2-24-2017

SR-16-17-27 APC

Marshall University

ACADEMIC PLANNING COMMITTEE
RECOMMENDATION

SR-16-17-27 APC

Recommends the approval of the Intent to Plan for Biomedical Engineering.

RATIONALE:

The Intent to Plan for Biomedical Engineering was discussed by the committee. There was concern that the program was too expensive for the projected benefits. It was also discussed that this would be a program appropriate for inclusion in the curriculum. The vote was 5-3 in favor of forwarding the Intent to Plan to the Faculty Senate for consideration.

FACULTY SENATE CHAIR:

APPROVED BY THE FACULTY SENATE: Paige Mueller-Neil DATE: 2/24/17

DISAPPROVED BY THE FACULTY SENATE: _____ DATE: _____

UNIVERSITY PRESIDENT:

APPROVED: Jerome A. Gilbert DATE: 4-12-17

DISAPPROVED: _____ DATE: _____

COMMENTS: _____

_____

_____

INTENT TO PLAN

BACHELOR OF SCIENCE IN BIOMEDICAL ENGINEERING

MARSHALL UNIVERSITY ADMINISTRATIVE UNIT:

THE WEISBERG DIVISION OF ENGINEERING

COLLEGE OF INFORMATION TECHNOLOGY AND ENGINEERING

PROPOSED IMPLEMENTATION DATE: FALL 2017

Contact Person:

Asad Salem, Chair
Weisberg Division of Engineering
(salema@marshall.edu)

August 29, 2016

ABET is the accreditation agency for engineering. Marshall University will seek ABET accreditation for the proposed undergraduate program in biomedical engineering. ABET, however, does not consider an institution for accreditation until the program produces its first graduate(s). It is anticipated that the first graduating class of the BSBE program will be by the end of the Spring 2021 semester. Therefore, MU will make a Request for Evaluation (RFE) to ABET during the 2020-2021 academic year, which would require completing a self-study report in June 2021 and a comprehensive site visit during the Fall 2021 semester. The results of the accreditation visit shall be known during the Fall 2022, and would be considered retroactively for the graduating student class in May 2021. All components of the program will be designed to be consistent with ABET accreditation standards, and accreditation expenditures have been built into the budget for the program beginning in the first year. Designing the program to meet ABET standards from the start will facilitate the program's eventual accreditation.

The proposed program will require five additional faculty members and one laboratory technician. The program will cost approximately **$2.88** million during its first five years, of which about **$940,000** will be used to develop the required undergraduate teaching laboratories. The program is expected to generate **$2.21** million in revenues and reallocated funds during the first five years. The program is projected to become financially viable in its fifth year. The projected net revenues in the fifth year is about $244,000. Enrollment is expected to increase over this period; it is expected that, after the first five years, **18** students will have graduated with a BSBE degree and approximately **73** students will be actively pursuing a BSBE degree at MU.

1. Program Description

The BE discipline is the application of engineering principles and design concepts to medicine and biology for health care purposes. This discipline aims to narrow the gap between engineering and medicine, combining the design and problem solving skills of engineering with medical and biosciences to advance health care treatment, including diagnosis, monitoring, and therapy. Biomedical engineering has only recently emerged as its own study, compared to many other engineering fields. Biomedical engineering is a rapidly growing field, and Marshall University has an opportunity to create a unique program that will highlight the technical strengths of the University and garner interest in the development of biomedical industry in the state.

1.1 Program Mission

The Program Objectives (POs') of the Bachelor of Science in Biomedical Engineering (BSBE) program has several key components:

1. Graduates demonstrate technical and/or professional skills, which may include engineering problem-solving, scientific inquiry, and/or engineering design, to solve challenging problems in biomedical engineering and related fields.
2. Graduates are accomplished at communicating and working collaboratively in diverse work environments.
3. Graduates engaging in life-long learning activities at graduate, medical or other professional programs or workshops. Graduates entering professional careers find appropriate career progression and success.

