Visvesvaraya Technological University, Belagavi.
PhD Coursework Courses – 2018 (EI/MB/ML)
As per 2017 Regulation

Group-1	Group-2	Group-3	Group-4	Group-5	Group-6
16LBI11 Real Time Signal Processing	16LBI14 Advanced Biomedical Signal Processing	16LBI21 Neural Network and Fuzzy Logic in Medicine	16LBI153 Biomaterials and Artificial Organs	16LBI13 Medical Instrumentation	16LBI152 ARM Embedded System Design
16LBI24 Advanced Medical Image Processing	16LBI154 Data Warehousing and Data Mining	16LBI22 Speech Signal Processing	16LBI423 Wavelets in Biomedical Engineering	16LBI253 Virtual Bioinstrumentation	16LBI23 Medical Imaging Techniques and Systems
16LBI422 Biomechanics and Rehabilitation Engineering	16LBI255 Clinical Medicine for Biomedical Engineers	16LBI425 Modelling and Simulation in Biomedical Engineering	16LBI424 Artificial Intelligence and Pattern Recognition	16LBI41 Bio-MEMS and Nanotechnology	16LBI421 Biostatistics

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PhD Coursework Courses – 2018 (EI/MB/ML)

As per 2017 Regulation

01	16LBI11	Group-1	Real Time Signal Processing
Exam Hours:03		**Exam Marks:100**	

Module -1 Introduction to Discrete Fourier Transform (DFT) and its relationship with other transforms. DFT properties. Introduction to PSoC 3/5, PSoC 3/5 Architecture – Block Diagram, System Wide Resources, I/O Interfaces, CPU Subsystem, Memory Organization, Digital Subsystems, Analog Subsystems

Module -2. Direct computation of DFT, Need for efficient computation of DFT (FFT Algorithms). Radix-2 FFT algorithm for the computation of DFT and IDFT – decimation in time and decimation in frequency algorithms.
Real Time Transforms: Discrete Cosine Transform, Walsh Transform, Hadamard Transform.

Module -3 IIR Filter Design: Design of IIR filters from analog filters (Butterworth and Chebyshev). Impulse invariance method and bilinear transformation methods. Verification for stability and linearity during mapping.

Module -4 Implementation of discrete time systems: Structures for IIR and FIR systems -Direct form I, Form-II, Cascade and parallel realizations.
Multirate Signal Processing: Concepts of multirate signal processing, Sampling rate converter, decimators and interpolators.

Module -5 Introduction to FIR filters, Design of FIR filters using Hamming, Rectangular, Barlet window method, FIR filter design using frequency mapping method.
Adaptive Digital Filters: Concepts of Adaptive filtering, LMS adaptive algorithm, Recursive least square algorithm.

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

REFERENCE BOOKS:

1. "Digital Signal Processing", John G Proakis and Dimitrius G Manolakis, 3rdEdn, PHI, ISBN: 81-203-1129-9
2. "Digital Signal Processing", Emmanuel C Ifeachor and Barrie W Jervis, 2nd Edition, Pearson Education 2004.ISBN:81-7808-609-3
3. "Real Time Digital Signal Processing,Fundamentals,Algorithms and implementation using TMS processors", V.Udhayashankara, PHI Publishing,2010.ISBN: 978-81-203-4049-7
4. "ARM System On Chip Architecture",2nd edition, Pearson Publication, ISBN: 978-81-317-0840-8
5. "Digital Signal Processors", B Venkataramani and M Bhaskar, TMH, New Delhi 2002

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PhD Coursework Courses – 2018 (EI/MB/ML)

As per 2017 Regulation

02	16LBI24	Group-1	Advanced Medical Image Processing
Exam Hours:03		**Exam Marks:100**	

Module -1 Fundamentals: Introduction, Fundamental steps in DIP, A simple image formation model, representing digital images, Spatial & Gray level resolution, Basic relationship between pixels.
Image Enhancement: Point operations, Spatial averaging, Median filtering, Spatial low pass, high pass and band pass filtering, Histogram equalization, Transform operations.

Module -2. **Image Compression:** Huffman coding, DFT, DCT, Wavelet coding & JPEG standard.

Module -3Image segmentation: Detection of discontinuities, Edge linking and Boundary detection by local processing & global processing using Hough transform, Region based segmentation.

Module -4 Image Representation and Description: Representation – Chain codes, polygonal approximations, signatures, boundary segments, skeletons, Boundary descriptors – Some simple descriptors, Shape numbers, Fourier descriptors, statistical moments, Regional descriptors – Some simple descriptors, topological descriptors, texture.

Module -5 Morphological Image Processing : Basic concepts of set theory, Logical operations involving binary images, Dilation and erosion, Opening and closing, The hit-or-miss transformation, Basic morphological algorithms.

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

REFERENCE BOOKS:

1. "Digital Image Processing" Rafael C. Gonzalez & Richard E. Woods, SecondEdition. Pearson Education Inc.
2. "Fundamentals of Digital Image Processing" Anil K. Jain. Prentice Hall of India.
3. "Image Processing, Analysis and Machine Vision" Milan Sonka, Vaclav Hlavac& Roger Boyle, 2nd Edition.
4. "Digital Image Processing" Rafael C. Gonzalez & Richard E. Woods, First Edition. Pearson Education Inc.
5. "Practical Algorithms for Image Analysis" Description, Examples & Codes by Michael Seul, Lawrence O'Gorman, Michel J.Sammon, Cambridge University Press.
6. "Biomedical Imaging visualization and analysis" Richard A Robb, John Wiley& sons, Inc. publication.

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PhD Coursework Courses – 2018 (EI/MB/ML)

As per 2017 Regulation

03	16LBI422	Group-1	Biomechanics and Rehabilitation Engineering
Exam Hours:03		**Exam Marks:100**	

Module -1 Biomechanics Applications to Joint Structure and Function : Introduction to Kinematics; Displacement in space; Force vectors and gravity; Linear forces and concurrent forces; Kinetics of rotary and translatory forces; Classes of levers; Close chain force analysis.

