Biomedical engineering syllabus

Biomedical engineering examinations

Group A - Compulsory examinations (six required)

20-Bio-A1 Biomaterials and Biocompatibility

Structure and properties of amorphous solids. Physical and chemical bases for properties exhibited by materials. Polymeric biomaterials. Metallic biomaterials. Ceramic biomaterials. Composite materials. Material properties including mechanical, electrical, magnetic and thermal behavior; estimation of these properties through experimental means. Applications of biomaterials in tissue and organ systems. Relationship between physical and chemical structure of materials and biological system response. Selection, fabrication and modification of materials for specific biomedical applications. Biomaterials processing. Biomaterials degradation. Implant requirements. Host-implants reactions including wound healing response and inflammatory response. Physiological and biomechanical basis for soft-tissue implants. Design of modified biomaterials. Bulk and surface characterization of materials. Regulatory (e.g. FDA/CE processes), ethical, and standards (e.g. ISO & ASTM) considerations for the implementation and commercialisation of biomaterials and medical devices.

Textbooks (most recent edition is recommended):

- J Temenoff & A Mikos, Biomaterials The Intersection of Biology and Materials Science, Pearson.
- Joon Park and R S Lakes, Biomaterials, Springer.
- Michael M. Domach, Introduction to Biomedical Engineering, Pearson Prentice Hall.

20-Bio-A2 Process Dynamics and Control


Textbooks (most recent edition is recommended):

- Luyben, W.L., Process Modelling, Simulation and Control for Chemical Engineers, McGraw Hill, N.Y.
- K Ogata, Modern Control Engineering, Prentice Hall.
- Seborg et al.’s, Process Dynamics and Control.

20-Bio-A3 Biomechanics

Biomechanics of 1. musculoskeletal, 2. cardiovascular, and 3. respiratory systems including general tissue characteristics, healthy systems function, and methods to measure these values. 1. Musculoskeletal system: characteristics and classification of tissues and joints, elastic and viscoelastic mechanical characterization of bone, cartilage, ligament and tendon; the stress-strain-time or constitutive equations for soft connective tissue components; basic kinematic and kinetic analysis of simplified cases. 2. Cardiovascular system: properties of tissues that form the heart, and major-to-minor arteries and veins; mechanisms and characteristics of healthy heart and blood vessel function (rhythm, pressure patterns, blood return, etc.); stress-strain-time relationships in cardiac and vascular tissues. 3. Respiratory system: properties of the tissues that form sinuses-to-alveoli; mechanisms and characteristics of respiration (e.g. diaphragm induced pressure differential), oxygen diffusion through alveolar walls; stress-strain-time relationships in pulmonary tissues.
Textbooks (most recent edition is recommended):

- Editors Hoskins, Peter R., Lawford, Patricia V., Doyle, Barry J. (Eds.), *Cardiovascular Biomechanics*.
- Carol A. Oatis, *Kinesiology: The Mechanics & Pathomechanics Of Human Movement*. Philadelphia: Lippincott Williams & Wilkins. (Parts I, II (1,2), III (5), IV (6,7)).

**20-Bio-A4 Anatomy and Physiology**

Description of the human systems. Skeletal system with anatomy of superior members, inferior members and rachis. Osteoarticular system: physiology of bones, osseous tissues, articular cartilage, tendons, ligaments and muscles. Respiratory system, circulatory system, digestive system, urinary system, nervous system, and reproductive system. Structure-function relationships in human body systems.

Textbooks (most recent edition is recommended):

- Guyton, AC and Hall, JE, *Medical Physiology*.
- Saladin Dr, Kenneth S, *Anatomy and Physiology*.

**20-Bio-A5 Systems Analysis & Control (16-Mec-A3)**

Open-loop and feedback control. Laws governing mechanical, electrical, fluid, and thermal control components. Mathematical models of mechanical, hydraulic, pneumatic, electrical and control devices. Block diagrams, transfer functions, response of servomechanisms to typical input signals (step function, impulse, harmonic), frequency response, Bode diagram, stability analysis, and stability criteria.


Textbooks (most recent edition is recommended):

- Gene F. Franklin, *Feedback Control of Dynamic Systems*.

**20-Bio-A6 Biomedical Signal Processing**

Analysis of continuous-time signals: impulse response and convolution; Fourier series and Fourier transform; magnitude, phase, and power spectra. Analysis of discrete-time signals: Nyquist sampling theorem; the Z-transform. Analog filters: standard prototypes, transformations, passive and active implementation. Design of finite impulse response (FIR) and infinite impulse response (IIR) filters. Generation and nature of bioelectric potentials including membrane and action potentials; electrodes and other transducers. Characteristics and processing of common biomedical signals including the electromyogram (EMG), the electrocardiogram (ECG), and the electroencephalogram (EEG).