These program objectives are consistent with the mission of the university; specifically, with the following components contained in the *Marshall University Mission Statement* (http://www.marshall.edu/www/mission.asp):

program will be designed to fulfill ABET engineering accreditation. Additionally, the BE curriculum will be designed to incorporate the most recent National Academy of Engineering (NAE) recommendations

1.2.1 Program Learning Outcomes

Biomedical engineering is a field of engineering that generally deals with the study and application of engineering principles and design concepts to medicine and biology for health care purposes. This discipline aims to narrow the gap between engineering and medicine, combining the design and problem solving skills of engineering with medical and biosciences to advance health care treatment, including diagnosis, monitoring, and therapy. Biomedical engineering has only recently emerged as its own study, compared to many other engineering fields.

BSBE Program Students Outcomes (SOs'): Marshall University BSBE graduates shall have:

a. an ability to apply knowledge of mathematics, science, and engineering
b. an ability to design and conduct experiments, as well as to analyze and interpret data
c. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
d. an ability to function on multidisciplinary teams
e. an ability to identify, formulate, and solve engineering problems
f. an understanding of professional and ethical responsibility
g. an ability to communicate effectively
h. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
i. a recognition of the need for, and an ability to engage in life-long learning
j. a knowledge of contemporary issues
k. an ability to use the techniques, skills, and modern engineering tools necessary for biomedical engineering practice.

1.2.2 Additional Program Outcomes:

In addition to above listed Outcomes the BSBE program will **allow students to complete the admission requirements** for MD (Pre-Med) programs. The BSBE curriculum is designed to allow biomedical students interested in MD programs to fulfil the required and recommended science and general education coursework as shown below.

Science Coursework

- Principles of Biology I and II (BSC 120 and 121)
- Introductory Biochemistry (BSC 365 for Biology majors or CHM 365 for Chemistry majors)
- Principles of Chemistry I and II and Labs (CHM 211, 212, 217, and 218)
- Organic Chemistry I and II and Organic Lab (CHM 355, 356, and 361)
- General Physics I and II and labs (PHY 201, 202, 203 and 204)
- Mathematics to meet prerequisite requirements for the science courses listed above (MTH 122, Trigonometry; MTH 127/130, College Algebra; MTH 140, Applied Calculus, or MTH 229, Calculus I). *COS requires Calculus (MTH 140 or 229) to meet graduation requirements.*

General Education Coursework

Number	Course	Credit Hours
1	BE 103 Biomedical Engineering Design	3
2	BE 112 Biomedical Engineering Computing	3
3	BE 201 Intr. To Biomedical Engineering	3
4	BE 305 Intro. To Biophysical Measurement	3
5	BE 302 Engineering Biomechanics	3
6	BE 301 Biomedical Engineering Seminar	2
7	BE 310 Modeling & Simulation of Biomedical Systems	3
8	BE 306 Mechanics of Biological Tissues	3
10	BE 405 Biomedical Measurements & Data Analysis	3
11	BE 465 Capstone I	2
12	BE 466 Capstone II	2
13	BSC 120 Principles of Biology I	4
14	BSC 227 Human Anatomy	4
15	BSC 121 Principles of Biology II	4
16	BSC 228 Human Physiology	4
17	CHM 211 Chemistry I	3
18	CHM 217 Chemistry I Lab	2
19	CHM 212 Chemistry II	3
20	CHM 218 Chemistry II Lab	2
21	ENGR 245 Circuits & Controls	3
22	ENGR 219 Engineering Thermodynamics	3
23	ENGR 220 Engineering Mechanics	4
24	ENGR 216 Mech. of Mater. **OR** CHM 335 Organic Chem. I	3
25	ENGR 202 Circuits II **OR** BSC 322 Prin. Cell Biology	4
26	MTH 229 Calculus I	5
27	MTH 230 Calculus II	4
28	MTH 231 Calculus III	4
29	MTH 335 Differential Equations	3
30	PHY 211 Physics I	4
31	PHY 213 Physics II	4