Module -2. **Joint Structure and Function:** Properties of connective tissues; Human Joint design; Joint Function and changes in disease.

Integrated Functions : Kinetics and Kinematics of Poistures; Static and Dynamic Poistures; Analysis of Standing, Sitting and Lying Poistures.

Module -3Gait: Gait cycle and joint motion; Ground reaction forces; Trunk and upper extremity motion; internal and external forces, moments and conventions; Gait measurements and analysis.

Force Platform and Kinematic Analysis: Design of force platforms, Integrating force and Kinematic data; linked segment, free-body analysis.

Module -4 Orthotic Devices in Rehabilitation Engineering:

General orthotics, Classification of orthotics-functional & regional, General principles of Orthosis, Biomechanics of orthoses, merits & demerits of orthotics, Material design consideration in orthotics, Calipers-FO, AFO, KAFO, HKAFO. Spinal Orthosis, Cervical, Head cervical thoracic orthosis, Thoraco lumbar sacral orthosis, Lumbosacroorthosis, Splints-its functions & types.

Module -5 Prosthetic Devices: Introduction, Partial Foot Prostheses- Foot-ankle assembly, Trans femoral Prostheses – Knee unit, Axis system, Friction Mechanisms, Extension aid, Stabilizers, Socket. Disarticulation Prostheses, Knee Disarticulation Prostheses, Hip Disarticulation Prostheses

Mobility Aids: Walking frames, Parallel bars, Rollators, Quadripods, Tripods & walking sticks, Crutches, Wheel chairs

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

REFERENCE BOOKS:

1. "Joint Structure and Function, A Comprehensive Analysis", Pamela K. Levangie and Cynthia C. Norkin, JAYPEE Publications, Fourth Edition, 2006.
2. "Biomechanics; Mechanical Properties of Living Tissues",Y. C. Fung SpringerVerlag, 1985.
3. "Biomechanics, Structures and Systems", A. A. Biewener, Sports Publication
4. "Biomechanics of Human Motion", T. McClurg, Anderson.
5. "Rehabilitation Medicine" - By Dr. S. Sunder, 2nd Edition, Jaypee Medical Publications, Reprint 2004.
6. "Physical Rehabilitation" - by Susan B O'Sullivan, Thomas J Schmitz. 5th Edition, Jaypee Pub.,2007.

Visvesvaraya Technological University, Belagavi.

PhD Coursework Courses – 2018 (EI/MB/ML)

As per 2017 Regulation

01	16LBI14	Group-2	Advanced Biomedical Signal Processing
Exam Hours:03		**Exam Marks:100**	

Module -1 Introduction: General measurement and diagnostic system, classification of signals, introduction to biomedical signals, Biomedical signal acquisition and processing, Difficulties in signal acquisition.

ECG: ECG signal origin, ECG parameters-QRS detection different techniques, ST segment analysis, Arrhythmia, Arrhythmia analysis, Arrhythmia monitoring system.

Module -2. **ECG Data Reduction:** Direct data compression Techniques: Turning Point, AZTEC, Cortes, FAN, Transformation Compression Techniques: Karhunen - Loeve Transform, Other data compression Techniques: DPCM, Huffman coding, Data compression Techniques comparison.

Signal averaging: Basics of signal averaging, Signal averaging as a digital filter, A typical averager, Software and limitations of signal averaging.

Module -3Frequency Domain Analysis: Introduction, Spectral analysis, linear filtering, cepstral analysis and homomorphic filtering. Removal of high frequency noise (power line interference), motion artifacts (low frequency) and power line interference in ECG,

Time Series Analysis: Introduction, AR models, Estimation of AR parameters by method of least squares and Durbin's algorithm, ARMA models. Spectral modeling and analysis of PCG signals.

Module -4 Spectral Estimation: Introduction, Blackman- tukey method, The periodogram, Pisarenko's Harmonic decomposition, Prony' method, Evaluation of prosthetic heart valves using PSD techniques. Comparison of the PSD estimation methods.

Event Detection and waveform analysis: Need for event detection, Detection of events & waves, Correlation analysis of EEG signals, The matched filter, Detection of the P wave , Identification of heart sounds, Morphological analysis of ECG waves, analysis of activity.

Module -5 Adaptive Filtering: Introduction, General structure of adaptive filters, LMS adaptive filter, adaptive noise cancellation, Cancellation of 60 Hz interference in ECG, cancellation of ECG from EMG signal, Cancellation of maternal ECG in fetal ECG.

EEG: EEG signal characteristics, Sleep EEG classification and epilepsy.

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

REFERENCE BOOKS:

1. Biomedical Signal Processing Time and Frequency Domains Analysis (Volume I)", Arnon Cohen, CRC press.
2. "Biomedical Signal Analysis" A case study approach, Rangaraj M Rangayyan, John Wiley publications.
3. "Biomedical Signal Processing Principles and Techniques" D.C.Reddy, Tata McGraw-Hill
4. "Biomedical Digital Signal Processing", Willis J. Tompkins, PHI.

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PhD Coursework Courses – 2018 (EI/MB/ML)

As per 2017 Regulation

02	16LBI154	Group-2	Data Warehousing and Data Mining
Exam Hours:03		**Exam Marks:100**	

Module -1 Data Warehousing and Business Analysis: - Data warehousing Components –Building a Data warehouse – Mapping the Data Warehouse to a Multiprocessor Architecture – DBMS Schemas for Decision Support – Data Extraction, Cleanup, and Transformation Tools –Metadata – reporting – Query tools and Applications – Online Analytical Processing (OLAP) – OLAP and Multidimensional Data Analysis.

