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13. SUPPLEMENTARY NOTES					
14. ABSTRACT The Masters of Engineering program with concentration in Biomedical Engineering at Tennessee State University was established in fall 2000. Under this educational program, this lab provides a state-of-the-art facilities to enhance the education with hand-on experience and research in the area of biomedical engineering. The lab is fully equipped with 10 Pentium5-based, 2 Pentium4-based laptop for mobile experiment at remote locations, 8 Biopac systems which provides the most complete physiological data acquisition and on-line analysis of the biomedical signals. Each Biopac system-based laboratory station consists of real-time data acquisition system, amplifiers for EMG, EKG, EEG, and equipment for the study of Plethysmography, evoked response, cardiovascular hemodynamics, pulmonary function, exercise physiology, sleep studies, remote monitoring, eyes movement etc. The transducer includes accelerometers, goniometers, active electrodes, hand dynamometer, force transducers etc. Currently, 10 graduate students and many undergraduate students (prospective graduate students in biomedical engineering) are regularly using this lab. This summer, 8 new prospective graduate students, sponsored through a training grant from National Science Foundation, used this laboratory facilities and conducted research in the area of biomedical engineering. This was a great experience for these prospective graduate students to motivate further in the area of biomedical engineering research who will be the future biomedical engineers to improve the nation's healthcare system.					
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## FINAL PERFORMANCE REPORT

**Title:** Biomedical Engineering Laboratory  
**Author:** Mohammad Bodruzzaman, Ph.D.  
**Organization:** Tennessee State University

### OBJECTIVES

The objectives to develop the Biomedical Engineering Laboratory were to:

1. Support all graduate courses for hands-on experience by conducting practical sessions on the theories learned in each class in the Biomedical Engineering program at Tennessee State University.
2. Provide state-of-the-art research facilities for undergraduate seniors and graduate students to develop senior projects and Masters theses.
3. Provide state-of-the-art non-invasive physiological measurement facilities for the faculties interested in advanced research in the area of Biomedical Engineering.

### ACCOMPLISHMENTS

A fully functional Biomedical Engineering Laboratory was established to enhance the graduate courses by practical learning through laboratory sessions. A list of the graduate courses associated with this laboratory and a list of experiments are given below:

#### Graduate Courses

The lab facilities were instructionally supported the following courses in the Biomedical Engineering program.

**BIO 524. Systemic Physiology (3):** Functions of different organ systems with emphasis on the human nervous system, muscular system, cardiovascular system, respiratory system, digestive system, urinary system, and endocrine system. Prerequisite: permission of instructor. Two lectures and one two-hour laboratory period.

**BIO 726 Neurobiology (3):** Principles and mechanisms of the nervous system in invertebrate and vertebrate organisms. Topics including neurotransmitters, effector control, integration, inhibition, and localized excitation are considered. A study of the ionic and electrical mechanism involved in the generation and conduction of nerve impulses is also included. Prerequisite: permission of instructor.

**BME 500: Biomedical Instrumentation (3).** This course provides instructional materials on the biomedical instrumentation, physiological measurements and analysis of physiological signals. Basic theory of measurements, electrodes, sensors, transducer, data acquisition and electrical safety are covered. The emphasis is on the use of Biopac system for physiological measurements (such as EEG, ECG, EMG etc.), use of Matlab and/or LabVIEW tools in developing analysis and data interpretation tool.

**BME 501. Introduction to Biomedical engineering (3):** A multi-disciplinary course of biomedical engineering which include: a historical perspective, basics of anatomy & physiology, bio-electric phenomena, biomedical sensors, bio-instrumentation, bio-signal

processing, physiological modeling, skeletal muscle mechanics, cardiovascular mechanics, bio-materials, tissue engineering, biotechnology, radiation imaging, rehabilitation engineering and technology assisted therapies. Laboratory experiments for biomedical project design are also part of this course.

**BME 502. Biotechnology and Instrumentation (3):** Introduction to biomedical instrumentation and measurement, basic theories of measurement, electrode, sensors and transducers, bio-electric amplifiers, the human respiratory systems and its measurement, medical laboratory instrument, electrical safety in the medical environment, computers in biomedical equipment, radiology and nuclear medicine equipment. Laboratory experience in the department of respiratory therapy and Meharry Medical College will be the major part of this course.

**BME 503 Medical Imaging and Signal Processing (3):** This course covers the principal methods for representing, storing, processing, coding, transmitting and analyzing of biomedical images by means of digital computers. Sampling theorems, image transforms, image enhancement and restoration, frequency domain and spatial domain techniques, image coding and transmission, and image segmentation and description are discussed. Applications will be on MRI, CAT, Ultrasound etc.

