



# 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. 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 The Human Nervous System

- 1.1 Explain the major functions of the nervous system
- 1.2 List the major parts/divisions of the nervous system
- 1.3 Describe the functions of each part/division of the nervous system including the peripheral and the autonomic nervous system
- 1.4 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.
- 1.5 Describe the function of the EEG machine
- 1.6 Describe the function of the cerebellum
- 1.7 Describe the function of the cerebrum
- 1.8 Describe the function of the central nervous system
- 1.9 List the functional problems associated with the EEG machine
- 1.10 List the basic care/maintenance procedures of the EEG machine

## 2.0 Medical Electrodes

- 2.1 Define an electrode
- 2.2 Define the term "biopotentials"
- 2.3 Explain how impedance mismatches between electrodes and skin surfaces can affect accuracy in measurements
- 2.4 Give an approximate impedance of wet human skin
- 2.5 Give an approximate impedance of dry skin
- 2.6 Define the term "Half cell potential"
- 2.7 Name different types of electrodes and the body organs to which they are applied
- 2.8 Describe the shapes of electrodes as they relate to their applications
- 2.9 Describe the chemical/paste applied between electrode and skin
- 2.10 Define the types of "artifacts" and their causes
- 2.11 List some measures which can be adopted to minimize or avoid artifacts

## 3.0 Cables and Cabling

- 3.1 Describe the unshielded twisted pair (UTP)
- 3.2 State where UTP cabling is used
- 3.3 Demonstrate ability to install RJ45/48 connectors and fittings
- 3.4 Explain the difference between single twisted pair and CAT-5
- 3.5 Explain where 10baseT is used and its frequency capabilities
- 3.6 Describe the T568A / T568B standards and explain their purpose
- 3.7 Explain how Cable TV coaxial cable wiring is used for data and voice services
- 3.8 Explain the differences between coax types RG 58, RG 59 and RG 6

## 4.0 Computer

- 4.1 Describe the interrelationship between computers and communications technology-show usage
- 4.2 Explain how a Modem interfaces with the computer
- 4.3 Describe worldwide numbering systems
- 4.4 Define network control points
- 4.5 Define database
- 4.6 Explain CTI—Computer Telephony Integration

## 5.0 Transducers

- 5.1 Describe a transducer
- 5.2 Sketch the configuration of a Wheatstone Bridge
- 5.3 Explain how a Wheatstone Bridge can be compared in configuration with most biomedical transducers
- 5.4 Describe the types of transducers used in biomedical instrumentation
- 5.5 Sketch the electrical configuration of different transducers
- 5.6 Name the units of transducer sensitivity
- 5.7 Define the terms associated with transducers. e.g.: piezoresistance, thermocouple, impedance

**6.0 Medical Electronics Safety**

- 6.1 Define electrical safety
- 6.2 List the names of major organizations which publish electrical safety codes and standards
- 6.3 List responsibilities of hospital staff regarding safety
- 6.4 Relate how preventive maintenance reduces electrical hazards
- 6.5 Define corrective maintenance
- 6.6 Define preventive maintenance
- 6.7 Explain the insurance and legal requirements regarding electrical safety
- 6.8 Develop an electrical safety program for a typical hospital
- 6.9 Explain the physiological effects of poor safety measures on the human body
- 6.10 Define leakage current
- 6.11 Explain the usefulness of A.C. line isolation systems
- 6.12 List the dangers associated with poor grounding
- 6.13 Describe required grounding of electronics equipment
- 6.14 Explain how hazards through ground faults can be reduced
- 6.15 Administer electrical safety tests on equipment
- 6.16 Explain precautions required for H.I.V. or TB prevention for hospital workers
- 6.17 List precautions for working with/on ladders
- 6.18 List extra precautions biomed personnel must take to maintain cleanliness standards in medical facilities
- 6.19 Describe the following safety code standards:
  - 6.19.1 NFPA 99
  - 6.19.2 NFPA 70
  - 6.19.3 NFPA 102
  - 6.19.4 CFR 21
- 6.20 Describe microshock (also called cardiac shock)
- 6.21 Describe macroshock
- 6.22 State the ground resistance limit for *existing* portable medical equipment in patient care areas
- 6.23 State the ground resistance limit for *new* portable medical equipment in patient care
- 6.24 State the chassis leakage current limit for portable medical equipment in patient care areas
- 6.25 State the lead leakage current limit for portable medical equipment in patient care areas
- 6.26 Describe the current rules for radiation safety required in medical equipment maintenance and use
- 6.27 Describe the current rules for safety in the maintenance and use of medical laser equipment
- 6.28 Describe fire safety rules commonly required for medical equipment maintenance personnel
- 6.29 Describe chemical rules commonly required for medical equipment maintenance personnel