Table 2: Tracks & Technical Elective Courses

Course Title	Credit Hours
BE 318 Biomaterials	3
BE 360 Mechanics of Bio-fluids	3
BE 440 Adv. Biomaterials	3
BE 410 Biosensors	3
BE 420 Design of Medical Devices	3
BE 450 Tissue Engineering	3
BE 445 Engineering Bioinformatics	3
BE 415 Biomedical Signals & Image Processing	3
BE 425 Design of Medical Imaging Systems	3

2. Program Need and Justification

There is only one BE program in West Virginia at West Virginia University-Morgantown. The WVU BE program currently has an enrollment cap of 40 students per year. Twenty of the US's 97 ABET accredited Biomedical Engineering programs are in the neighboring states of Ohio, Pennsylvania, Maryland, Kentucky, and Virginia. However, not all of the twenty neighboring programs offers a bachelor of Science in biomedical engineering. Indeed, many of these twenty programs are limited to graduate programs or offer an option within biological, biomass or chemical engineering programs. For instance, the University of Kentucky (UK) offers an undergraduate option in biomedical engineering while Ohio University's program is limited only to graduate students. Establishing this program at Marshall University will develop new opportunities for West Virginia and the Tri-States region students to remain in their home state and will promote the image of the University nationally.

2.2.1 National Needs:

According to the U.S. Bureau of Labor; employment of biomedical engineers is projected to grow 23 percent from 2014 to 2024, much faster than the average for all occupations. Growing technology and its application to medical equipment and devices, along with an aging population, will increase demand for the work of biomedical engineers.

Several studies at the national, state, and local levels have delineated the overall needs for additional engineers and scientific personnel. For example, the National Academy of Engineering, the National Academy of Sciences and the Institute of Medicine produced a report (2007): "Rising Above The Gathering Storm: Energizing and Employing America for a Brighter Economic Future." This report summarizes the huge demand for engineers and science (STEM) graduates in U.S. industries and universities. The report indicates that to address the deficit in engineering and scientific knowledge, the nation must import foreign nationals to close the gap between supply and demand. As financial opportunities in foreign countries increasingly develop via globalization, the U.S. is going to find itself with a deficit of talent that will negatively impact its ability to maintain its world leadership in science and engineering. The Gathering Storm report defines a "compelling call to action" to draw more underrepresented U.S. citizens into engineering and science.

Engineering education is one of the most important aspects of this innovation cultivating process. Many states are now recognizing a shortage of engineers and are taking actions to address this urgent problem. These conclusions have been reached through a deliberate process of studying the current state of engineering education in the state and country, future trends and needs of society, the role of the U.S. in the knowledge-based society and global economy for high-impacting jobs and markets, the need of the state for economic development and the role of MU as a public supported university in economic development.

The proposed BE program will differ significantly from WVU's program in that there will be much more emphasis on the core liberal arts component and learning communities approach, more cross-integration of subject materials in the engineering courses for a systems approach, and a cooperative education component involving industrial experiences. The model that MU will use has been successfully implemented at Drexel University, Rochester Institute of Technology, and Georgia Tech.

The program will contain unique features that differentiate it from traditional biomedical engineering offerings. The BE program will allow students to complete the admission requirements for MD (Pre-Med)

by health care providers as clinical or support engineers. Auto, aviation, aerospace, tooling, sports, and furniture industries higher about 50% of the biomedical engineers. Furthermore, regulatory agencies, such as FDA, NASA, CDC, NIH, NSF, ..., etc., and insurance companies provide employment opportunities to around for 15-20% biomedical engineers. About 10-20% of the graduates of this discipline find their way to medical schools or other professional programs. The Bureau of Labor Statistics predicts (May 2015) an employment of biomedical engineers is projected to grow 23 percent from 2014 to 2024, much faster than the average for all occupations. Growing technology and its application to medical equipment and devices, along with an aging population, will increase demand for the work of biomedical engineers. According to the same Bureau (May 2015) there are 110-120 biomedical engineers working in the State of West Virginia, and it seems that around 40 of those were added during 2014 and 2015. It is very obvious, that a Program (WVU) which only admits 40 students per year will not be able to meet the State's demand of biomedical engineers, especially, if this Program is located in the close proximity of states that have high demand of biomedical engineers.

