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.

CLARITY ADDED

Textbooks (most recent edition is recommended):

- Ratner, Buddy DS., Allan S. Hoffman, Frederick J. Schoen and Jack E. Lemons editors, Biomaterials Science: An Introduction to Materials in Medicine, Academic Press, NY.
- J Temenoff & A Mikos, Biomaterials The Intersection of Biology and Materials Science, Pearson.
- William Callister, Materials Science and Engineering: An Introduction, Wiley.
- Joon Park and R S Lakes, Biomaterials, Springer.
- Michael M. Domach, Introduction to Biomedical Engineering, Pearson Prentice Hall.
- Askeland and Wright, The Science and Engineering of Materials, Cengage Learning.

20-Bio-A2 Process Dynamics and Control

Linear models of physical systems and processes, the concept of the transfer function. The transient response of linear systems to step, ramp and sinusoidal inputs. Bode plots and the frequency response analysis of systems. On-off, proportional, integral, derivative and combined control actions. Stability analysis of closed-loop systems. Feedback and feed-forward control. The state-space

analysis of control systems. Modeling of nonlinear systems using the phase-plane and describing functions methods, stability of control systems involving nonlinear elements, the concept of limit cycles. A basic knowledge of sampled-data control systems including the z transform. The design of simple digital controllers. Application of the concepts of process dynamics and control to biological systems.

Textbooks (most recent edition is recommended):

- Coughanowr and Koppel, Process Systems Analysis and Control, McGraw Hill.
- Luyben, W.L., Process Modelling, Simulation and Control for Chemical Engineers, McGraw Hill, N.Y.
- K Ogata, Modern Control Engineering, Prentice Hall.
- Khoo, M., Physiological Control Systems: Analysis, Simulation, and Estimation, Wiley-IEEE Press.
- Seborg et al.'s, Process Dynamics and Control.

20-Bio-A3 Biomechanics

WAS 04-BIO-A4. REWRITTEN. ADDED CARDIOVASCULAR.
23-MEC-B13 TEXT IS UNCHANGED. IMPACT NOT CLEAR.

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):

- Nordin, Margareta and Victor H. Frankel, Basic Biomechanics of the Musculoskeletal System. Lippincott Williams&Wilkins.
- Edited by John Enderle, Joseph Bronzino, Introduction to biomedical engineering, Burlington, MA : Academic Press.

- Editors Hoskins, Peter R., Lawford, Patricia V., Doyle, Barry J. (Eds.), Cardiovascular Biomechanics.
- Editors Mary A. Farrell Epstein James R. Ligas, Respiratory Biomechanics: Engineering Analysis of Structure and Function.
- VC Mow and R Huiskes, Review of Basic Orthopaedic Biomechanics and Mechano-Biology, Philadelphia: Lippincott Williams & Wilkins. (ch. 1 à 7 & 12).
- Carol A. Oatis, Kinesiology: The Mechanics & Pathomechanics Of Human Movement, Philadelphia: Lippincott Williams & Wilkins. (Parts I, II (1,2), III (5), IV (6,7)).
- D. Bartel, D. Davy and T. Keaveny, Orthopaedic Biomechanics: Mechanics and design in Musculoskeletal Systems, Prentice Hall.

20-Bio-A4 Anatomy and Physiology WAS 04-BIO-A6

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.
- Joseph Feher, Quantitative Human Physiology, Academic Press.
- Saladin Dr, Kenneth S, Anatomy and Physiology

(22-MEC-A3)

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.

Improvement of system response by introduction of simple elements in the control circuit. Regulation of physical process: proportional, integral, and derivative control. Theory of linear controller design.

Textbooks (most recent edition is recommended):

- Bissell, C.C., Control Engineering, Taylor & Francis.
- Gene F. Franklin, Feedback Control of Dynamic Systems.
- Michael C. K. Khoo, Physiological Control Systems: Analysis, Simulation, and Estimation.

