts/divisions of the nervous system

2.3 Describe the functions of each part/division of the nervous system including the peripheral and the autonomic nervous system
2.4 Define the terms related to each part/division of the nervous system. e.g.: homeostasis; nerve impulse; neuron; reflex action; equilibrium cerebral dysfunction; lobes; etc.
2.5 Describe the function of the EEG machine
  2.5.1 List the functional problems associated with the EEG machine
  2.5.2 List the basic care/maintenance procedures of the EEG machine
2.6 Describe the function of the cerebellum
2.7 Describe the function of the cerebrum
2.8 Describe the function of the central nervous system

3.0 MEDICAL ELECTRODES

3.1. Define an electrode
3.2 Define the term “biopotentials”
3.3 Explain how impedance mismatches between electrodes and skin surfaces can affect accuracy in measurements
3.4 Give an approximate impedance of wet human skin
3.5 Give an approximate impedance of dry skin
3.6 Define the term “Half cell potential”
3.7 Name different types of electrodes and the body organs to which they are applied
3.8 Describe the shapes of electrodes as they relate to their applications
3.9 Describe the chemical/paste applied between electrode and skin
3.10 Define the types of “artifacts” and their causes
3.11 List some measures which can be adopted to minimize or avoid artifacts

4.0 BUILDING WIRING, CABLES AND CABLING

4.1 List the standards used in the electrical wiring of medical buildings
4.2 Explain National Electrical Code (NEC®) and other safety rules pertaining to building wiring and grounding
4.3 Explain methods of pre-wiring and re- wiring existing buildings including entry, attic, plenum, riser and crawl space precautions
4.4 Describe copper cabling and how it’s used
  4.4.1 Twisted pair (25-pair - UTP (unshielded) or STP (shielded))
  4.4.2 Coaxial
4.5 Describe skills used to install RJ45/48 connectors and fittings
4.6 Explain the difference between single twisted pair and CAT-5 (5e, 6, 6_A)
4.7 Explain where Ethernet standards cabling is used and its frequency capabilities
4.8 Describe the TIA 568A / TIA 568B standards and explain their purpose
4.9 Explain how Cable TV coaxial cabling is used for data and voice services
4.10 Explain the differences between coax types RG 58, RG 59 and RG 6
4.11 Describe color coding systems (NEC®, TIA-568, TIA-598) used for electronics components and electrical wiring
4.12 Apply decibels (dB) to calculate signal loss in coaxial and fiber cabling
4.13 Describe the types of optical cables, knowledge of their different parameters and applications
4.14 Describe the rules for disposal and eye safety when working with fiber optics cabling
4.15 Describe the conversion process from copper to fiber signals and from fiber to copper

5.0 COMPUTERS AND NETWORKING

5.1 Describe the interrelationship between computers and communications technology usage
5.2 Explain how a Modem interfaces with the computer
  5.2.1 Explain CTI—Computer Telephony Integration
5.3 Describe worldwide numbering systems
5.4 Define network control points
5.5 Describe database usage in medical facilities
5.6 Describe the problems which are commonly encountered when interconnecting electronics products
5.7 Explain electrical surge potentials
5.8 List ways to combat damage from electrical surges

5.9 State the expected voltage, current or signals expected at interconnection or equipment interface points
5.10 Describe wireless computer communications interfacing procedures used with medical equipment
5.11 Describe the Internet and its usefulness in medical data communications
5.12 Explain TCP/IP duties and protocols
5.13 Explain cybersecurity problems with Internet and wireless applications

6.0 TRANSDUCERS

6.1 Describe a transducer
6.2 Sketch the configuration of a Wheatstone Bridge
6.3 Explain how a Wheatstone Bridge can be compared in configuration with most biomedical transducers
6.4 Describe the types of transducers used in biomedical instrumentation
6.5 Sketch the electrical configuration of different transducers
6.6 Name the units of transducer sensitivity
6.7 Define the terms associated with transducers. e.g.: piezoresistance, thermocouple, impedance

7.0 HEMODIALYSIS EQUIPMENT

7.1 Describe the functions of the kidneys
7.2 Define terms used in the study of the kidneys (e.g.: dialysis, renal, dialysate, etc.)
7.3 Explain why kidney failure requires hemodialysis treatment
7.4 State the functions of the dialysis machine
7.5 Sketch the main function blocks of a dialysis machine (e.g.: power supply, pressure monitor, blood pump, control panel and these systems - temperature, bath delivery, drain, circulating)
7.6 Explain the function of each block or section of the machine
7.7 State the special safety precautions associated with the wet environment of a dialysis machine (e.g.: magnetically coupled motor shaft impeller system, ground fault interrupters)
7.8 State some of the common problems with dialysis machines
7.9 List a weekly maintenance schedule for a dialysis machine