**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, temperature system, bath delivery system, drain system, circulating system and control panel)
- 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 Networking**

- 8.1 Describe the problems which are commonly encountered when interconnecting electronics products
- 8.2 Explain electrical surge potentials
- 8.3 List ways to combat damage from electrical surges
- 8.4 Describe medical industry safety standards
- 8.5 State the expected voltage, current or signals expected at interconnection or equipment interface points
- 8.6 Describe PCIA and wireless computer communications interfacing procedures used with medical equipment
- 8.7 Describe the Internet and its usefulness in medical data communications
- 8.8 Explain TCP/IP duties and protocols
- 8.9 Explain security problems with Internet service



**9.0 Medical Ultrasound Instruments**

- 9.1 Describe applications of medical diagnostic ultrasound (cardiology, ob/gyn, general radiology, etc.)
- 9.2 Explain the purpose of ultrasound in medical applications
- 9.3 Define the terms associated with ultrasound (e.g.: wavelength, acoustics, reflection, refraction, piezo effects, echocardiography, doppler effects)
- 9.4 Explain the physics of sound waves w.r.t., wavelength, velocity, period, frequency, reflection, refraction and resonator
- 9.5 Explain the biological effects of ultrasound
- 9.6 Describe the operation of the instruments used in delivering ultrasound (e.g.: the Doppler flow meter, blood pressure monitor, fetal monitor, echocardiography and echoencephalography)
- 9.7 Describe the operation ultrasound instruments
- 9.8 List safety precautions regarding the maintenance and use of ultrasound instruments
- 9.9 Describe the types of transducers used in medical diagnostic ultrasound
- 9.10 Distinguish between “sector” scans and “linear” scans
- 9.11 Define “axial resolution” and “lateral resolution”
- 9.12 Define “dead zone” as it applies to ultrasound
- 9.13 Describe the “front end” of an ultrasound scanner
- 9.14 Define “scan conversion”
- 9.15 Distinguish between “Spectral Doppler” and “Color Flow Doppler”
- 9.16 Define and describe a DICOM system
- 9.17 Explain the components of a video signal

**10.0 Mathematics**

- 10.1 Use mathematics to solve biomedical problems
- 10.2 Describe color coding systems used for electronics components and electrical wiring
- 10.3 Apply decibels to calculate signal loss in coaxial and fiber wiring
- 10.4 Convert numbering systems such as binary, decimal, octal and hexadecimal
- 10.5 Demonstrate the ability to use scientific calculators
- 10.6 Prepare cost estimates for a major electronic repair or installation

**11.0 Building Wiring**

- 11.1 List the standards used in the electrical wiring of buildings
- 11.2 Explain methods of pre-wiring and ways to wire existing buildings including entry, attic and crawl space precautions and methods of fishing walls and routing wiring through false ceilings.
- 11.3 Explain NEC or other safety rules pertaining to building wiring and grounding

**12.0 Optical Wiring**

- 12.1 Demonstrate the rules for disposal and eye safety when working with fiber optics cabling
- 12.2 Describe the types of optical cables-show knowledge of different parameters and reasons for choosing each
- 12.3 Describe the conversion process from copper to fiber signals and from fiber to copper
- 12.4 Define and explain the term SONET