20-Bio-A6 Biomedical Signal Processing NEW

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):

- R. M. Rangayyan, Biomedical Signal Analysis, Wiley.
- Lathi, B.P., Signal Processing and Linear Systems. Oxford University Press.
- Haykin, Simon & Barry Van Veen, Signals and Systems, Interactive Solutions Edition, John Wiley & Sons Canada Ltd.
- John Semmlow, Circuits, Signals and Systems for Bioengineers
- Suresh R. Devasahayam, Signals and Systems in Biomedical Engineering

20-Bio-A7 Bioinstrumentation WAS 04-BIO-B6

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

ADD

standards. Risk assessment and management. Quality management systems (QMS) and documentation protocols. ADD

Textbooks (most recent edition is recommended):

- Webster, J.G. (Editor), Bioinstrumentation. Wiley.
- Webster, J.G. (Editor), Medical Instrumentation: Application and Design, Wiley.
- Biomedical Device Technology: Principles And Design 1st Edition, by Anthony Chan

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.
- Shuler, M.L. and F. Kargi, Biochemical Engineering Basic Concepts. Prentice Hall.

20-Bio-B2 Biotransport Phenomena WAS 04-BIO-B3

Momentum, heat and mass transfer. Mass, linear momentum and energy balances. Differential analysis of laminar viscous flow. Differential analysis of heat conduction. Differential analysis of diffusion and convective transport. Biological examples of transport phenomena including: pharmacology and pharmacokinetics; absorption distribution, biotransformation, elimination, calculation of dosages; variability in drug response and adverse drug responses; drug delivery; microenvironment, transport and binding of small and large molecules; movement of cancer and immune cells; metastatic process, radiotherapy, chemotherapy, immunotherapy, hyperthermia, and photodynamic therapy of solid tumors. Numerical methods for computer simulation.

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 WAS 04-BIO-B5

Integration of relevant aspects of physiology, pathology, developmental biology, disease treatment and biomaterials to regenerative medicine in complex organ systems. Host response to tissue engineered constructs including complement, coagulation, immunological responses. Engineered replacements of kidney, lung, vascular, skin. Chemical, electrical, mechanical, materials, pathological and surgical aspects of construct development. Integrative exploration of the use of three-dimensional polymeric scaffolds and drug delivery vehicles, and gene therapy and cellular engineering for functional repair of injured tissues. Cell selection.

Textbooks (most recent edition is recommended):

- Lanza, R.P., R. Langer and W.L. Chick (eds), Principles of Tissue Engineering, Academic Press.
- Berhard O. Palsson, Sangeeta N. Bhatia, Tissue Engineering, Pearson Prentice Hall, New Jersey.

(22-MEC-B12)

20-Bio-B4 Robotics (16-Mec-B12) NEW

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):

- Paul, R.P., Robot Manipulators - Mathematics, Programming and Control, MIT Press.
- Craig, J.J., Introduction to Robotics: Mechanism and Control, Addison-Wesley Publishing Co

20-Bio-B5 Rehabilitation Engineering WAS 04-BIO-B8

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):

- Rory A Cooper, Hisaichi Ohnabe, Douglas A. Hobson, An Introduction to Rehabilitation Engineering, CRC Press, Taylor and Francis
- Emily C. Bouck, Assistive Technology, Michigan State University

20-Bio-B6 Analytical Biochemistry WAS 04-BIO-B10

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):

- Mikkelsen, Susan R. and Eduardo Corton, Bioanalytical chemistry, Wiley Interscience.
- Holme, D.J. and H. Peck, Analytical Biochemistry, Longman.

(23-IND-B5)

20-Bio-B7 Ergonomics (17-Ind-B5 Ergonomics) WAS 04-BIO-B11

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

WAS 04-BIO-B12

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 photodiagnosis, tissue oximetry, optical spectroscopy and microscopy, fluorescence marking, microarray technologies, flow cytometry. ADD

Textbooks (most recent edition is recommended):

- Prasad, N., Introduction to Biophotonics, Wiley.

20-Bio-B9 Medical Imaging

NEW
04-BIO-B4 HEAVILY REVISED

Image quality analysis criteria. Image filtering in the spatial and frequency domains. Image restoration: regularization filters, deconvolution filters, optimal filtering. Segmentation of medical images: thresholding techniques, segmentation into regions, pattern recognition. Registration of medical images. X-ray radiography: sources and their characteristics, spectrum, interaction with tissue, instrumentation, image formation and characteristics. Computed tomography: CT instrumentation, image formation, line itegrals, backprojection, projection-slice theorem, fan-beam reconstruction. Nuclear medecine: general principles, radiotracers, gamma camera, image characteristics, SPECT. Positron emission tomography: general principles, instrumentation, tracers, image formation. Ultrasound imaging: ultrasound wave propagation, tissue properties, transducers and properties, modes, clinical applications. Magnetic resonance imaging: nuclear magnetism, classic description, spin-spin relaxation, spin-echo sequences, imaging and signal encoding, instrumentation, excitation sequences, functional imaging.