Module -2. Data Mining: - Data Mining Functionalities – Data Preprocessing – Data Cleaning – Data Integration and Transformation – Data Reduction – Data Discretization and Concept Hierarchy Generation. Association Rule Mining: - Efficient and Scalable Frequent Item set Mining Methods – Mining Various Kinds of Association Rules – Association Mining to Correlation Analysis – Constraint-Based Association Mining.

Module -3 Classification and Prediction: - Issues Regarding Classification and Prediction – Classification by Decision Tree Introduction – Bayesian Classification – Rule Based Classification – Classification by Back propagation – Support Vector Machines – Associative Classification – Lazy Learners – Other Classification Methods – Prediction – Accuracy and Error Measures – Evaluating the Accuracy of a Classifier or Predictor – Ensemble Methods – Model Section.

Module -4 Cluster Analysis: - Types of Data in Cluster Analysis – A Categorization of Major Clustering Methods – Partitioning Methods – Hierarchical methods – Density-Based Methods – Grid-Based Methods – Model-Based Clustering Methods – Clustering High Dimensional Data – Constraint-Based Cluster Analysis – Outlier Analysis.

Module -5 Mining Object, Spatial, Multimedia, Text and Web Data: Multidimensional Analysis and Descriptive Mining of Complex Data Objects – Spatial Data Mining – Multimedia Data Mining – Text Mining – Mining the World Wide Web.

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

REFERENCE BOOKS

1. Jiawei Han and MichelineKamber “Data Mining Concepts and Techniques” Second Edition, Elsevier, Reprinted 2008.
2. Alex Berson and Stephen J. Smith “Data Warehousing, Data Mining &OLAP”, Tata McGraw – Hill Edition, Tenth Reprint 2007.
3. K.P. Soman, ShyamDiwakar and V. Ajay “Insight into Data mining Theory and Practice”, Easter Economy Edition, Prentice Hall of India, 2006.
4. G. K. Gupta “Introduction to Data Mining with Case Studies”, Easter Economy Edition, Prentice Hall of India, 2006.
5. Pang-Ning Tan, Michael Steinbach and Vipin Kumar “Introduction to Data Mining”, Pearson Education, 2007.

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PhD Coursework Courses – 2018 (EI/MB/ML)

As per 2017 Regulation

03	16LBI255	Group-2	Clinical Medicine for Biomedical Engineers

Exam Hours:03 **Exam Marks:100**

Module -1 Introduction to Medicine: History taking, palpation, Percussion, Auscultation, General Physical Examination of the patient.

Respiratory System: Basic investigations in Respiratory diseases which includes x-ray, CT-Scan Pulmonary function tests, Nuclear Medicine imaging, Ultrasound, Serological tests, bronchoscopy, Cough and Sputum, Inflammation of Bronchus, Bronchial-Asthma, COPD, Pulmonary Tuberculosis**.**

Module -2. **Renal and urological Disorders**; Investigations in Renal and urology Disease such as renal imaging techniques, uroflowmetry, Haematuria, Acute and chronic Renal failure, Glomerular Diseases, UTI, Renal Calculi.

Cardiovascular System : Investigation in Cardiovascular Disease which includes ECG, Non-invasive methods of cardiac examination ECHO,X-ray, Radionuclide imaging of the heart, New cardiac imaging techniques CT-Angiogram, MRI, PET Scans, Diagnostic cardiac catheterization and Angiography, cardiac arrhythmias and Murmurs, IHD, Hypertension, Cardiac arrest Myocardial infarction**.**

Module -3GIS: Basic investigation in GIS such as endoscopy, Blood tests, colonoscopy, Laproscopy, Imaging techniques, Ulcers in Stomach, Liver function test, Hepatitis Cirrhosis of Liver, Gall stones, Chronic Diahorrhea

Nervous System; Investigation in Neurology CT scan, MRI, EEG , Disorders of Speech, Cranial Nerves, Headaches, Epilepsy, Cerebrovascular Diseases, Myasthenia gravis.

Module -4 Hematological Disorders; Lab Diagnosis in Haematology, Anaemia, Leukaemia, Lymphoma, blood Transfusion, The spleen.

Endocrine glands; Pituatary gland, Thyroid gland, Adrenals, Pancreas this includes types of Diabetes, management of Diabetes.

Sense organs; **Eye**; Investigations in Diagnosis of blindness, causes of blindness cataract, glaucoma.

E.N.T; Causes of Deafness, Tests for diagnosis of Deafness.

Module -5 Infectious Diseases; Diphtheria, Meningitis and analysis of CSF influenza, Chickenpox,Mumps, PUO

Communicable Diseases; Malaria, Typhoid fever, Leprosy, Dengue, Rabies, worm-Infestations, HIV

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

REFERENCE BOOKS:

1. Medicine for students A handbook of Medicine by Golwalla 24th Edition.
2. Davidson's Principles and Practice of Medicine, 22nd Edition
3. Harrisons Principles of internal Medicine 19th edition

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PhD Coursework Courses – 2018 (EI/MB/ML)

As per 2017 Regulation

01	16LBI21	Group-3	Neural Network and Fuzzy Logic in Medicine
Exam Hours:03		**Exam Marks:100**	

Module -1 Learning and Soft Computing: Examples, basic tools of soft computing, basic mathematics of soft computing, Differences between neural network and Biological neural network, Network Architecture, Artificial Intelligent

Learning process : Error correction Algorithm, Memory based Learning, Hebian Learning, Learning with Teacher, Learning without Teacher

Module -2. **Single Layer Networks:** Perception, Perceptron Convergence theorem, Realization of Basic logic gates using single layer Perceptron, Adaptive linear neuron (Adaline) and the LMS algorithm.

Module -3Multilayer Perception: Error back propagation algorithm, generalized delta rule, XOR Problem, Practical Aspects of Error Back Propagation Algorithm. Problems

Radial Basis Function Networks: Ill Posed Problems And Regularization Technique, Stabilizers and Basis Functions, Generalized Radial Basis Function Networks.