**13.0 Radiology**

- 13.1 List the main functions of an X-ray machine
- 13.2 Describe the therapeutic applications of X-ray machines
- 13.3 State the diagnostic (measurement) function of an X-ray machine
- 13.4 State the different categories of X-ray machines (e.g.: still picture, continuous picture and motion picture)
- 13.5 List the dangers associated with X-rays
- 13.6 Name the units used for measuring radioactivity (e.g.: curie, Roentgen, Dose rate)
- 13.7 Explain the terms used in the study of radiology (e.g.: gamma, beta and alpha rays, nuclear radiation, etc.)
- 13.8 Sketch the circuit diagram of an X-ray tube
- 13.9 Sketch the circuit diagram of a Geiger-Mueller tube
- 13.10 Explain how the X-ray tubes work
- 13.11 Discuss the safety precautions associated with the handling of X-ray tubes
- 13.12 List common problems/faults of X-ray tubes
- 13.13 Sketch the circuit diagram of an X-ray machine



**14.0 Test Equipment and Tools**

- 14.1 Demonstrate proper use of common biomedical and electronic test equipment
- 14.2 Describe the use of Time Domain Reflectometers and OTDRs
- 14.3 List services which provide test equipment calibration for commonly used biomedical instruments
- 14.4 Describe proper use and care of soldering and desoldering equipment and the hazards of utilizing leaded solder
- 14.5 Show ability to properly prepare cable ends
- 14.6 Install fittings on cable ends and splices
- 14.7 Describe the functions of a medical oscilloscope
- 14.8 List the main differences between a medical, and a laboratory or service oscilloscope
- 14.9 List the characteristics of a medical oscilloscope (sweep speed, display format, persistence, etc.)
- 14.10 Sketch the block diagram of a medical oscilloscope
- 14.11 Explain the difference between a single beam and a dual trace scope
- 14.12 Define related terms e.g.: gating amplifier, bouncing ball, and nonfade designs

**15.0 Troubleshooting**

- 15.1 Demonstrate proper usage of test equipment as well as common DVM's, signal tracers and sources, oscilloscopes and loop and network testing equipment
- 15.2 Describe "Last good, first Bad" troubleshooting
- 15.3 Describe "Divide and Conquer" troubleshooting technique
- 15.4 Show how to use static arresting test procedures
- 15.5 List types of EMI which may affect the validity of test equipment results
- 15.6 Demonstrate diagnosis and repair of defective electronic medical equipment

**16.0 Operating Room Familiarization**

- 16.1 Describe the functions of the Operating Room (OR)
- 16.2 Describe the protocols involved in working in the Operating Room (dress code, cleanliness and attitude)
- 16.3 List the duties of the personnel employed in the Operating Room (e.g.: the nursing staff, biomedical technician, surgeon, etc.)
- 16.4 List the special equipment used in the OR
- 16.5 List the functions of the equipment used in the OR
- 16.6 Describe why anesthetics are used and what types are commonly used
- 16.7 List the safety precautions observed in the OR
- 16.8 List the different methods of sterilization
- 16.9 Define terms used in surgery. e.g.: antiseptic, suture thread, autoclave, orderlies, sterilization spore strip, etc.
- 16.10 Describe different methods of sterilization (steam, ETO, etc.)

**17.0 Instrumentation—Respiratory**

- 17.1 List the principle pulmonary parameters measured (capacities such as vital, functional, inspiratory, total lung; tidal, inspiratory reserve, expiratory, reserve, residual minute)
- 17.2 Describe the various respiratory transducers
- 17.3 List the instruments used with the respiratory system (spirometers, apnea monitor, etc.)
- 17.4 Describe the function of the instruments used in the respiratory system
- 17.5 Define the various volumes measured (Tidal, inspiratory reserve, expiratory, reserve, residual minute)
- 17.6 Describe the operation of adult and pediatric ventilators

**18.0 Instrumentation-The Medical Laboratory**

- 18.1 State the main functions and composition of blood
- 18.2 List the instruments used in the medical laboratory (calorimeters, photometer, spectrophotometer, pH analyzer, autoanalyzer, chromatograph, dialyzer)
- 18.3 State the maintenance procedures for the following medical lab instruments:
  - 18.3.1 Blood Gas Analyzers
  - 18.3.2 Co-Oximeters
  - 18.3.3 Centrifuges
  - 18.3.4 Microscopes
  - 18.3.5 Cell Counters
  - 18.3.6 Chemistry Analyzers