Textbooks (most recent edition is recommended):

- Prince & Links, Medical Imaging Signals & Systems, Pearson Prentice Hall.
- Suetens, P., Fundamentals of Medical Imaging, Cambridge University Press.

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

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 G. Yock, Biodesign: The Process of Innovating Medical Technologies.
- Jonathan S. Kahan, Medical Device Development: Regulation and Law.
- 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 NEW

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.
- D. Bartel, D. Davy and T. Keaveny, Orthopaedic Biomechanics: Mechanics and design in Musculoskeletal Systems, Prentice Hall.
- 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

(22-ELEC-B2)

20-Bio-B12 Advanced Control Systems (16-Elec-B2) NEW

Modelling of engineering systems; state variables and transfer function representations. Analytical and numerical solutions of state variable equations. Observability, controllability, stability; classical design, stabilization by pole assignment. Systems with noise. Computer control, discrete systems. System identification; least squares.

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.

(22-ELEC-B5)

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

Device models: circuit behaviour, high frequency, and feedback. Multi-stage amplifiers, oscillators, current mode op-amps, non-linear circuits. Power amplifiers and linear regulators. Instrumentation: differential amps, optical isolators, and analog-digital and digital-analog converters.

Textbooks (most recent edition is recommended):

- Sedra and Smith, Microelectronic Circuits, Oxford University Press.
- Horowitz, Paul, and Winfield Hill, The Art of Electronics, Cambridge University Press

20-Bio-B14 Cellular Physiology and Biophysics NEW

Chemical and physical structure of proteins, enzymes, nucleic acids, connective tissue and bone from molecular to microscopic levels. Relationship of chemical and physical structure of proteins to function including regulation of enzyme activity. Rate processes in biology. Systems of differential equations and stability analysis. Gene networks and signal transduction pathways. Enzyme kinetics, inhibition and cooperativity. Diffusion and mass transport in biological systems. Facilitated transport across membranes. Co-transport, counter-transport, ion pumps. Diffusion of macromolecules and random walks. Structure of cellular membranes, Singer-Nicholson fluid mosaic model. Membrane potentials, Gibbs-Donnan equilibrium potentials. Protein-protein and protein-DNA interactions, receptor –ligand interactions, cell adhesion, cell migration, signal transduction, cell growth and differentiation.

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 NEW

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.
- Aiba, S., A.E. Humphrey and N.F. Mills, Biochemical Engineering, Academic Press.

- Shuler, M.L. and F. Kargi, De Lisa, Bioprocessing Engineering Basic Concepts, Prentice Hall.

4.2 INTRODUCTION

Nineteen engineering disciplines are included in the Examination Syllabus issued by the Canadian Engineering Qualifications Board of the Canadian Council of Professional Engineers.

Each discipline examination syllabus is divided into two examination categories: compulsory and elective. A full set of Biomedical/Biochemical Engineering examinations consists of nine, three-hour examination papers. Candidates will be assigned examinations based on an assessment of their academic background. Examinations from discipline syllabi other than those specific to the candidates' discipline may be assigned at the discretion of the constituent Association/Ordre.

Before writing the discipline examinations, candidates must have passed, or have been exempted from, the Basic Studies Examinations.

The constituent Association/Ordre will supply information on examination scheduling, textbooks, materials provided or required, and whether the examinations are open or closed book.

4.2.1 BIOMEDICAL/BIOCHEMICAL ENGINEERING EXAMINATIONS

GROUP A

COMPULSORY EXAMINATIONS (SIX REQUIRED – A1, A2 AND FOUR OF THE REMAINING SEVEN)

04-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 behaviour. 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 and ethical concerns dealing with the implementation and commercialisation of biomaterials and medical devices.