Textbooks (most recent edition is recommended):

- John Semmlow, *Circuits, Signals and Systems for Bioengineers*.
- Suresh R. Devasahayam, *Signals and Systems in Biomedical Engineering*.

---

PDF generated on January 12, 2022
20-Bio-A7 Bioinstrumentation

Principles of design and analysis of electric instrumentation for biological applications. Ideal and non-ideal operational amplifiers, signal conditioning filters, sampling theory, analog to digital and digital to analog converters, sample and hold circuitry and multichannel data acquisition including the constraints imposed by real-time processing. The acquisition and processing of diagnostic signals such as the electrocardiogram, the echocardiogram, the blood pressure and hemoglobin oxygen saturation signals. Some basic knowledge of statistics for assessing the signal to noise characteristics of measured data. Safety standards in the clinical setting for electrical and electronic equipment in both non-invasive and invasive applications including applicable regulatory authorities and legal standards. Risk assessment and management. Quality management systems (QMS) and documentation protocols.

Textbooks (most recent edition is recommended):

- Webster, J.G. (Editor), Bioinstrumentation. Wiley.
- Webster, J.G. (Editor), Medical Instrumentation: Application and Design. Wiley.

Group B - Optional examinations (three required)

20-Bio-B1 Biochemical Separations

The fundamentals of downstream separation and purification processes such as membrane separation processes, protein separation and purification and other separation processes of economic importance to the fermentation industry. Cell Disruption. Solid Liquid Separation, filtration, centrifugation. Membrane separation. Isoelectric focussing. Adsorption. Chromatography principles, Crystallization.

Textbooks (most recent edition is recommended):

- E. Goldberg, Handbook of Downstream Processing.
- Blanch, H.W., D.S. Clark and Marcel Dekker, Biochemical Engineering.

20-Bio-B2 Biotransport Phenomena


Textbooks (most recent edition is recommended):

- Bird, Stewart and Lightfoot, Transport Phenomena.
- George A. Truskey et al.’s, Transport Phenomena in Biological Systems.

20-Bio-B3 Cell and Tissue Engineering


Textbooks (most recent edition is recommended):
20-Bio-B4 Robotics (16-Mec-B12)

Robot components (sensors, actuators, and end effectors, and their selection criteria); basic categories of robots (serial and parallel manipulators, mobile robots); mobility/constraint analysis; workspace analysis; rigid body kinematics (homogeneous transformation, angle and axis of rotation, Euler angles, cylindrical and spherical coordinates); manipulator kinematics and motion trajectories (displacement and velocity analyses, differential relations, Jacobian matrix); non-redundant and redundant sensing/actuation of manipulators; manipulator statics (force and stiffness); singularities; and manipulator dynamics.

Textbooks (most recent edition is recommended):
- Craig, J.J., Introduction to Robotics: Mechanism and Control, Addison-Wesley Publishing Co

20-Bio-B5 Rehabilitation Engineering

Introduction to rehabilitation engineering; Wheeled mobility: W/C history, technology and standards, fundamentals of manual W/Cs propulsion biomechanics, powered W/Cs and control systems; Functional disabilities: types of neuromuscular impairments; Specialized seating: classification of seating technologies, biomechanical principles of seating support & pressure, CAD/CAM seating applications; Hearing aids and cochlear implants: sensory and hearing aided technologies; Alternative & Augmentative Communication: rational, technologies & access strategies, principles of access & communication optimization; Prosthetics and orthotics: engineering principles of lower limb prostheses; ADL Devices: rational, design principles and use for upper & lower limb dysfunction; Measurement tools in rehabilitation engineering.

Textbooks (most recent edition is recommended):
- Emily C. Bouck, Assistive Technology, Michigan State University

20-Bio-B6 Analytical Biochemistry

Relevant analytical techniques for characterization of biological systems and materials. Nuclear magnetic resonance. Fourier transform infra red analysis. SDS-PAGE and Western blotting. HPLC. Flow cytometry. DNA gel extraction and ligation. Plasmid DNA mini-preps and PCR. Affinity purification and electrophoresis. Surface analysis techniques including x-ray photoelectron spectroscopy, atomic force microscopy, interfacial tension and ellipsometry.

Textbooks (most recent edition is recommended):

20-Bio-B7 Ergonomics (17-Ind-B5 Ergonomics)

Basic human abilities and characteristics, including vision and hearing. Psychomotor characteristics. Anthropometry: static and dynamic human body dimensions and muscle strength. Environmental factors, including illumination, atmospheric conditions, noise, and vibration. Ergonomic work design, including layout of equipment, manual work aids, design of seating, and person-machine interfaces: instruments, controls, and software. Regulated standards for work, safety and schedules.

Textbooks (most recent edition is recommended):
- RS Bridger, Introduction to Human Factors and Ergonomics.
- Kodak Ergonomics Group, Ergonomic Design for People at Work, Volumes I and II. Van Nostrand Reinhold Co. Ltd.

