SAHRDAYA AUTONOMOUS
COLLEGE OF ENGINEERING & TECHNOLOGY
A CENTRE OF EXCELLENCE IN SCIENCE & TECHNOLOGY | MANAGED BY IRINJALAKUDA DIOCESAN EDUCATION TRUST
Approved by AICTE & Affiliated to APJ Abdul Kalam Technological University | Accredited by:
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B. Tech
Curriculum and Syllabus (2024) - Semester III & IV

Biomedical Engineering

Branch Code: BME

(SHR/AC/Auto/ Acad. Council /B.Tech/3/Syll./BME/S3-S4)

Recommended by BoS on 16/06/2025

Approved by Academic Council on 05/07/2025

THIRD SEMESTER (July-December)												
Sl. No:	Slot	Course Code	Course Type	Course Title (Course Name)	Credit Structure				Total Marks		Credits	Hrs/ Week
					L	T	P	R	CIA	ESE		
1	A	24MAT321	BSC	Complex Analysis & Partial Differential Equations	3	0	0	0	40	60	3	3
2	B	24BMT302	PCC	Analog Electronics	3	1	0	0	40	60	4	4
3	C	24BMT303	PCC	Digital Electronics	3	1	0	0	40	60	4	4
4	D	24BMR304	PCC-PBL	Medical Physics	3	0	0	1	50	50	4	4
5	E	24HUT005	HMC	Engineering Economics	2	0	0	0	50	50	2	2
6	F	24EST306	ESC	Applied Data Science & Artificial Intelligence	3	1	0	0	40	60	4	4
7	L	24BML307	PCL	Analog Electronics Lab	0	0	3	0	50	50	2	3
8	Q	24BML308	PCL	Digital Electronics Lab	0	0	3	0	50	50	2	3
9	J*	24SEK10N	SEC	Skill Enhancement Course 3							1	
10	R/M	24BMG3XX	VAC	Remedial/Minor							4*	4*
Total											**26/ 30***	**27/ 31***

FOURTH SEMESTER (January-June)												
Sl. No:	Slot	Course Code	Course Type	Course Title (Course Name)	Credit Structure				Total Marks		Credits	Hrs./ Week
					L	T	P	R	CIA	ESE		
1	A	24MAT421	BSC	Probability Distributions, Numerical Methods and Transforms	3	0	0	0	40	60	3	3
2	B	24BMT402	PCC	Microcontrollers and Interfacing	3	1	0	0	40	60	4	4
3	C	24BMT403	PCC	Electronic Instrumentation and Communication Systems	4	0	0	0	40	60	4	4
4	D	24BMR404	PCC-PBL	Biosensors and Transducers	3	0	0	1	50	50	4	4
5	F	24BME41N	PE	PE-1	3	0	0	0	40	60	3	3
6	L	24BML406	PCL	Microcontrollers and Interfacing Lab	0	0	3	0	50	50	2	3
7	Q	24BML407	PCL	Medical Electronics Lab	0	0	3	0	50	50	2	3
8	I*	24PWT208	PW	UHV II, Life skills & Community work	1	0	0	0	100	-	1	1
9	J*	24SEK10N	SEC	Skill Enhancement Course 4							1	
10	R/ M	24BMG4XX/ 24BMH4XX	VAC	Remedial/Minor/ Honours							4*	4*
Total											**24/ 28***	**25/ 29***

PROGRAM ELECTIVE I: 24BME41N

Slot	Course Code	Courses	L-T-P-R	Hours	Credit
F	24BME411	Signals and Systems	**3-0-0-0**	**3**	**3**
	24BME412	IOT & Biomedical Applications	**3-0-0-0**		**3**
	24BME413	Clinical Engineering	**3-0-0-0**		**3**
	24BME414	Biostatistics	**3-0-0-0**		**3**
	24BME415	Introduction to Point-of- Care Diagnostic Devices (IVD- 1)	**3-0-0-0**		**3**
	24BME416	Quantitative Physiology#	**3-1-2-0**	**6**	5

#- Higher credit elective

SEMESTER-III
SYLLABUS

24MAT321	COMPLEX ANALYSIS & PARTIAL DIFFERENTIAL EQUATIONS	L	T	P	R	C	Year of Introduction
		3	0	0	0	3	2024

Preamble: The course enables the students to understand basic concepts and tools of Partial Differential equations and Complex Analysis. Topics like Partial Differential Equations, Complex Integration, and Residues are included. This course helps the learners to model and analyze physical phenomena involving continuous changes of variables or parameters with the help of modern tools and has applications across all engineering domains.