04-Bio-A2 Process Dynamics and Control

Linear models of physical systems and processes, the concept of the transfer function. The transient response of linear systems to step, ramp and sinusoidal inputs. Bode plots and the frequency response analysis of systems. On-off, proportional, integral, derivative and combined control actions. Stability analysis of closed-loop systems using the root locus method and the Nyquist criterion. Feedback and feed-forward control. The state-space analysis of control systems. Modeling of nonlinear systems using the phase-plane and describing functions methods, stability of control systems involving nonlinear elements, the concept of limit cycles. A basic knowledge of sampled-data control systems including the z transform. The design of simple digital controllers. Application of the concepts of process dynamics and control to biological systems with particular attention to neural physiology and homeostasis and bioreactors.

04-Bio-A3 Cellular and Molecular Biology and Biochemistry

Cell structure and function, including transport and chemical signals, adaptation of structure and function. Use of micro organisms in biotechnology. Biology of the prokarytoic cell. Chemical and physical structure of proteins, enzymes, nucleic acids, connective tissue and bone from molecular to microscopic levels. Relationship of chemical and physical structure of proteins to function including regulation of enzyme activity. Recombinant DNA technology including cloning, directed mutagenesis, DNA sequencing and expression of cloned genes. Development and use of recombinant proteins as therapeutic drugs. Fundamentals of therapeutic protein action. Site specific mutation of proteins. Protein-protein and protein-DNA interactions, receptor –ligand interactions, cell adhesion, cell migration, signal transduction, cell growth and differentiation. Post-translational processing and secretion of proteins. Gene cloning and expression in mammalian cells.

04-Bio-A4 Biomechanics

The musculoskeletal system; general characteristics and classification of tissues and joints. Elastic and viscoelastic mechanical characterization of biological tissues including bone, cartilage, ligament and tendon. Principles of viscoelastic and the rate sensitivity of biological materials. The stress-strain-time or constitutive equations for soft connective tissue components. Biomechanics and clinical problems in orthopaedics. Modelling and force analysis of musculoskeletal systems. Passive and active kinematics. Mechanical properties of biological and commonly used biomedical engineering materials.

04-Bio-A5 Enzyme and Microbial Kinetics

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.

04-Bio-A6 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.

04-Bio-A7 Fluid Mechanics

Basics of momentum transfer and fluid flow; their application to the solution of engineering problems. Topics include: Engineering unit systems, dimensionless quantities; Basic concepts of fluid statics; Newton's law of viscosity; Steady and unsteady flow; Compressible and incompressible flow; Turbulent shear stress; Bernoulli's theorem, momentum transfer equations, equation of continuity; Computational fluid dynamics principles; Newtonian and Non –Newtonian fluids; External and internal flow; Fluid flow in pipes; Friction factors; Pumps, compressors, turbines; Flow measurement devices.

04-Bio-A8 Biophysical Measurements

Biomedical sensors and their application to the measurement of blood pressure, cardiac output and respiratory function. The origin of biopotentials including membrane and action potentials. Measurement of the electrocardiogram, the electroencephalogram, and the electromyogram. Basic electrode, biochemical sensor and laser applications including cardiac pacemakers and defibrillators. The basic concepts underlying computed transmission and emission tomography, magnetic resonance and ultrasound imaging. The imaging methods should be understood in terms of how imaging information is generated, detected and processed and how different hardware configurations and other factors affect image quality.

04-Bio-A9 Bioreactor Design

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.

GROUP B

ELECTIVE EXAMINATIONS (THREE REQUIRED)

04-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.

04-Bio-B2 Prostheses and Orthoses

Introduction, historic, terminology and classification of prostheses and orthoses. Partial or total replacement of limb or joint. Introduction to biomechanics related to design of prostheses and orthoses: clinical and mechanical aspects, biomaterials, biocompatibility. General design objectives and criteria. Design and assessment standards.

04-Bio-B3 Biotransport Phenomena

Momentum, heat and mass transfer. Mass, linear momentum and energy balances. Differential analysis of laminar viscous flow. Differential analysis of heat conduction. Differential analysis of diffusion and convective transport. Biological examples of transport phenomena including: pharmacology and pharmacokinetics; absorption distribution, biotransformation, elimination, calculation of dosages; variability in drug response and adverse drug responses; drug delivery; microenvironment, transport and binding of small and large molecules; movement of cancer and immune cells; metastatic process, radiotherapy, chemotherapy, immunotherapy, hyperthermia, and photodynamic therapy of solid tumors. Numerical methods for computer simulation.