Module -4 Support Vector Machines : Risk minimization principles and the Concept of Uniform Convergence, VC dimension, Structural Risk Minimization, support vector machine algorithms

Fuzzy Logic: Introduction to Fuzzy Logic, Classical and Fuzzy Sets: Overview of Classical Sets, Membership Function, Operations on Fuzzy Sets, Fuzzy Arithmetic, Compliment, Intersections, Unions, Fuzzy Relation.

Module -5 Fuzzy Rule based system Linguistic Hedges. Rule based system, Graphical techniques for Inference, Fuzzification and Defuzifications, fuzzy additive models Applications.

Case studies: Fuzzy logic control of Blood pressure during Anesthesia, Fuzzy logic application to Image processing equipment, Adaptive fuzzy system. Introduction to Neuro-fuzzy logic tool usingLabView

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

REFERENCE BOOKS:

1. S.Haykin, "Neural networks: A Comprehensive Foundation"' Pearson Education (Asia) Pvt. Ltd/Prentice Hall of India, 2003.
2. Vojislav Kecman, "Learning and soft computing", Pearson Education (Asia) Pvt. Ltd.2004.
3. Timothy J Ross ,Fuzzy logic with Engineering Applications, McGraw Hill Publication, 2000.
4. M.T.Hagan, H.B.Demuth and M. Beale, "Neural Network Design", Thomson Learning, 2002.
5. Bart Kosko, "Neural Networks and Fuzzy Systems" Prentice Hall of India, 2005
6. George J. Klir and Bo Yaun, "Fuzzy sets and Fuzzy Logic:Theory and Application", Prentice Hall of India, 2001

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PhD Coursework Courses – 2018 (EI/MB/ML)

As per 2017 Regulation

02	16LBI22	Group-3	Speech Signal Processing
Exam Hours:03		**Exam Marks:100**	

Module -1 Digital Models for Speech Signals: Process of Speech Production, **The Acoustic Theory of speech production**, Digital models for Speech signals.

Time Domain Models for Speech Processing: Time dependent processing of speech, Short time Energy and average magnitude, Short time average zero crossing rate, Speech vs. silence discrimination using energy and zero crossing.

Module -2. **Time Domain Models for Speech Processing:** Pitch period estimation using parallel processing approach, Short time autocorrelation function, Short time average magnitude difference function, Pitch period estimation using autocorrelation function.

Short Time Fourier Analysis: Introduction, Definitions and properties, Fourier transform interpretation, Linear filtering interpretation.

Module -3Digital Representations of the Speech Waveform: Sampling speech signals, Review of the statistical model for speech, Instantaneous quantization, Adaptive quantization, General theory of differential quantization, Delta modulation, Differential PCM, Comparison of systems.

Module -4 Linear Predictive Coding of Speech: Basic principles of linear predictive analysis, Solution of LPC equations, Prediction error signal, Frequency domain interpretation, Relation between the various speech parameters, Applications of LPC parameters.

Module -5 Speech Synthesis: Principles of Speech synthesis, Synthesis based on waveform coding, Synthesis based on analysis synthesis method, Synthesis based on speech production mechanism, Synthesis by rule, Text to speech conversion.

Speech Recognition: Principles of Speech recognition, Speech period detection, Spectral distance measures, Structure of word recognition systems, Dynamic time warping (DTW), Word recognition using phoneme units.

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

REFERENCE BOOKS:

1. Digital Processing of Speech Signals", L R Rabiner and R W Schafer, Pearson Education 2004.
2. "Digital Speech Processing, Synthesis and Recognition", SadoakiFurui, Second Edition, Mercel Dekker 2002.
3. "Designing with speech processing chips", Ricardo Jimenez, Academic press, INC 1991.
4. "Introduction to Data Compression", Khalid Sayood, Third Edition, Elsevier Publications.
5. "Digital Speech", A M Kondoz, Second Edition, Wiley Publications

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PhD Coursework Courses – 2018 (EI/MB/ML)

As per 2017 Regulation

03	16LBI425	Group-3	Modelling and Simulation in Biomedical Engineering

Exam Hours:03 | **Exam Marks:100**

Module -1 Modeling continuous – time signals as sums of sine waves

Introduction, analysis of circadian rhythm, orthogonal functions, sinusoidal basis functions, the Fourier series, the frequency response and non-sinusoidal periodic inputs, Parseval's relation for periodic signals, CTFT, relationship of Fourier transform to frequency response, properties of the Fourier transform, the generalized Fourier transform, examples Fourier transform calculations, Parseval's relation for nonperiodic signals, filtering, output response via the Fourier transform.

Module -2. Modeling signals as sums of discrete-time sine waves

Introduction, introductory example, the discrete-time Fourier series, Fourier transform of discrete-time signals, Parseval's relation for DT nonperiodic signals, output of an LSI system, relation of DFS and DTFT, windowing, sampling, DFT, biomedical applications.

Module -3 Modeling stochastic signals as filtered white noise

Introduction, EEG analysis, random processes, mean and auto correlation function of random process, stationarity and ergodicity, general linear processes, Yule-Walker equations, Autoregressive(AR) processes, Moving Average (MA) processes, Autoregressive - Moving Average (ARMA) processes, harmonic processes, biomedical examples.

Module -4 Non linear models of signals

Introduction, non linear signals and systems, Poincare sections and return maps, chaos, measures of non linear signals and systems, characteristic multipliers and Lyapunov exponents, estimating the dimension of real data, tests of null hypotheses based on surrogate data, biomedical applications.

Module -5 Modeling biomedical systems

Problem statement, illustration of the problem, point processes, parametric system modeling, autoregressive or all-pole modeling, pole-zero modeling, electromechanical models of signal generation, applications.