#### **List Of Laboratory Experiments With Brief Description**

The following are the laboratory sessions in which students were required to use the laboratory for hands-on-experience on the class teaching materials:

##### **1. Electromyography I**

EMG lesson I investigates the properties of skeletal muscle. The students recorded the EMG data associated with the maximum grip clench for their dominant hand and then do the same for their non-dominant hand. The system recorded and displayed both the raw and integrated EMG signals. This lesson allowed the students to compare the grip clench between their two arms and listen to the sound of their EMG.

##### **2. Electromyography II**

EMG lesson II explores the role of skeletal muscle in performing mechanical tasks. The lesson uses a hand dynamometer to demonstrate the use of skeletal muscle when recording the maximum grip strength for both hands. This lesson also allowed the students to record EMG while inducing muscle fatigue. The system automatically calibrated the hand dynamometer and scale the force values to kilograms. The students saw the level of motor unit recruitment associated with the precise amount of applied force.

##### **3. Electroencephalography I**

EEG lesson I was an introduction to electroencephalographic recording techniques. The lesson demonstrated how the brain's electrical activity varies dependent upon the task being performed. The students recorded EEG from the occipital lobe while performing a number of different tasks. The software automatically filtered the data to display alpha, beta, delta, and theta wave components. The students measured and compared the EEG activity associated with various tasks.

#### 4. Electroencephalography II

Students discovered how the brain constantly receives sensory input and integrates the information before processing it. The students recorded EEG data from the occipital lobe while performing a number of tasks. The system recorded and displayed the raw EEG together with the alpha wave and alpha-RMS activity. They compared their baseline EEG with the data recorded during the different tasks.

#### 5. Electrocardiography I

This lesson provided an introduction to the electrocardiograph and the recording of the heart's electrical signal. The lesson familiarizes the students with a Lead II ECG recording and with the components of the ECG complex. They learned to correlate the electrical events of the ECG (P, Q, R, S & T components) with the mechanical events of the cardiac cycle. The students performed a number of tasks designed to promote changes in the ECG complex. They performed a detailed analysis of their ECG recording.

#### 6. Electrocardiography II

This lesson explained Einthoven's triangle and allowed the students to record their ECG using bipolar Leads (I, II & III). The students attached Leads I and III and the software calculated Lead II for them, using Einthoven's law. The system displayed the data for all three Leads. The students performed a number of tasks designed to change the rhythm of the heart. They analyzed the data and calculated the Mean Electrical Axis of the heart.

#### 7. ECG & Pulse

This lesson examined the mechanical action of the heart and peripheral pulse pressure. The lesson demonstrated how the heart pumped the blood throughout the body using a pulse plethysmogram transducer and Lead II ECG. The students recorded their data while performing a number of different tasks. They analyzed the data and determined the speed of their own pressure pulse wave under different conditions.

#### 8. Respiratory Cycle I

This lesson demonstrated the effects of cerebral influence and chemoreceptor influence on the medullary control centers. The student recorded chest contraction and expansion using a respiration transducer and correlated the changes with ventilation. A temperature transducer located beneath one nostril recorded the ventilation data. The student performed a variety of tasks designed to demonstrate certain respiratory phenomena. This procedure allowed them to compare baseline values with response data.

#### 9. Galvanic Skin Response & The Polygraph

This lesson was familiarized the students with the standard physiological measures recorded by a polygraph. The lesson looked at the effects of cognitive behavior and emotion. The students recorded changes in respiratory rate, heart rate and skin resistance. Each subject answered a number of simple questions and watched a presentation. The presentation stimulated a response. It was possible to use a variety of different stimuli for the lesson.

#### 10. The Electrooculogram (EOG) I

This lesson allowed the student to record horizontal and vertical eye movement. It demonstrated eye fixation and tracking. The student performed a number of tasks that allowed

them to record the duration of saccades and fixation. The lesson was also permitted the student to record spatial position of eye movements.

#### 11. Pulmonary Function I

This lesson introduced the students to pulmonary function tests. The student used a hand-held airflow transducer to record their data. The lesson automatically calculated and displayed both the airflow and volume signals. The students performed a variety of pulmonary measurements such as: Tidal volume, Inspiratory capacity, Expiratory capacity, Functional residual capacity, Vital capacity and Total lung capacity.