**19.0 Electrosurgery Generators**

- 19.1 Describe the function of the Electrosurgery (ESU) generator
- 19.2 Describe the operation of the Electrosurgery generator
- 19.3 Sketch the block diagram and related waveforms of an Electrosurgery generator
- 19.4 List the safety measures to be adopted when using the Electrosurgery generator
- 19.5 Describe the type of waveforms generated (coagulate, cut)
- 19.6 List the frequencies commonly used by Electrosurgical scalpels
- 19.7 Describe "REM"
- 19.8 Describe testing requirements for Electrosurgery Units

**20.0 Intensive and Coronary Care Units**

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

**21.0 Cardiac Support System**

- 21.1 Describe the principles of defibrillation
- 21.2 Describe the principles and operation of the pacemaker
- 21.3 Describe the principles and operation of the cardioverter
- 21.4 Describe the principles and operation of the intraaortic balloon pump
- 21.5 List three types of cardiac arrhythmias
- 21.6 Describe the events taking place in each part of the ECG waveform
- 21.7 Detail the minimum energy required from an implantable pacemaker
- 21.8 Detail the minimum energy required from an external pacemaker
- 21.9 Troubleshoot problems associated with cardiac support machines
- 21.10 Describe the principles and operation of the cell saver machine
- 21.11 Sketch the main parts of a basic cardiopulmonary bypass circuit
- 21.12 Describe all the available types of blood pumps (roller pump; modified roller pump for pulsatile perfusion, centrifugal pump)
- 21.13 Describe proper testing of a defibrillator (general steps)

**22.0 Bioelectric Amplifiers**

- 22.1 Describe the functions of the bioelectric amplifier
- 22.2 State the requirements for bioelectric amplifiers
- 22.3 Describe the basic principles of operation of a bioelectric amplifier
- 22.4 Describe the different configurations used in the design of bioelectric amplifiers
- 22.5 State the principles of operation of isolation amplifiers
- 22.6 List the basic properties of the operational amplifier
- 22.7 Sketch the circuit diagram of an op amp
- 22.8 Calculate voltage gain, impedance (input and output) and other characteristics of op amps
- 22.9 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 22 major Categories)

Course suggested prerequisite: Associate C.E.T. or equivalent

**Notes:**

The purpose in distributing the above Competencies list is to provide a detailed syllabus for electronics educational institutions and instructors. Also to go further and explain what the student should be able to do with each of the items included in the Categories and Competencies listings.

**Find An ETA Test Site:**

<http://www.eta-i.org/testing.html>



**Suggested Study Material:**

**Introduction to Biomedical Equipment Technology, 4E;** Carr, Brown; ISBN 978-0130104922; Prentice Hall, 2000

**Electromagnetic Compatibility in Medical Equipment: A Guide for Designers and Installers;** Kimmel, Gerke; ISBN 978-0935184808; CRC Press, 1995

**Principles of Biomedical Instrumentation and Measurement;** Aston; ISBN 978-0675209434; Prentice Hall, 1990

**Biomedical Instrumentation And Measurements, 2E;** Cromwell, Weibell, Pfeiffer; ISBN 978-0130764485; Prentice Hall, 1979

**Biophysical Measurements;** Strong; ASIN: B000B78AY0; Tektronix, 1973 (oop)

**Biomed: From the Student's Perspective (English Translation Version);** Villafane; ISBN 978-1615396634; [www.techniciansfriend.com](http://www.techniciansfriend.com)

**Critical Careers: A Guide to Opportunities in Medical Equipment Service;** Bowles; ISBN 978-0970105844; Upstream Press, 2001

**Servicing Electrocardiographs;** Kanter; ISBN 978-0672212109; H.W.Sams, 1975

**Bebop to the Boolean Boogie, Third Edition: An Unconventional Guide to Electronics;** Maxfield; ISBN 978-1856175074; Newnes, 2008

**BMET Self Study Certification Review;** Morse Medical, Inc. presents BMET Self Study Course for the ICC Certification Exam; Morse Medical, Inc., 2008; [www.morsemedical.com](http://www.morsemedical.com); Available through **ETA-I** at 800-288-3824 or [www.eta-i.org](http://www.eta-i.org)

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