In West Virginia, as reported by many industrial leaders, a substantial percentage of all engineering jobs in the state are filled by graduates of out-of-state or foreign institutions. There are a number of large businesses in the Tri-State region that employ biomedical engineers. For instance, and according to the Bureau of Labor Statistics (May & December 2015) WV's biomedical engineering Location Quotient (LQ) was 0.36 which is much lower than OHIO's LQ of 0.83 and Pennsylvania's 0.98. Location Quotient (LQ) is basically a way of quantifying the availability of the needed workforce for a particular industry in a region as compared to the nation. It, also, can reveal what makes a particular region "unique" in comparison to the national average. Low LQ is an excellent indicator that more workforce in a certain sector of the economy is needed in order to advance or expand it. The proposed BE program has the full support of the Joan C. Edwards School of Medicine. Sample letters of support are available in Appendix C.

2.3 Program Impact:

- This program will enable Marshall University to develop, educate, graduate, and provide new opportunities to the citizens of West Virginia. The best high school students have shown interest in taking on the challenges that cross the fields of engineering, the health sciences, and the physical sciences. This convergence is being promoted more actively nationally and will be a major contributor to new technology that will increase US global competitiveness in the field of health care in the coming years.
- A Biomedical Engineering degree program will create exciting and productive new paths for research and development, and will increase graduate education opportunities and research collaborations with health and biomedical sciences and several other disciplines across the campus. This program will give undergraduate and graduate students the opportunity to learn and implement advanced technologies and to perform leading edge research in biomedical engineering.
- Currently, the College of Information Technology and Engineering (CITE) is below the national average in female student enrollment (~18%) at 12%. This Biomedical Engineering degree program will increase diversity at the University, and certainly in CITE since this field is attractive to female students and boasts the highest percentage of female graduates among all of the engineering disciplines (50% nationally, ASEE 2015).
- In West Virginia, statistics indicate that over 50% of the deaths in 2012 were a result of heart disease, diabetic, respiratory, or cancer diseases. Development of a Biomedical Engineering program will produce in-state graduates well-poised to address these illnesses and others, making progress to stabilize or cure these diseases a reality. Additionally, West Virginia has a rapidly aging population with 25% of the population predicted to be over the age of 65 by 2030. This increase will be a major driving force in the expansion of the biomedical engineering discipline,

and UK) with biomedical or bio- engineering programs. Some of the current BSE, BSME, BSEE, or BSCS students will undoubtedly transfer to BSBE and these will tend to stay since they have achieved a level of success in their programs and will be better prepared for the BSBE than students who are new to the program. It is conceivable that once the BSBE program is approved and ABET accredited, the newly founded INTO program at MU may recruit foreign students interested in the BSBE degree, but these figures are not included in the table below.

This new degree is projected to have around 73 majors in its fifth year. MU has a very strong commitment to recruiting students from underrepresented groups. **The engineering program will actively recruit students from the underrepresented groups and International students to advance this mission. The Program is expected to graduate 7 students in 2020-2021.**

Table 3: Student Enrollment Projections

	Change of Major	New Students	Attrition	Graduation	Cumulative Head Count
1St year 2017	3	15	0	0	18
2nd Year 2018	2	18	4	0	34
3rd Year 2019	0	20	6	0	48
4th Year 2020	0	25	8	0	65
5th Year 2021	0	25	10	7 (2020)	73

Form 1: Five-Year Projection of Program Size

3.1 Projected Faculty Undergraduate Teaching Load

BE students will have many options to fulfill their BE tracks and BE technical electives course requirements. Students can choose, in coordination with their faculty advisors, from a large list of courses that are offered by many programs within MU. Students will be encouraged to take courses from the following programs: ENGR, EE, ME, CS, CHM, SFT, HS, PHY, and BMS. When the Program is fully implemented, BE faculty are expected to cover 15-20 undergraduate BE courses (48-50 CHS) per academic year. A full list of these courses is attached in Appendix A.