8.0 MEDICAL ULTRASOUND (SONOGRAPHY) INSTRUMENTS

8.1 Describe applications of medical diagnostic ultrasound (cardiology, ob/gyn, radiology, etc.)
8.2 Explain the purpose of ultrasound in medical applications
    8.2.1 Differentiate between bone, cartilage, ligament, tendon, muscle, circulatory and organ views on screen/imaging
8.3 Define the terms associated with ultrasound (e.g.: wavelength, acoustics, reflection, refraction, piezo effects, echocardiography, Doppler effects)
8.4 Explain the physics of sound waves w.r.t., wavelength, velocity, period, frequency, reflection, refraction and resonator
8.5 Explain the biological effects of ultrasound
8.6 Describe the operation of the instruments used in delivering ultrasound (e.g.: the Doppler flow meter, blood pressure monitor, fetal monitor, echocardiography and echoencephalography)
8.7 Describe the operation ultrasound instruments
8.8 List safety precautions regarding the maintenance and use of ultrasound instruments
8.9 Describe the types of transducers used in medical diagnostic ultrasound
8.10 Distinguish between “sector” scans and “linear” scans
8.11 Define “axial resolution” and “lateral resolution”
8.12 Define “dead zone” as it applies to ultrasound
8.13 Describe the “front end” of an ultrasound scanner
8.14 Define “scan conversion”
8.15 Distinguish between “Spectral Doppler” and “Color Flow Doppler”
8.16 Describe a DICOM system (Digital Imaging and Communications in Medicine standard)
8.17 Explain the components of a video signal

9.0 RADIOLOGY

9.1 List the main functions of an X-ray machine
    9.1.1 Describe the skeletal system
    9.1.2 Differentiate between bone, cartilage, ligament, tendon, muscle, circulatory and organ views on screen/images
9.2 Describe the therapeutic applications of X-ray machines

9.3 State the diagnostic (measurement) function of an X-ray machine
9.4 State the different categories of X-ray machines (e.g.: still picture, continuous and motion picture)
9.5 List the dangers associated with X-rays
9.6 Name the units used for measuring radioactivity (e.g.: curie, Roentgen, Dose rate)
9.7 Explain the terms used in the study of radiology (e.g.: gamma, beta and alpha rays, nuclear radiation, etc.)
9.8 Sketch the circuit diagram of an X-ray tube
9.9 Sketch the circuit diagram of a Geiger-Mueller tube
9.10 Explain how the X-ray tubes work
9.11 Discuss the safety precautions associated with the handling of X-ray tubes
9.12 List common problems/faults of X-ray tubes
9.13 Sketch the circuit diagram of an X-ray machine

10.0 TEST EQUIPMENT AND TOOLS

10.1 Explain proper use of common biomedical and electronic test equipment
10.2 Describe the use of Time Domain Reflectometers and OTDRs
10.3 List services which provide test equipment calibration for commonly used biomedical instruments
10.4 Describe proper use and care of soldering and desoldering equipment and the hazards of utilizing leaded solder
10.5 Show ability to properly prepare cable connectors
10.5.1 Explain installation of fittings/connectors on cable ends and splices
10.7 Describe the functions of a medical oscilloscope
10.8 List the main differences between a medical, and a laboratory or service oscilloscope
10.9 List the characteristics of a medical oscilloscope (sweep speed, display format, persistence, etc.)
10.10 Sketch the block diagram of a medical oscilloscope
10.11 Explain the difference between a single beam and a dual trace scope
10.12 Define related terms e.g.: gating amplifier, bouncing ball, and nonfade designs

11.0 TROUBLESHOOTING AND DOCUMENTATION

11.1 Describe proper usage of test equipment as well as common DMM's, signal tracers and sources, oscilloscopes and loop and network testing equipment
11.2 Describe "Last good, first Bad" troubleshooting
11.3 Describe "Divide and Conquer" troubleshooting technique
11.4 Show how to use static arresting test procedures
11.5 List types of EMI (electromagnetic interference) which may affect the validity of test results
11.6 Describe diagnosis and repair of defective electronic medical equipment procedures
11.7 Prepare cost estimates for a major electronic repair or installation
11.8 List recordkeeping and documentation requirements

12.0 OPERATING ROOM FAMILIARIZATION

12.1 Describe the functions of the Operating Room (OR)
12.2 Describe the protocols involved in working in the OR (dress code, cleanliness and attitude)
12.3 List the duties of the personnel employed in the OR (e.g.: the nursing staff, biomedical technician, surgeon, etc.)
12.4 List the special equipment used in the OR
12.5 List the functions of the equipment used in the OR
12.6 Describe why anesthetics are used and what types are commonly used
12.7 List the safety precautions observed in the OR
12.8 Describe different methods of sterilization (steam, ETO, etc.)
12.9 Define terms used in surgery: e.g.: antiseptic, suture thread, autoclave, orderlies, sterilization spore strip, etc.