Prerequisite: A basic course in multi-variable calculus and complex numbers

Course Outcomes: After the completion of the course, the student will be able to

CO 1	Solve partial differential equations which are widely used in different engineering situations, modeling and applying partial differential equations in the analysis of various physical phenomena **[Apply]**
CO 2	Apply complex variables and conformality to transform functions from one domain to another **[Apply]**
CO 3	Apply indefinite integration and substitution of limits in the context of complex functions, integrating over paths and contours in the complex plane. **[Apply]**
CO 4	Apply residue theory to solve real integrals, and how this connection enhances the evaluation of integrals in both real and complex domains. **[Apply]**

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	3	3	3					2			2
CO2	2	3									2
CO3	3	3									2
CO4	3	3									2

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	√	√	√	√
Understand	√	√	√	√
Apply	√	√	√	√
Analyze				
Evaluate				
Create				

Course Structure [L-T-P-R]	Lecture [L]				Total Marks
	Attendance	Assignment	Test-1	Test-2	
3-0-0-0	5	10	12.5	12.5	40

Total Mark distribution

Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	40	60	2.5 hours

End Semester Examination [ESE]: Pattern			
PATTERN	**PART A**	**PART B**	**ESE Marks**
PATTERN 1	8 Questions (2 Questions from each module), each question carries 3 marks Marks: (3x8 =24 marks)	2 questions will be given from each module, out of which 1 should be answered. Each question can have a maximum of two sub-divisions. Each question carries 9 marks. Marks: (9x4 = 36 marks)	60

SYLLABUS

MODULE I: [Partial Differential Equations & Applications] (9 Hrs)

(Text 2-Relevant portions of sections 17.1, 17.2, 17.3, 17.4, 17.5,18.2,18.3,18.4,18.5)
Partial differential equations, Formation of partial differential equations –elimination of arbitrary constants and arbitrary functions, Solutions of partial differential equations- Equations solvable by direct integration, Linear equations of the first order- Lagrange's linear equation, Solution of equation by method of separation of variables, One- dimensional wave equation- vibrations of a stretched string, One- dimensional heat equation (problems only)

Self Study (14 hours) :-

1. Derivation of PDEs from real-world physics problems (e.g., heat equation, wave equation)
2. Relevance of PDE in your branch of study.
3. Narrate different methods to solve nonlinear equations with examples.
4. Review three or four of the most important PDEs and their main applications.
5. Solve five problems by the method of separation of variables.

MODULE II: [Complex Variable – Differentiation] (9 Hrs)

(Text 1: Relevant portions of sections 13.3, 13.4, 17.1, 17.2 , 17.4)

Complex function, limit, continuity, derivative, analytic functions, Cauchy-Riemann equations, harmonic functions, finding harmonic conjugate, Conformal mappings- mappings $w = z^2$, $w = e^z$, $w = \frac{1}{z}$, $w = \sin z$ (problems based on these transformations need to be discussed)

Self Study (13 hours) :-

1. Write some analytic functions with proof.
2. Write notes on Mobius transformations with examples.
3. Discuss the conformal mapping of cosz.

4. Write the properties of the Inversion w = 1/z.
5. Solve five problems using the Cauchy-Riemann equations.

MODULE III: [Complex Variable – Integration] (9 Hrs)

(Text 1- Relevant topics from sections 14.1, 14.2, 14.3, 14.4)

Complex integration, Line integrals in the complex plane, Indefinite integration and substitution of limit, Contour integrals, Cauchy's integral theorem (without proof) on simply connected and multiply connected domain, Cauchy Integral formula (without proof), Cauchy Integral formula for derivatives of an analytic function

Self Study (13 hours) :-

1. Write the basic properties of a complex line integral.
2. Integrate f(z) counter clockwise around the unit circle. Indicate whether Cauchy's integral theorem applies. Show the details.: f(z) = 1/(2z - 1).
3. Review the situations where Cauchy's integral formula and theorem are used in problems with suitable examples.
4. Solve five problems using Cauchy's integral formula.