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

REFERENCE BOOKS:

1. Eugene N Bruce, "Biomedical Signal Processing and Signal Modeling" John Wiley & Sons, Inc, reprint 2009 (Chapters I-IV)
2. Rangaraj M. Rangayyan, "Biomedical Signal Analysis", John Wiley & Sons, Inc, reprint 2000, (Chapter- V)

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PhD Coursework Courses – 2018 (EI/MB/ML)

As per 2017 Regulation

01	16LBI153	Group-4	Biomaterials and Artificial Organs
Exam Hours:03		**Exam Marks:100**	

Module -1 STRUCTURE OF BIO-MATERIALS AND BIO-COMPATIBILITY

Definition and classification of bio-materials, mechanical properties, visco-elasticity, wound-healing process, body response to implants, blood compatibility.

Module -2. IMPLANT MATERIALS

Metallic implant materials, stainless steels, co-based alloys, Ti-based alloys, ceramic implant materials, aluminum oxides, hydroxyapatite glass ceramics carbons, medical applications.

Module -3POLYMERIC IMPLANT MATERIALS

Polymerization, polyamides, Acryrilic polymers, rubbers, high strength thermoplastics, medical applications. Bio polymers: Collagen and Elastin.

Module -4 TISSUE REPLACEMENT IMPLANTS

Soft-tissue replacements, sutures, surgical tapes, adhesive, Percutaneous and skin implants, maxillofacial augmentation, blood interfacing implants, hard tissue replacement implants, internal fracture fixation devices, joint replacements.

Module -5 ARTIFICIAL ORGANS

Artificial Heart, Prosthetic Cardiac Valves, Artificial lung (oxygenator), Artificial Kidney (Dialyser membrane) , Dental Implants – Artificial limb & hand.

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

REFERENCE BOOKS:

1. Sujata V. Bhatt, Biomaterials Second Edition, Narosa Publishing House,2005.
2. JoonB.Park Joseph D. Bronzino, Biomaterials - Principles and Applications – CRCPress, 2003
3. Park J.B., “Biomaterials Science and Engineering”, Plenum Press, 1984.
4. Myer Kutz, “Standard Handbook of Biomedical Engineering & Design”, McGraw-Hill, 2003
5. John Enderle, Joseph D. Bronzino, Susan M. Blanchard, “Introduction to Biomedical Engineering”, Elsevier, 2005.

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PhD Coursework Courses – 2018 (EI/MB/ML)

As per 2017 Regulation

02	16LBI423	Group-4	Wavelets in Biomedical Engineering
Exam Hours:03		**Exam Marks:100**	

Module -1 Wavelet Transforms: **Overview of WT, fundamentals-FT, STFT, resolution, Multi resolution analysis-CWT,DWT**

Module -2. **Wavelets in Medical Imaging and Tomography**

Applications of wavelet shrinkage to tomography
Wavelet denoising of functional MRI data
Statistical analysis of image differences by wavelet decomposition
Feature extraction in digital mammography
Adapted wavelet techniques for encoding MRI diagnosis of coronary artery disease using wavelet based neural networks.

Module -3

Module -4

Module -5

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

REFERENCE BOOKS:

1. "Tutorial on Wavelets", part I-IV, RobiPolikar (WWW.Rohen University.edu)
2. "Wavelets in medicine and biology" AkramAldroubi and Michael Unser. CRC press.

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PhD Coursework Courses – 2018 (EI/MB/ML)

As per 2017 Regulation

03	16LBI424	Group-4	Artificial Intelligence and Pattern Recognition
Exam Hours:03		**Exam Marks:100**	

Module -1 Introduction: Machine perception, an example; Pattern Recognition System; The Design Cycle, Learning and Adaptation.

Probability: Introduction to probability, conditional probability, Random Variables, The Binomial and Poisson distribution, Joint Distribution and Density, Moments of Random Variables, Estimation of Parameters from Samples.

Module -2. **Bayesian Decision Theory:** Minimum Error Rate Classification, Classifiers, Discriminant functions, and decision surfaces; the normal density; Discriminant functions for the normal density.

Module -3Maximum-likelihood and Bayesian Parameter Estimation: Introduction, Maximum-likelihood estimation; Bayesian Estimation; Bayesian parameter estimation: Gaussian Case, general theory; Hidden Markov Models.

Module -4 Processing of waveforms and Images: Introduction, Gray Level Scaling Transformations, Equalization, Geometric Image Scaling and Interpolation, Smoothing Transformations, Edge Detections, Line Detection And Template Matching.

Module -5 Clustering: Introduction, Hierarchical clustering, Partitional clustering.

Introduction to Biometric Recognition: Biometric Methodologies: Finger Prints; Hand Geometry; Facial Recognition; Iris Scanning; Retina Scanning.

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

REFERENCE BOOKS:

1. Richard O. Duda, Peter E. Hart, and David G.Stork: Pattern Classification, 2nd Edition, Wiley-Interscience, 2001.
2. Earl Gose, Richard Johnsonbaugh, Steve Jost: Pattern Recognition and Image Analysis, Pearson Education, 2007.
3. K. Jain, R. Bolle, S. Pankanti: Biometrics: Personal Identification in Networked Society, Kluwer Academic, 1999.

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PhD Coursework Courses – 2018 (EI/MB/ML)

As per 2017 Regulation

01	16LBI13	Group-5	Medical Instrumentation
Exam Hours:03		**Exam Marks:100**	

Module -1 Bioelectric Signals and Electrodes : Sources of biomedical signals, basic medical instrumentation system, PC based medical instruments, General constraints in design of medical instrumentation systems, origin of bioelectric signals, Electrocardiogram (ECG), Electroencephalogram (EEG), Electromyogram (EMG), Electrooculogram (EOG), Electroretinogram (ERG), Recording Electrodes – Electrode-tissue interface, polarization, skin contact impedance, motion artifacts, Silver-Silver Chloride electrodes, Electrodes for ECG, Electrodes for EEG, Electrodes of EMG, Electrical conductivity of electrode jellies and creams, microelectrodes.