13.0 RESPIRATORY INSTRUMENTATION

13.1 List the principle pulmonary parameters measured (capacities such as vital, functional, inspiratory, total lung; tidal, inspiratory reserve, expiratory, reserve, residual minute)
13.2 Describe the various respiratory transducers
13.3 List the instruments used with the respiratory system (spirometers, apnea monitor, etc.)
13.4 Describe the function of the instruments used in the respiratory system
13.5 Define the various volumes measured (Tidal, inspiratory reserve, expiratory, reserve, residual minute)
13.6 Describe the operation of adult and pediatric ventilators

14.0 INSTRUMENTATION-THE MEDICAL LABORATORY

- 14.1 State the main functions and composition of blood
- 14.2 List the instruments used in the medical laboratory including:
  - 14.2.1 calorimeters
  - 14.2.2 photometer
  - 14.2.3 spectrophotometer
  - 14.2.4 pH analyzer
  - 14.2.5 autoanalyzer
  - 14.2.6 chromatograph
  - 14.2.7 dialyzer
- 14.3 State the maintenance procedures for the following medical lab instruments:
  - 14.3.1 Blood Gas Analyzers
  - 14.3.2 Co-Oximeters
  - 14.3.3 Centrifuges
  - 14.3.4 Microscopes
  - 14.3.5 Cell Counters
  - 14.3.6 Chemistry Analyzers

15.0 ELECTROSURGERY GENERATORS

- 15.1 Describe the function of the Electrosurgery (ESU) generator
- 15.2 Describe the operation of the Electrosurgery generator
- 15.3 Sketch the block diagram and related waveforms of an Electrosurgery generator
- 15.4 List the safety measures to be adopted when using the Electrosurgery generator
- 15.5 Describe the type of waveforms generated (coagulate, cut)
- 15.6 List the frequencies commonly used by Electrosurgical scalpels
- 15.7 Describe “REM” (return electrode monitoring)
- 15.8 Describe testing requirements for Electrosurgery Units

16.0 INTENSIVE AND CORONARY CARE UNITS

- 16.1 Describe the function and purpose of the special care units in the hospital
- 16.2 List the instrument systems used in ICU and CCU
- 16.3 Troubleshoot common problems associated with equipment used in ICU and CCU (e.g.: bedside monitors, cardiotachometers, alarms, lead fault indicators, central monitoring consoles, invasive blood pressure and radiotelemetry)

17.0 CARDIAC SUPPORT SYSTEM

- 17.1 Describe the principles of defibrillation
- 17.2 Describe the principles and operation of the pacemaker
- 17.3 Describe the principles and operation of the cardioverter
- 17.4 Describe the principles and operation of the intra-aortic balloon pump
- 17.5 List three types of cardiac arrhythmias
- 17.6 Describe the events taking place in each part of the ECG waveform
- 17.7 Detail the minimum energy required from an implantable pacemaker
- 17.8 Detail the minimum energy required from an external pacemaker
- 17.9 Troubleshoot problems associated with cardiac support machines
- 17.10 Describe the principles and operation of the cell salvage machine (Cell Saver®)
- 17.11 Sketch the main parts of a basic cardiopulmonary bypass circuit
- 17.12 Describe all the available types of blood pumps including:
  - 17.12.1 roller pump
  - 17.12.2 modified roller pump for pulsatile perfusion
  - 17.12.3 centrifugal pump
- 17.13 Describe proper testing of a defibrillator (general steps)

18.0 BIOELECTRIC AMPLIFIERS

- 18.1 Describe the functions of the bioelectric amplifier
- 18.2 State the requirements for bioelectric amplifiers
- 18.3 Describe the basic principles of operation of a bioelectric amplifier
- 18.4 Describe the different configurations used in the design of bioelectric amplifiers
- 18.5 State the principles of operation of isolation amplifiers

18.6 List the basic properties of the operational amplifier
18.7 Sketch the circuit diagram of an op amp
18.8 Calculate voltage gain, impedance (input and output) and other characteristics of op amps
18.9 Define terms used in bioelectric amps (e.g.: inverter, offset null, zero suppression, summing junction, common mode rejection and virtual ground)