MODULE IV: [Complex Variable – Residue Integration] (9 Hrs)

(Text 1- Relevant topics from sections 16.2, 16.3,16.4)

Zeros of analytic functions, singularities, poles, removable singularities, essential singularities, Residues, Cauchy Residue theorem (without proof), Evaluation of definite integral using residue theorem, Residue integration of real integrals – integrals of rational functions of $cos\theta$ and $sin\theta$

Self Study (13 hours) :-

1. Importance of singularities in your branch of study.
2. Solve five problems using the concept of poles.
3. Write a few examples for Laurent's series.
4. Explain the process of solving improper integrals with examples

Text Books

1. Erwin Kreyszig, Advanced Engineering Mathematics, 10thEdition, John Wiley & Sons, 2016.
2. B.S. Grewal, Higher Engineering Mathematics, Khanna Publishers, 43rd Edition,2015

Reference books

1. Peter V. O'Neil, Advanced Engineering Mathematics, Cengage, 7th Edition, 2012

NPTEL/SWAYAM Courses for reference:

1. Nandakumaran, A. K. (2020). Complex analysis. National Programme on Technology Enhanced Learning (NPTEL), IIT Madras. https://archive.nptel.ac.in/courses/111/106/111106141/
2. Venkata Balaji, T.E. (2020). Advanced Complex Analysis - Part 1: Zeros of Analytic Functions, Analytic Continuation, Monodromy, Hyperbolic Geometry, and the Riemann

Mapping Theorem. National Programme on Technology Enhanced Learning (NPTEL), IIT Madras. https://archive.nptel.ac.in/courses/111/106/111106084/NPTEL+1btechguru.com+1		
No.	**COURSE CONTENTS AND LECTURE SCHEDULE**	**No. of Hours [36 hours]**
MODULE 1 [9 hours]		
1.1	Partial differential equations, Formation of partial differential equations - elimination of arbitrary constants	1
1.2	Formation of partial differential equations -elimination of arbitrary functions	1
1.3	Solutions of partial differential equations-Equations solvable by direct integration	1
1.4	Linear equations of the first order- Lagrange's linear equation	1
1.5	Solution of equation by method of separation of variables	1
1.6	One- dimensional wave equation- vibrations of a stretched string	2
1.7	One- dimensional heat equation	2
MODULE II [9 hours]		
2.1	Complex function, limit, continuity, derivative, analytic functions	1
2.2	Cauchy-Riemann equations	2
2.3	harmonic functions, finding harmonic conjugate	2
2.4	Conformal mappings- mappings w = z^2	1
2.5	Conformal mappings- w = e^z	1
2.6	Conformal mappings- w = $\frac{1}{z}$	1
2.7	Conformal mappings- w = sinz	1
MODULE III [9 hours]		
3.1	Complex integration, Line integrals in the complex plane	1
3.2	Indefinite integration and substitution of limit	1
3.3	Contour integrals, Cauchy's integral theorem (without proof) on simply connected connected domain	2
3.4	Contour integrals, Cauchy's integral theorem (without proof) on multiply connected domain	1
3.5	Cauchy Integral formula (without proof)	2
3.6	Cauchy Integral formula for derivatives of an analytic function	2
MODULE IV [9 hours]		
4.1	Zeros of analytic functions	1
4.2	singularities, poles	1
4.3	removable singularities, essential singularities	1
4.4	Residues	1
4.5	Cauchy Residue theorem (without proof)	1
4.6	Evaluation of definite integral using residue theorem	2
4.7	Residue integration of real integrals – integrals of rational functions of $cos\theta$ and $sin\theta$	2

CO Assessment Questions	
CO1	1. Form the PDE by eliminating the arbitrary function 'f' from the equation z = f(x-y). **[Apply]** 2. Solve the one-dimensional heat equation subject to the initial condition u(x,0) = $\sin^2 x$. **[Apply]** **Team Work**: Discuss and present solutions to PDEs, highlighting the physical significance and applications of the results.
CO2	1. Show that if u is harmonic and v is a harmonic conjugate of u, then u is a harmonic conjugate of -v. **[Understanding]** 2.Why do the images of the straight lines x=constant and y=constant under a mapping by an analytic function intersect at right angles? The same question for the curves z =constant and Arg z = constant. Are there exceptional points? **[Apply]** 3.Find the fixed point of w =a z +b.**[Understanding]** **Team Work:** As a group, analyze the behavior of the transformation w=1/z on different regions in the complex plane, such as the upper half-plane and the unit disk. What are the effects on these regions under the transformation?
CO3	1.What is the significance of Cauchy's Integral Theorem for integrals over closed paths in a simply connected domain? **[Apply]** 2. Evaluate the indefinite integral of the complex function $f(z)=e^{2z}$ and express the result in terms of z. **[Apply]** 3.Integrate counterclockwise around the unit circle $\oint_C \frac{Sin\, z}{z^4}\, dz$. **[Apply]** **Team Work**: In your group, work together to prove that for an analytic function f(z), the integral ∫f(z) dz= 0 for any closed path C inside a simply connected domain.
CO4	1. Evaluate the integral $\int_0^{2\pi} \frac{d\theta}{3-2cos\theta}$ **[Apply]** 2.Consider the function $f(z)=\frac{1}{z^2+1}$. Identify and classify the singularities of this function. **[Analyze]** **Team Work:** Investigate the function $f(z)=\frac{z^2+1}{(z-1)(z+2)}$. Identify and classify all singularities of the function.