Table 4: B.S. of Biomedical Engineering Faculty

Name of Core Faculty and Faculty Rank	Highest Degree	% of time assigned to the Program
Salem, Asad * [Primary responsibility for administering the program]	PhD in Mechanical Engineering	10
New Faculty (I) in Year 2017-18	PhD in Biomedical Engineering (Biomechanics)	50
New Faculty (2) in Year 2018-19	PhD in Biomedical Engineering (Medical Instrumentation)	50
New Faculty (3) in Year 2018-19	PhD in Biomedical Engineering (Biomaterials & Tissues)	50
New Faculty (4) in Year 2019-20	PhD in Biomedical Engineering (Medical Imaging)	50
New Faculty (5) in Year 2020-21	PhD in Biomedical Engineering (Nano and Micro Scale Devices, Biosensors, and Bioinformatics)	50

4. Library Resources and Instructional Materials

MU libraries have many of the resources necessary to support a new program in Biomedical Engineering such as MEDLINE database. Monographic, journal and database holdings enable the libraries to provide initial support for the program. Most of the resources available are not discipline specific but are available through multidisciplinary databases and may provide the depth of breadth of material required to support such a degree. Keeping in mind, MU libraries are currently supporting the BSE, MSE, BSCS, MSCS, BSIS, MSIS, BSME, MSME, BSEE, Biomedical Science (BMS), Biological Sciences (BSC), and Medicine

6. Facilities Requirements

The space for the required labs need to be allocated. Space for classrooms, computer labs, and faculty offices is adequate. The project cost for remolding and renovating of the required lab space is about $300,000 based on standard cost of $80-90 per square foot.

7. Operating Resource Requirements

Normal operating expenses will be necessary for his program. Office space for the additional faculty is available. Additional office supplies would be required, along with voice and data services and devices. Other requirements may include nonrecurring expenses such as program start-up/development expenses are presented in FORM 2. The operational budget will come from student tuitions and fees.

8. Expenses and Revenue Projection

All operational support will come from student tuitions and program specific fees.

FORM 2 shows the operating resources requirements as well as the sources of operating resources, including personnel expenses, and nonrecurring expenses (such as program start-up/ development expenses), annual operating expenses. It also, shows the total and net annual revenues and the cumulative return.

Appendix A
Bachelor of Science –Biomedical Engineering (BSBE)

BSBE Four –Years Curriculum Guide

1st Year

Fall	SCH	Spring	SCH
MTH 229 Calculus I	5	MTH 230 Calculus II	4
ENG 101 English Composition I	3	CHEM 212 Chemistry II	3
CHM 211 Chemistry I	3	BE 112 Biomedical Engineering Computing	3
CHM 217 Chemistry I Lab	2	BSC 120 Principles of Biology I	4
BE 103 Biomedical Engineering Design	3	CHM 218 Chemistry II lab	2
		FYS 100 First Year Seminar	3
	16		19

2nd Year

Fall		Spring	
MTH 231 Calculus III	4	PHY 213 Physics II	4
BSC 227 Human Anatomy	4	ENGR 245 Circuits and Controls	3
BSC 121 Principles of Biology II	4	ENGR 219 Engineering Thermodynamics	3
PHY 211 Physics I	4	ENGR 220 Engineering Mechanics	4
BE 201 Intr. to Biomedical Engineering	3	BSC 228 Human Physiology	4
	19		18

- BE 318 Biomaterials* (3)
- *SFT 373 Principles in Ergonomics and Human Factors (3)*

BE Track II: One of the following:

- *EE 320 Signals & Systems* (3)*
- *EE 350 Electrical Properties of Materials* (3)*
- BE 360 Mechanics of Bio-fluids* (3)
- *ME 410 Kinematics & Design of Machines (3)*
- BE 440 Adv. Biomaterials* (3)
- BE 410 Biosensors* (3)
- *CHM 365 Introductory to Biochemistry*

BE Track III: one of the following:

- BE 420 Design of Medical Devices (3)
- *ENGR 470/570 Finite Elements Analysis (3)*
- *ME 420 Instrumentations and Control* (3)*
- *EE 410 Digital Control Systems* (3)*
- BE 450 Tissue Engineering* (3)
- BE 445 Engineering Bioinformatics (3)
- *ME 520 Intro. to CFD (3)*
- *HS 465 Biomechanical Analysis of Movement (3)*