Module -2. **Biomedical Recording Systems & Recorders :** Electrocardiograph-block diagram, ECG leads, effects of artifacts, multi-channel, ECG machine, Phonocardiograph-origin of heart sounds, microphones and amplifiers for PCG, Electroencephalograph- block diagram, computerized analysis of EEG, Electromyograph, biofeedback instrumentation.

Module -3Patient Monitoring Systems &Oximeters: Bedside monitors, Central Monitors, Measurement of Heart Rate, Average Heart Rate meter, Instantaneous heart rate meter, Measurement of pulse rate, Blood Pressure measurement ,Direct and indirect method, Automatic blood pressure measuring apparatus using Korotkoff's method. Oximetry, ear oximeter, pulse oximeter, skin reflectance oximeter and intravascular oximeter.

Module -4 Blood Flow Meters, Cardiac Pacemakers and Defibrillators:
Electromagnetic blood flow meter, Types of electromagnetic blood flow meters, Ultrasonic blood flow meters, NMR blood flow meters, Laser Doppler blood flow meters. Need for Cardiac pacemaker, External Pacemaker, Implantable Pacemaker, Types of Implantable Pacemaker, Ventricular Synchronous Demand Pacemaker and Programmable Pacemaker. Need for a defibrillator, DC defibrillator. Defibrillator electrodes, DC defibrillator with synchronizer.

Module -5 Respiratory & Advanced Diagnostic & Therapeutic Instruments: Pulmonary function measurement, basic spirometer, ultrasonic spirometer, Pneumotachometer, Measurement of volume by Nitrogen washout technique. Artificial kidney-Principle and haemodialysis machine. Lithotriptors- principle, modern lithotriptor-block diagram and working. Anesthesia-Need for anesthesia, delivery of anesthesia, anesthesia machine. Infusion pumps-principle and programmable volumetric infusion pump.

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

REFERENCE BOOKS:

1. R. S. Khandpur , Handbook of Biomedical Instrumentation, Tata McGraw-Hill ,2nd Edition, 2008, ISBN: 9780070473553.
2. Leslie Cromwell & others, Biomedical Instrumentation and Measurements, Wiley Publications, 2nd Edition, 2010, ISBN: 9780130771315.
3. J. G. Webster, Medical instrumentation: Application and Design, Wiley Publications, 3rd Edition, 2008,ISBN: 9788126511068.
4. Richard Aston, Principles of Biomedical Instrumentation and Measurement, Prentice Hall of India, 4th Edition, 2005,ISBN: 9780675209434.

Visvesvaraya Technological University, Belagavi.

PhD Coursework Courses – 2018 (EI/MB/ML)

As per 2017 Regulation

02	16LBI253	Group-5	Virtual Bioinstrumentation
Exam Hours:03		**Exam Marks:100**	

Module -1 Basic Concepts: Data Acquisition (DAQ) basics**,** Lab VIEW Basics, Bio Bench basics.
Biopotentials: TypicalLaboratory Workstation, LabLayout and Design, Generic Instrumentation/ Data Acquisition Issues.
Electroneurology: Physiological basics, Experiment setup, Di section, Nerve chamberpreparation, generic VI Development, Experiment descriptions, Troubleshooting the nerve recording.

Module -2. **Neuromuscular Electrophysiology (Electromyography):** Physiological basis, Experiment set up, Experiment descriptions, Troubleshooting the nerve –Muscle Preparation.
Cardiac Electrophysiology (Electrocardiology): Physiological basis, Experiment descriptions.
Cardiopulmonary Dynamics: TypicalLaboratory Workstation, Generic Instrumentation/Data Acquisition Issues.

Module -3Pulmonary Function: Physiological Basis, Experiment setup, PulmonaryDAQ system operation.
Lung Tissue Viscoelastance: Experiment setup, Experiment Description.
Cardiovascular Hemodynamics: Physiological Basis, Canine Cardiovascular, pressure measurements
A Cardiovascular Pressure – Dimension Analysis System:S ystem setup, Data Acquisition and Analysis, Clinical Significance.

Module -4 Medical Device Development Applications:The Endotester – A Virtual Instrument –Based Quality control and Technology, Assessment System for surgical video Systems: Introduction, Materials and Methods, Endoscope Tests, Results, Discussion.
FluidSenseInnovative IV PumpTesting : Introduction, The test System, Training Emulator.

Module -5 Healthcare Information management Systems :
Medical Informatics : Defining medicalinformatics, Computers in medicine, Electronic Medical record, Computerized physicianorder entry, Decision support.
Information Retrieval, Medical Imaging, Patient Monitoring, Medical Education, Medical Simulation.
Managing Disparate Information: ActiveX, ActiveX Data Objects(ADO), Dynamic Link Libraries, Database Connectivity, Integrated Dashboards.

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

REFERENCE BOOK:

1. "Virtual Bio-Instrumentation" Biomedical, Clinical, and Healthcare Applications in Lab VIEW. ,by JON B. OLANSEN and ERIC ROSOW, Prentice Hall Publication, 2002.

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PhD Coursework Courses – 2018 (EI/MB/ML)

As per 2017 Regulation

03	16LBI41	Group-5	Bio-MEMS and Nanotechnology

Exam Hours:03	Exam Marks:100

Module -1 Over view of MEMS& Microsystems and Working Principles of Microsystems: MEMS and Microsystems, Typical MEMS and Microsystem Products, Evolution of Microfabrication, Microsystems and Microelectronics, Multidisciplinary Nature of Microsystem Design and Manufacture, Applications of Microsystems in Automotive, Health Care, Aerospace and other Industries. **Working Principle of Microsystems:Microsensors:**Acoustic, Chemical, Optical, Pressure, Thermal and Biomedical& Biosensors. **Microactuation:** Using Thermal forces, Shape Memory alloys, Piezoelectric Crystals and Electrostatic forces. **MEMS with Microactuators:**Microgrippers, Micromotors, Microvalves and Micropumps.