20-Bio-B8 Applied Optics/Photonics
Basic optics of rays; reflection, refraction, and polarization. Lens systems and image formation. Principles of basic optical instruments such as magnifiers, microscopes and telescopes. Basics of light sources: lasers, light emitting diodes, thermal light sources, fluorescence, and photodetectors. Tissue optics and light-tissue interactions and dosimetry. Principles of fibre optics and light guides, endoscopic systems and applications. Biomedical applications of photonics such as phototherapy and photodiagnostics, tissue oximetry, optical spectroscopy and microscopy, fluorescence marking, microarray technologies, flow cytometry.

Textbooks (most recent edition is recommended):

### 20-Bio-B9 Medical Imaging


Textbooks (most recent edition is recommended):

### 20-Bio-B10 Biomechanical Device Design & Human Factors

Introduction, terminology and classification of biomedical devices (primarily mechanical in nature) including implantable devices (joint prostheses, heart valve replacements, etc.), surgical devices/tools (i.e. non-permanent internal use), and external devices (e.g. orthoses, assistive devices, etc.). Assessing device usability through usability studies and clinical trials. Design History Files, QMS process (quality management system), Safety and Risk Assessment and Management: risk analysis; planned use; identification of dangerous physical and biological phenomena; assessment of the probability and severity of damage; control of risks; follow-up of incidents/post-deployment surveillance. Laws, regulations and standards (e.g. development and verification). Quantitative assessment and conditions of clinical trials.

Textbooks (most recent edition is recommended):
- Paul H. King, Richard C. Fries and Arthur T. Johnson, *Design of Biomedical Devices and Systems*.
- Shurr and Michael, *Prosthetics and Orthoses*.

### 20-Bio-B11 Orthopaedic and Injury Biomechanics

Introduction to chronic diseases and acute injuries effecting the musculoskeletal system, and methods to treat these conditions. Conditions to be addressed include osteoarthritis, bone fracture/healing, muscular injuries (chronic/acute), ligament/tendon injuries, traumatic head injuries. Analysis of existing and design of novel devices/methods for treating the above conditions including partial/total joint replacements (i.e. arthroplasty), internal fracture fixation (e.g. plates/rods, screws, etc.), biologics/biomaterials for muscle/tendon healing, tools for surgical treatment, devices to prevent brain injury (e.g. helmets/restraint systems). Testing methods for assessing disease/injury conditions and treatment methods.

Textbooks (most recent edition is recommended):
- Nordin, Margareta and Victor H. Frankel, *Basic Biomechanics of the Musculoskeletal System*, Lippincott Williams & Wilkins.
• Schmitt, K.-U., Niederer, P.F., Cronin, D.S., Morrison III, B., Muser, M.H., Walz, F., Trauma Biomechanics: An Introduction to Injury Biomechanics.
• Beth A. Winkelstein, Orthopaedic Biomechanics


Textbooks (most recent edition is recommended):
• Dutton, Ken, Steve Thompson, and Bill Barraclough, The Art of Control Engineering, Prentice Hall.
• Nise, Norman, John Wiley, Control Systems Engineering.

20-Bio-B13 Advanced Electronics (16-Elec-B5)


Textbooks (most recent edition is recommended):
• Sedra and Smith, Microelectronic Circuits, Oxford University Press.

20-Bio-B14 Cellular Physiology and Biophysics


Textbooks (most recent edition is recommended):
• Rodney Cotterill, Biophysics: An Introduction.
• Andrey Rubin, Fundamentals of Biophysics.
• Rob Phillips, Jane Kondev, Julie Theriot and Hernan Garcia, Physical Biology of the Cell.

20-Bio-B15 Fundamentals of Microbial Kinetics

Recombinant DNA technology, including cloning, directed mutagenesis, DNA sequencing and expression of cloned genes. Genomic engineering techniques. Basic principles of bioprocessing fundamentals, which includes: kinetics of enzymatic reactions and microbial growth, batch and continuous cell growth kinetics, products formation and nutrient utilization, bioreactor systems. Basic principles of biochemical engineering. Applied enzyme catalysis, immobilized enzyme technology, kinetics of substrate utilization, product formation and biomass production in cell culture, batch and continuous culture. Applications of biochemical engineering. Transport phenomena in biochemical engineering systems, design and analysis of bioreactors, mixing, aeration, sterilization, instrumentation and control in bioprocesses. Internal and external mass transfer in immobilized systems. Oxygen mass transfer parameters of a bioreactor and design of an aeration system. Scale up of Bioprocesses. Development and use of recombinant proteins as therapeutic drugs.

Textbooks (most recent edition is recommended):
• Blanch, H.W., D.S. Clark and Marcel Dekker, Biochemical Engineering.
• Bailey, J.E. and E.F. Ollis, Biochemical Engineering Fundamentals, McGraw Hill.