04-Bio-B4 Digital Image Processing

The extension of one dimensional sampling theory to two dimensions. Knowledge of the concepts of sampling geometry and sampling density. Two dimensional image transforms particularly the Fourier and Wavelet transforms. Important pixel operations for image enhancement particularly gray-scale modification and algebraic and geometric transforms. Convolution in two dimensions with particular application to image interpolation (upsampling). The spatial domain and frequency domain application of finite-extent point-spread filters for noise reduction, edge detection and image sharpening. Knowledge of the design and application of some common filters such as the Laplacian, the gradient and the Gaussian filters. Some knowledge of the concepts of image restoration from known degradations such as blur due to camera motion using some of the most common methods such as inverse and Wiener filtering and constrained deconvolution. The reconstruction of images from parallel and fan-beam projections as used in computed transmission tomography (CT).

04-Bio-B5 Cell and Tissue Engineering

Integration of relevant aspects of physiology, pathology, developmental biology, disease treatment and biomaterials to regenerative medicine in complex organ systems. Host response to tissue engineered constructs including complement, coagulation, immunological responses. Engineered replacements of kidney, lung, vascular, skin. Chemical, electrical, mechanical, materials, pathological and surgical

aspects of construct development. Integrative exploration of the use of three-dimensional polymeric scaffolds and drug delivery vehicles, and gene therapy and cellular engineering for functional repair of injured tissues. Cell selection.

04-Bio-B6 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.

04-Bio-B7 Robotics and Manufacturing Automation

An overview of robotics and manufacturing technology and principles. Topics include: Automatic production and assembly, PLCs, sensors, actuators and drives, mechanization of part handling, industrial robots, and machine vision systems. Emphasis will be on the planning, design and implementation of automation systems.

04-Bio-B8 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.

04-Bio-B9 Artificial Intelligence and Expert Systems

AI-based decision making in biology and medicine using predicate calculus, structures and strategies for state space search, heuristic search and stochastic methods. Knowledge representation, reasoning and decision-making under uncertainty as well as case-based reasoning, decision trees. Rule-based and expert systems, inference mechanisms and knowledge engineering. Machine learning including supervised learning, self-organization, reinforcement learning and evolutionary computing. Intelligent biomedical information systems, intelligent devices and instruments such as interactive implants and replacements and measurement systems. Automated reasoning and data mining. Advanced methods for problem solving including natural language processing, planning and perception.

04-Bio-B10 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.

04-Bio-B11 Ergonomics (98-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. Repetitive Strain Injuries, also known as Cumulative Trauma Disorders.

04-Bio-B12 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 photodiagnosis, tissue oximetry, optical spectroscopy and microscopy, fluorescence marking.

04-Bio-A1 Biomaterials and Biocompatibility

Ratner, Buddy DS., Allan S. Hoffman, Frederick J. Schoen and Jack E. Lemons editors, Biomaterials Science, An Introduction to Materials in Medicine. Academic Press, NY, 1996.

04-Bio-A2 Process Dynamics and Control

Coughanowr and Koppel, Process Systems Analysis and Control. 2nd Edition, McGraw Hill, 1991.

Luyben, W.L. Process Modelling, Simulation and Control for Chemical Engineers. 2nd Edition, McGraw Hill, N.Y. 1991.

04-Bio-A3 Cellular and Molecular Biology and Biochemistry

Madigan, T., J. Martinko, and J. Parker, Brock Biology Of Microorganisms. Prentice-Hall, NJ. 2003.

04-Bio-A4 Biomechanics

Berger, S.A., W. Goldsmith and E.R. Lewis, Introduction to Bioengineering. Oxford University Press, 2000.

Nordin, Margareta and Victor H. Frankel, Basic Biomechanics of the Musculoskeletal System. Lippincott Williams&Wilkins, 3rd edition, 2001.

04-Bio-A5 Enzyme and Microbial Kinetics

Blanch, H.W., D.S. Clark and Marcel Dekker, Biochemical Engineering. 1996.

Bailey, J.E. and E.F. Ollis, Biochemical Engineering Fundamentals. 2nd edition, McGraw Hill, 1986.