Module -2. **Thermo-fluid Engineering and Microsystem Design, Scaling Laws in Miniaturization:** Introduction to Thermofluid Engineering, Overview of the Basics of Fluid Mechanics in Macro and Mesoscales: Viscosity of fluids, Streamlines and Stream Tubes, Control Volumes and Control Surfaces, Flow Patterns and Reynolds Number. Basic Equations in Continum Fluid Dynamics: The Continuity Equation, The Momentum Equation and the Equation of motion. Laminar Fluid Flow in Circular Conduits, Computational Fluid Dynamics, Incompressible Fluid Flow in Microconduits, Fluid Flow in Submicrometer and Nanoscale, Heatconduction in Multilayered Thin Films. Introduction to Scaling, Scaling in Geometry, Scaling in Rigid-Body Dynamics, Scaling in Electrostatic Forces, Scaling in Electromagnetic Forces and Scaling in Fluid Mechanics.

Module -3Materials for MEMS and Microsystems, Microsystems Fabrication Processes: Substrates and Wafers, Active Substrate Materials, Silicon as a Substrate Material, Silicon Compounds, Silicon Piezoresistors, Galium Arsenide, Quartz, Piezoelectric Crystals, Polymers and Packaging Materials. Introduction to Microsystem Fabrication Process, Photolithography, Ion Implantation, Diffusion, Oxidation, Chemical Vapor Deposition (CVD), Physical Vapor Deposition-Sputtering, Deposition by Epitaxy, Etching, The LIGA Process: General Description of LIGA Process, Materials for Substrates and Photoresists, Electroplating and SLIGA process.

Module -4 Introduction to BioMEMSMicroactuators and Drug Delivery: What are BioMEMS, the Driving force behind Biomedical Applications, Biocompatibility, Reliability Considerations Regulatory Considerations, Activation Methods, Microactuators for Microfluidics, Equivalent Representation, Drug Delivery, Introduction to Clinical Laboratory Medicine, Chemistry, Hematology, Immunology, Microbiology, Urinalysis, Coagulation Assays, Arterial Blood gases.

Module -5 Micro-Total-Analysis Systems (μTAS): Lab-on-Chip, Capillary Electrophoresis Arrays (CEA), Cell, Molecule and Particle Handling, Surface Modification Microspheres, Cell Based Bioassay Systems. Introduction to Emerging BioMEMs Technology, Minimally Invasive Surgery, Point-of-care Clinical Diagnosis, Cardiovascular, Diabetes, Endoscopy, Neurosciences, Oncology Ophthalmology, Dermabrasion, Tissue Engineering, Cell based Biosensors.

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

REFERENCE BOOKS :

1. Tai Ran Hsu, "MEMS and Microsystems, Design & Manufacture" , TMH2002.
2. Mohammed had-el-hak, "MEMS Introduction & Fundamentals" ,CRC Press.
3. HarisinghNalwa, "Nanoscience and Nanotechnology", American Scientific Publishers.
4. Sergey Edward Lyshevski, "Nano &MEMS", CRC press
5. NadimMaluf, "An Introduction to MEMS Engineering" ,Artech House Publishing.
6. Taun-Vo-Dish, "Nanotechnology in Biology & Medicine methods" , devices & Applications, CRC
7. Steven S. Saliterman, "Fundamentals of BioMEMS and Medical Microdevices", CENGAGE Learning, INDIA EDITION.

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PhD Coursework Courses – 2018 (EI/MB/ML)

As per 2017 Regulation

01	16LBI152	Group-6	ARM Embedded System Design
Exam Hours:03		**Exam Marks:100**	

Module -1 Introduction To Embedded systems

Introduction, Processor embedded into a system, embedded hardware units and devices in a system, examples, SOC and use of VLSI, Complex systems design, formalization of system design, classification of embedded systems, skills required for an embedded system designer, processor and memory organization.

Module -2. ARM Embedded Systems and ARM processor fundamentals

The RISC Design philosophy, The ARM Design philosophy, Embedded system hardware , Registers, Current program status register, pipeline, exceptions, interrupts and Vector table, Core extensions, Architecture revisions, ARM processor families.

Module -3Introduction to ARM instruction set and

Data processing instructions, branch instructions, load-store instructions, software interrupts instruction, Program status register instructions, loading constants, ARMv5E extensions, conditional execution.

Module -4 Introduction to the thumb instruction set and Exception and interrupt handling

Thumb register usage, ARM-Thumb interworking, data processing instructions, Single & multiple-register Load-store instruction, stack instructions, software interrupt instruction, Exception handling, interrupts, interrupt handling schemes.

Module -5 Embedded operating systems and Future of the Architecture

Fundamental components, **Example:** Simple little operating system. Advanced DSP and SIMD support in ARMv6, System and multiprocessor support additions to ARMv6, Armv6 implementations, Future technologies beyond ARMv6.

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

REFERENCE BOOKS:

1. "ARM system developers guide", Andrew N Sloss, Dominic Symes and Chris wright, Elsevier, Morgan Kaufman publishers, 2008,ISBN:1558608745
2. "ARM Architecture reference manual", David seal: Addison-Wesley second edition, 2009, ISBN:978- 0201737196.
3. "ARM System on chip Architecture" Addison Wesley, Formatted: paperback, 2008, ISBN:978- 0201675191.
4. "Embedded Systems", Rajkamal, Tata McGraw-Hill publishers, 2008,ISBN:0070494703

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PhD Coursework Courses – 2018 (EI/MB/ML)

As per 2017 Regulation

02	16LBI123	Group-6	Medical Imaging Techniques and Systems
Exam Hours:03		**Exam Marks:100**	

Module -1 Introduction: Basic imaging principle, Imaging modalities-Projection radiography,Computed Tomography, Nuclear medicine, Ultrasound imaging, Magnetic Resonance Imaging.