Technical Electives: Three of the following:

- *ME 465 Mechatronics (3)*
- *ME 520 Intro. to CFD (3)*
- BE 415 Biomedical Signals and Image Processing* (3)
- BE 425 Design of Medical Imaging Systems (3)
- BE 435 Experimental Techniques in Biomechanics* (3)
- BE437 Experimental Techniques in Biomaterials and Tissue Engineering* (3)
- BE 455 Neural Engineering (3)
- BE 440 Adv. Biomaterials* (3)
- BE 410 Biosensors* (3)
- BE 420 Design of Medical Devices (3)
- BE 445 Engineering Bioinformatics (3)
- *HS 465 Biomechanical Analysis of Movement (3)*
- BE 450 Tissue Engineering* (3)
- *ENGR 470/570 Finite Elements Analysis (3)*
- *ME 420 Instrumentations and Control* (3)*
- *BE 409 Introduction to Biomedical Engineering Research (3)*
- *BE 485 ST: Biomedical Engineering (1-3)*
- *BMS 401 Intro. to Nucleic Acids and proteins** (3)*
- *BMS 402 Introduction to Cell Structure and Metabolism ** (3)*
- *BMS 403 Regulation of Cell Function *** (3)*
- *BMS 404 Cellular of Disease *** (3)*

*with lab component
** Co-Requests offered in Fall
*** Co-Requests offered in Spring

OPTION II

	Fall	Spring	Summer
Freshman Year	Classes	Classes	
Sophomore Year	Classes	Classes Apply to CO-OP	CO-OP
Junior Year	CO-OP	Classes	CO-OP (Optional)
Senior Year 1	Classes	CO-OP	CO-OP
Senior Year 2	Classes	Classes	

FRESHMAN YEAR & SOPHOMORE YEAR

Students spend their freshman and sophomore years in classes trying to earn the highest GPA as possible. In the summer between freshman and sophomore years, students are encouraged to pursue internships, participate in research, or take summer courses to get ahead or improve GPAs. These years should be dedicated to building strong resumes for the CO-OP program.

SOPHOMORE

SPRING: Students apply to the CO-OP program, attend an orientation meeting, attend all professional preparation meetings, and interview with companies looking for students.

SUMMER: After accepting a CO-OP position in the spring, students spend the summer gaining full- time, paid, engineering experience at a company.

JUNIOR YEAR

FALL: Students continue to gain full-time, paid, engineering experience at a company.

SPRING: Students resume taking and completing coursework.

SUMMER: Some students will be given the opportunity by their companies to complete a summer CO-OP. While only the length of a typical internship, summer CO-OP students are typically still provided the same level of work as a CO-OP because they do not need to be retrained by the company. This extra summer CO-OP is not required for the program.

SENIOR YEAR 1

FALL: Students resume taking classes, but again go through the interview process for a second CO-OP position. This position could be with the same company the student first CO-OPed with, but does not need to be. Many students prefer to explore multiple kinds of companies.

SPRING: After accepting a CO-OP in the fall, students gain full-time, paid, engineering experience at a company.

SENIOR YEAR 2

FALL: Students resume taking classes.

SPRING: Students complete their final semester of classes in order to graduate. CO-OP students report ease in finding full-time positions in a competitive market due to their professional experience.

Alcon A Novartis Division

Alcon Laboratories, Inc.
6065 Kyle Lane
Huntington, Wv25702

304-733-7432

September 27, 2016

Asad A. Salem, Ph.D
Professor and Chair
Weisberg Division of Engineering
College of Information Technology and Engineering
Suite WAEC Room - 2201
Weisberg Family Applied Engineering Complex
Marshall University
Huntington, WV 25755-2586

Dear Dr. Salem,

It is my pleasure to write a letter of support for Marshall University to develop a Bachelor of Science in Biomedical Engineering program (BSBE),

Biomedical Engineering Education is impactful at the national and local level. The Biomedical Engineering curriculum provides engineers a background in engineering and biological sciences to address challenges where medicine, health, biology and traditional engineering intersect. Strong analytical, communication, math, and problem-solving skills are the foundational skills that enable Biomedical Engineers to understand and solve healthcare issues. As the population ages, the healthcare and medical innovation will impact the economy; the US Bureau of Labor and Statistics predicts a 23 % increase in job growth 2014-2024 (www.bls.gov). Locally, it is a challenge to recruit and retain technical skills. An ABET accredited Biomedical Engineering program at Marshall University would provide a pool of engineering talent with local ties to the community that would be beneficial to the Alcon Huntington Manufacturing site.