End of Biomedical Competencies Listings (with 18 major Categories)

Prerequisite: Associate C.E.T. or equivalent

Find An ETA Test Site: http://www.eta-i.org/test_sites.html

Other Additional Suggested Study Material:

ISO 13485:2016 - Medical devices – a practical guide; ISO; ISBN 978- 92-67-10774-5; ISO copyright office, 2017, ppg 200+.
Biomed: From the Student's Perspective (English Translation Version); Villafane; ISBN 978-1615396634; http://techniciansfriend.com/ (Spanish language website) or http://tecnicosbiomedicos.com/ for the English language website (www.Biomedtechnicians.com). mailto:villita2000@gmail.com
TechCareers: Biomedical Equipment Technicians; Bowles; ISBN 978-1934302293; TechCareers-TSTC Publishing, 2008, ppg108.
Basic Electronic Troubleshooting for Biomedical Technicians, 2E; Cram, Holder; ISBN 978-1934302514; TSTC Publishing, 2010, ppg. 205
Biomedical Instrumentation Systems; Chatterjee, Miller; ISBN 978-1418018665; Cengage Learning, 2010, ppg. 704
Medical Instrumentation: Application and Design, 5E; Webster, Nimunkar; ISBN 978- 1119457336; Wiley, May 2020; ppg. 720.
Introduction to Biomedical Instrumentation: The Technology of Patient Care, 2E; Christie; ISBN 978-1107185012; Cambridge University Press, 2017, ppg. 244.
Principles of Biomedical Instrumentation; Webb; ISBN 978-0675209434; Cambridge University Press, 2018, ppg. 344
Process Validation for Medical Devices; Tobin; ISBN 978-1977834010; Create Space Independent Publishing Platform, 2017; ppg. 242
Principles of Transducers & Biomedical Instrumentation: Designs and Applications; Sachan; ISBN 978-1689704465; BOOK 10, Independently published, 2019; ppg. 381.
Design of Biomedical Devices and Systems, 4E; King, Fries, Johnson; ISBN 978-1138723061; CRC Press, 2018; ppg. 542.
Medical Instruments and Devices: Principles and Practices; Schreiner, Bronzino, Peterson; ISBN 978-1439871454; CRC Press, 2015; ppg. 320.
Biomedical Device Technology: Principles and Design, 2E; Yang; ISBN 978-0398090838; Charles C Thomas Pub Ltd, 2016; ppg. 758.
Medical Instrumentation for Nurses and Allied Health-Care Professionals, 2E; Aston, Brown; ISBN 978-0867206883; Jones & Bartlett Pub, 1994
Biomedical Equipment Technician: Air Force Career Education and Training Plan, 2E; U.S. Air Force; ISBN 978-1249204596; BiblioGov, 2012; ppg. 90
Biomedical Instrumentation And Measurements, 2E; Nataraian; ISBN 978- 8120352155; Prentice Hall of India Private Ltd, 2016
Measurement, Instrumentation, and Sensors Handbook: Electromagnetic, Optical, Radiation, Chemical, and Biomedical Measurement, 2E; Webster, Eren; ISBN: 978-1138072183; CRC Press, 2017; ppg. 1921
Measurement, Instrumentation, and Sensors Handbook: Spatial, Mechanical, Thermal, and Radiation Measurement, 2E; Webster, Eren; ISBN: 978-1439848883; CRC Press, 2014; ppg. 1640

Critical Careers: A Guide to Opportunities in Medical Equipment Service; Bowles; ISBN 978-0970105844; Upstream Press, 2001
Introduction to Biomedical Equipment Technology, 4E; Carr, Brown; ISBN 978-0130104922; Prentice Hall, 2000, ppg. 743.
Bebop to the Boolean Boogie, Third Edition: An Unconventional Guide to Electronics; Maxfield; ISBN 978-1856175074; Newnes, 2008
Electromagnetic Compatibility in Medical Equipment: A Guide for Designers and Installers; Kimmel, Gerke; ISBN 978-0935184808; CRC Press, 1995.

In addition to contacting ETA (www.eta-i.org or eta@eta-i.org) for white papers, PDFs, other materials, see these additional webpages: https://www.asatt.org/; https://www.fda.gov/medical-devices/medical-device-databases/code-federal-regulations-title-21-food-and-drugs; https://www.fda.gov/medical-devices/digital-health/wireless-medical-devices;

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ETA certification programs are accredited through the ICAC, complying with the ISO/IEC 17024 standard.