X-Ray : Interaction between X-Rays and matter, Intensity of an X-Ray, Attenuation, X-Ray Generation andGenerators, Beam Restrictors and Grids, Intensifying screens, fluorescent screens and Image intensifiers, X-Raydetectors, Conventional X-Ray radiography, Fluoroscopy, Angiography, Digital radiography, X-Ray image characteristics, Biological effects of ionizing radiation.

Module -2. **Computed Tomography** : Conventional tomography, Computed tomography principle, Generations of CT machines – First, Second, Third, Fourth, Fifth, Sixth & Seventh, Projection function,
Reconstruction algorithms – Back Projection Method, 2D Fourier Transform Method, Filtered Back Projection Method, Iteration Method, Parallel Beam Reconstruction, Fan Beam Reconstruction, Helical CT Reconstruction.

Module -3Ultrasound : Acoustic propagation, Attenuation, Absorption and Scattering, Ultrasonic transducers, Transducer Arrays, A mode, B mode, M mode scanners, Tissue characterization, Color Doppler flow imaging, Echocardiography

Module -4 Radio Nuclide Imaging: Interaction of nuclear particles and matter, Nuclear sources, Radionuclide generators,Nuclear radiation detectors, Rectilinear scanner, scintillation camera, SPECT, PET.

INFRA RED IMAGING

Physics of thermography – imaging systems – pyroelectricvidicon camera clinical thermography – liquid crystal thermography

Module -5 Magnetic Resonance Imaging : Angular momentum, Magnetic dipole moment, Magnetization, Larmorfrequency, Rotating frame of reference, Free induction decay, Relaxation times, Pulse sequences, Generationand Detection of NMR Imager. Slice selection, Frequency encoding, Phase encoding, Spin-Echo imaging,
Gradient-Echo imaging, Imaging safety, Biological effects of magnetic field, Introduction to Functional MRI.

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

REFERENCE BOOKS:

1. "Principles of Medical Imaging", K Kirk Shung, Michael B Smith &Benjamim M W Tsui,Academic Press Inc.
2. "Medical Imaging Signals and Systems", Jerry L Prince & Jonathan M Links, Pearson Prentice Hall.
3. Steve Webb, "The physics of medical imaging", Adam Hilger, Bristol, England, Philadelphia, USA, 1988.
4. "Hand Book Of Biomedical Instrumentation", R S Khandpur, Tata McGraw Hill Publication, Second Edition.
5. "Basics of MRI", Ray H Hashemi& William G Bradley Jr, Lippincott Williams & Wilkins.
6. "Diagnostic Ultrasound Principles & Instruments", 5th Edition, Frederick W Kremkau.
7. "2D Echocardiography", Jay N Schapira, Williams & Wilkins

Visvesvaraya Technological University, Belagavi.

PhD Coursework Courses – 2018 (EI/MB/ML)

As per 2017 Regulation

03	16LBI421	Group-6	Biostatistics
Exam Hours:03		**Exam Marks:100**	

Module -1 Introduction to Biostatistics : Introduction, Some basic concepts, Measurement and Measurement Scales, Simple random sample, Computers and biostatistical analysis.

Descriptive Statistics: Introduction, ordered array, grouped data-frequency distribution, descriptive statistics – measure of central tendency, measure of dispersion, measure of central tendency computed from grouped data, variance and standard deviation-grouped data.

Module -2. **Basic Probability Concepts:** Introduction, two views of probability – objective and subjective, elementary properties of probability, calculating the probability of an event.

Probability Distributions : Introduction, probability distribution of discrete variables, binomial distribution, Poisson distribution, continuous probability distributions, normal distribution and applications.

Module -3Sampling Distribution : Introduction, sampling distribution, distribution of the sample mean, distribution of the difference between two samples means, distribution of the sample proportion, distribution of the difference between two sample proportions.

Estimation : Introduction, confidence interval for population mean, t-distribution, confidence interval for difference between two population means, population proportion and difference between two population proportions, determination of sample size for estimating means, estimating proportions, confidence interval for the variance of normally distributed population and ratio of the variances of two normally distributed populations.

Module -4 Hypothesis Testing : Introduction, hypothesis testing – single population mean, difference between two population means, paired comparisons, hypothesis testing-single population proportion, difference between two population proportions, single population variance, ratio of two population variances.

Analysis of Variance (ANOVA): Introduction, completely randomized design, randomized complete block design, repeated measures design, factorial experiment.

Module -5 Linear Regression and Correlation: Introduction, regression model, sample regression equation, evaluating the regression equation, using the regression equation, correlation model, correlation coefficient.

Multiple Regression and Chi-Square Distribution : Multiple linear regression model, obtaining multiple regression equation, evaluating multiple regression equation, using the multiple regression equation, multiple correlation model, mathematical properties of Chi-square distribution, tests of goodness of fit, tests of independence, tests of homogeneity, nonparametric regression analysis.

Question paper pattern:

- The question paper will have ten questions.
- Each full question consists of 20 marks.
- There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

REFERENCE BOOKS:

1. **"Biostatistics-A Foundation for Analysis in the Health Sciences"** Wayne W. Daniel, John Wiley & Sons Publication, 6th Edition.
2. **"Principles of Biostatistics",** Marcello Pagano and KimberleeGauvreu, Thomson Learning Publication, 2006.
3. **"Introduction to Biostatistics"** by Ronald N Forthofer and EunSul Lee, Academic Press
4. **"Basic Biostatistics and its Applications"**Animesh K. Dutta (2006)