In summary, I fully support Marshall University pursuing the development of a Bachelor of Science in Biomedical Engineering program (BSBE) designed to prepare students for successful careers in academia, medicine, and industry. The proposed program would beneficial to the students, and the larger community, locally and nationally.

Sincerely,

Linda Phinney

Linda Phinney
Site Head R&D

Introduction to measurements and data collection and analysis including combinatorics of probability and statistics. Special emphasis is on the application of these concepts toward discovery of biomedical principles from experimental observations and large-scale data as well as the design of experiments. Topics in combinatorics include permutations and selections, the binomial theorem and Vandermonde's identity, the binomial probability distribution, and the limits of the Poisson distribution and the normal distribution.

BE409 INTRODUCTION TO BIOMEDICAL ENGINEERING RESEARCH 3 credits

Application of engineering principles to local area medical research. Includes biomaterials, orthopedics, artificial organs, bio-stereometrics, biometrics, biological signal and image analysis, biomechanics and computers in medicine.

BE 410 BIOSENORS 3 credits

Fundamental of microbiology and biochemistry from engineering prospective, bioelectricity, action potential, bio-membrane and Huxley model, design, development and application of biosensors and Bioelectronics.

BE 415 BIOMEDICAL SIGNAL AND IMAGE PROCESSING 3 credits

Introduction to the basic problems associated with biological signal and image processing applications, and appropriate approaches to dealing with them.

BE 420 DESIGN OF MEDICAL DEVICES 3 credits

Design of Medical Devices, design criteria, human factors, patient care and monitoring devices, surgical devices, bench testing and legal liability.

BE 425 DESIGN OF MEDEDICAL IMAGING SYSTEMS 3 credits

Physical principles and engineering design of medical imaging systems, with emphasis on digital radiography, computed tomography, nuclear medicine, ultrasound and magnetic resonance.

BE 435 EXPERIMENTAL TECHNIQUES IN BIOMECHANICS 3 credits

Principles of testing and measuring devices commonly used for bio-fluid and bio-solid mechanics studies. Laboratories for demonstration and hands-on experience.

BE 437 EXPERIMENTAL TECHNIQUES IN BIOMATERIALS and TISSUE ENGINEERING 3 credits

Laboratory experience that applies engineering concepts and practices to the analysis of biomaterials and tissue engineering.

BE 440 ADVANCED BIOMATERIALS 3 credits

The interactions between biomaterials and medical devices will be analyzed with respect to their potential fractionation of biological mechanisms.

BE 445 ENGINEERING BIOINFORMATICS 3 credits

Development of design project in bioinformatics in relation to biomedical engineering applications that include integration of medical instrumentations, devices, and sensors.

BE 450 TISSUE ENGINEERING 3 credits

This course will explore topics to successfully design tissue engineered devices. For advanced engineering students with a back ground in materials, mechanics, and transport phenomena.

BE 465 BIOMEDICAL ENGINEERING CAPSTONE I 2 credits

The design process will be further discussed utilizing case studies and detailed biomedical engineering design projects.

BE 466 BIOMEDICAL ENGINEERING CAPSTONE II 2 credits

The design process will be further discussed utilizing detailed biomedical engineering design projects. Projects will be required to be interdisciplinary in nature.

BE 455 Neural Engineering 3 credits

Engineering principles for systems analysis and control, biological control mechanisms, computational properties of biological neural networks, engineering neural networks for control applications, equivalent circuit models for biological neurons and networks, non-linear differential equation