#### 12. Pulmonary Function II

Pulmonary Function II builds on the principles established by the previous pulmonary function lesson. The lesson demonstrated how to record and analyze Forced Vital Capacity, Forced Expiratory Volume (FEV 1,2,3) and Maximal Voluntary Ventilation (MVV). The students performed two tasks in order to record their data. They compared their results with other students and with published normal values for specified height, weight and age.

#### 13. Biofeedback

This lesson demonstrated the principles of biofeedback training for relaxation purposes. The student recorded and viewed ECG, heart rate and galvanic skin response. The subject controlled the position of a vertical bar graph by influencing their heart rate and GSR. If their heart rate increased the bar moved up, inversely, the bar moved down if the heart beats slower. If GSR increased, the bar was moved upwards and downwards if it was decreased.

#### 14. Aerobic Exercise Physiology

The Aerobic Exercise Physiology lesson allowed the student to record ECG, heart rate, airflow and skin temperature under a variety of conditions. The student had seen how their respiration pattern, the electrical activity of the heart, heart rate, and skin temperature changes to meet changing metabolic demands. The student performed a number of tasks designed to reach their personal maximum heart rate.

#### 15. Blood Pressure

The Systemic Blood Pressure Lesson allowed students to record arterial blood pressure using the auscultatory technique. The student recorded blood pressure using a cuff, pump and pressure gauge, Korotkoff sounds using a microphone, and ECG using Lead II. The system displayed cuff pressure, Korotkoff sounds and ECG for easy determination of systolic blood pressure. The student viewed the Korotkoff sounds and listened to them with a stethoscope. They performed a task designed to change their blood pressure.

#### 16. Heart Sounds

Students listened to their own heart sounds by positioning the SS30L Stethoscope over the aortic semilunar, pulmonic semilunar, tricuspid, and mitral (bicuspid) valves. They distinguished the volume, pitch and duration of the sound at each point and determined the point where sounds were best heard which would be used as the recording point for the heart sounds. Lead II ECG was also recorded, and students compared the mechanical events (heart sounds) with the electrical events (ECG) of the cardiac cycle.

### PERSONNEL SUPPORTED

The following undergraduate senior (with project title) in Electrical Engineering are in the process of completion of their senior projects and using the Biomedical Engineering Lab.

1. Samuel Scott Taylor, "Design of Web-based patient monitoring system". Senior in Electrical Engineering.

The following undergraduate seniors (with project titles) in Electrical Engineering had completed their senior projects in 2002 and used the Biomedical Engineering Lab facilities:

1. Ingrid Wright and Enrique Martinez, "Design of a device to rapidly assess changes in cardiac functions for cardiovascular research".
2. April Bush, Jacinda Gray and Chistina Lovejoy, "Wireless monitoring system to detect infant vitals".

The following is a list of graduate student and their project titles who had completed their Summer 2003 projects, sponsored by National Science Foundation, using the facilities of Biomedical Engineering laboratory.

1. Bush, April. "Intelligent Pattern Recognition for the Diagnosis of Neuromuscular Diseases."
2. Carey, Geminia. "Determining the speed of the pulse wave traveling between the heart and finger using dynamic electrocardiogram (ECG) signal."
3. Gold, Kimberly "Remote Monitoring Device to aid in the prevention of Sudden Infant Death Syndrome (SIDS)."
4. Graham, Stacia, "The Relationship Between Touch and the Resulting EEG Signals."
5. Lake, Angela, "Design of a Graphical Muscle Fatigue Monitoring System"
6. McKee, De'Nise, "Determine the Correlation Between Music and Electroencephalogram Signals"
7. Parker, Khari, "Determine the effect of odors on the Electroencephalogram (EEG) with respect to the Human Olfactory System"
8. Perkins, Anita, "Comparing Myoelectric (ME) Signals of the Quadriceps Between Males and Females."

The following student used this laboratory facilities in fall 2002 and will continue using in Fall 2003 and Spring 2004 for her training in Biomedical research under the Minority Access To Research Careers (MARC) program at Tennessee State University.

1. Latasha Taylor, Senior in Biology

### CONCLUSIONS

The equipment grant obtained from the Air Force Office of Scientific Research (AFOSR) to establish the Biomedical Engineering Laboratory, indeed, directly helped to enhance the educational and research infrastructure at Tennessee State University. This provides students with a great experience by conducting practical physiological measurements and on-line analysis of biomedical signals. The laboratory experiences also motivated students towards advanced study in the area of biomedical engineering where they will be the future biomedical engineers to improve the nation's healthcare system.