04-Bio-A6 Anatomy and Physiology

Guyton, Arthur C. and John E. Hall, Human Physiology and Mechanisms of Disease. 6th Ed., W.B. Saunders, Philadelphia, Pa., 1997.

Moffett, David F., Stacie B. Moffett, and Charles L. Schauf; Human Physiology, 2nd Ed.; Mosby, 1993.

04-Bio-A7 Fluid Mechanics

Middleman, S. An Introduction to Fluid Dynamics. Wiley, 1998.

04-Bio-A8 Biophysical Measurements

Webster, J.G. (Editor), Medical Instrumentation: Application and Design. 3rd Ed., Wiley, 1997.

04-Bio-A9 Bioreactor Design

Blanch, H.W., D.S. Clark and Marcel Dekker, Biochemical Engineering. 1996.

Bailey, J.E. and E.F. Ollis, Biochemical Engineering Fundamentals. 2nd edition, McGraw Hill, 1986.

Aiba, S., A.E. Humphrey and N.F. Mills, Biochemical Engineering. 2nd edition, Academic Press, 1973.

Shuler, M.L. and F. Kargi, Biochemical Engineering Basic Concepts. Prentice Hall, 1992.

04-Bio-B1 Biochemical Separations

Blanch, H.W., D.S. Clark and Marcel Dekker, Biochemical Engineering. 1996.

Shuler, M.L. and F. Kargi, Biochemical Engineering Basic Concepts. Prentice Hall, 1992.

04-Bio-B2 Prostheses and Orthoses

04-Bio-B3 Biotransport Phenomena

Welty, James, Charles E. Wicks, Robert E. Wilson, and Gregory L. Rorrer, Fundamentals of momentum, Heat, and Mass Transfer. 4th Ed., Wiley, 2000.

Middleman, Stanley, An Introduction to Mass and Heat Transfer: Principles of Analysis and Design. Wiley, 1997.

04-Bio-B4 Digital Image Processing

Gonzalez, R. and R. Woods, Digital Image Processing. 2nd Ed., Prentice Hall, 2002.

Suetens, P., Fundamentals of Medical Imaging. Cambridge University Press, 2002.

04-Bio-B5 Cell and Tissue Engineering

Lanza, R.P., R. Langer and W.L. Chick (eds), Principles of Tissue Engineering. 2nd edition, Academic Press, 2000.

04-Bio-B6 Bioinstrumentation

Webster, J.G. (Editor), Bioinstrumentation. Wiley, 2004

Webster, J.G. (Editor), Medical Instrumentation: Application and Design. 3rd Ed., Wiley, 1997.

04-Bio-B7 Robotics and Manufacturing Automation

04-Bio-B8 Rehabilitation Engineering

Smith, Raymond V. & John H. Leslie, Rehabilitation Engineering. CRC Press, 1990.

Mann, William C. and Joseph P. Pane, Assistive Technology for Persons with Disabilities. The American Occupation Therapy Association Inc., 1991.

Webster, John G. et al, Electronic Devices for Rehabilitation. John Wiley & Sons, 1985.

04-Bio-B9 Artificial Intelligence and Expert Systems

Russell, S. and P. Norvig, Artificial Intelligence: A Modern Approach. 2nd Edition. Prentice Hall, 2003. ISBN: 0137903952

Luger, G., Artificial Intelligence: Structures and Strategies for Complex Problem Solving. 5th Ed., Addison Wesley, 2005.

04-Bio-B10 Analytical Biochemistry

Mikkelsen, Susan R. and Eduardo Corton, Bioanalytical chemistry. Wiley Interscience, 2004. ISBN: 0-471-54447-7

Holme, D.J. and H. Peck, Analytical Biochemistry. 3rd ed., Longman, 1998.

04-Bio-B11 Ergonomics (98-Ind-B5 Ergonomics)

Bridger, R.S., Introduction to Ergonomics. McGraw-Hill, 1995. ISBN 0-07-007741-X.

Kodak Ergonomics Group, Ergonomic Design for People at Work, Volumes I and II. Van Nostrand Reinhold Co. Ltd., 1986.

04-Bio-B12 Applied Optics/Photonics

Prasad, N., Introduction to Biophotonics. Wiley, 2004.