Prepared by:
Ms. Rani Thomas, Assistant Professor
Dept of Applied Science and Humanities

24BMT302	ANALOG ELECTRONICS	L	T	P	R	C	Year of Introduction
		3	1	0	0	4	2024

Preamble: This course with the continuous-time processing of electrical signals using components like resistors, capacitors, diodes, and transistors. They play a vital role in applications such as amplification, filtering, and signal modulation. Unlike digital systems, analog circuits handle a range of values, making them essential for interfacing with real-world signals. This subject focuses on analyzing and designing circuits like amplifiers and oscillators.

Prerequisite: Basics of Electronics and Electrical Engineering

Course Outcomes: After the completion of the course, the student will be able to

CO 1	Apply the characteristics of analog components (diodes, photodiodes, rectifiers) to design and explain basic biomedical sensing and power supply circuits **[Apply]**
CO 2	Design and implement op-amp–based amplifier and signal conditioning circuits for biomedical applications, meeting given performance specifications. **[Apply/Design]**
CO 3	Analyze the behavior of active and passive filters in biomedical circuits and evaluate their effectiveness in reducing noise and interference in biosignal acquisition. **[Analyze]**
CO 4	Examine analog front-end systems in biomedical devices, analyzing their safety, isolation, and regulatory compliance through case studies and circuit simulations. **[Analyze]**

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	3	3	2		2						2
CO2	3	3	3	2	3			2	2	2	2
CO3	3	3	3	3	3			2	2	2	2
CO4	3	3	3	3	2	3	3	2	2	2	2

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember				
Understand				
Apply	√	√	√	√
Analyze	√	√	√	√
Evaluate				
Create				

Course Structure [L-T-P-R]	Lecture [L]				Total Marks
	Attendance	Assignment	Test-1	Test-2	
3-1-0-0	5	10	12.5	12.5	40

Total Mark distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	40	60	2.5 hours

End Semester Examination [ESE]: Pattern			
PATTERN	**PART A**	**PART B**	**ESE Marks**
PATTERN 1	8 Questions (2 Questions from each module), each question carries 3 marks Marks: (3x8 =24 marks)	2 questions will be given from each module, out of which 1 should be answered. Each question can have a maximum of two sub-divisions. Each question carries 9 marks. Marks: (9x4 = 36 marks)	60

SYLLABUS

MODULE I: Analog Building Blocks for Biomedical Applications (9 hrs(L)+ 3 hrs(T))

Overview of analog circuits in biomedical systems: Why analog matters, where it is used, Semiconductor devices in biomedical circuits: review of diodes, Zener diodes, LEDs, photodiodes, Rectifiers and filters in medical power supplies: half-wave, full-wave, bridge rectifiers, capacitor filters, Optical sensors and photodiode circuits: biomedical sensing applications, BJT/FET overview (without biasing details): switching applications in medical electronics.

Tutorial: Problem-solving on diode circuits, photodiode configurations, rectifier ripple calculations

Self-Study: (18 hours)

1. Read and summarize datasheets for photodiodes, LEDs, and Zener diodes used in biomedical sensors.
2. Study real-world diode applications in medical devices (e.g., pulse oximeters, photo plethysmographs).
3. In teams, compare commercially available photodiode sensors and LED driver circuits, then present which combination would work best in a wearable medical device.
4. Analyze the LED and photodiode systems in a fingertip pulse oximeter: how do they measure blood oxygen saturation? What analog circuits are involved?
5. Build and test a simple photodiode-based light sensor circuit; record and explain how different light conditions affect output.

MODULE II: Operational Amplifiers in Biomedical Circuits (9 hrs(L)+ 3 hrs(T))

Op-amp fundamentals: ideal vs real behaviour, input/output impedance, slew rate, Inverting, non-inverting, summing amplifiers: design and analysis, Instrumentation amplifiers: principles, design, and applications in ECG, EMG circuits, Op-amp-based

comparators, Schmitt triggers, and zero-crossing detectors, Troubleshooting standard op-amp circuits: gain errors, offset, bandwidth limitations

Tutorial: Design and analysis problems on op-amp circuits, gain calculations, CMRR, and instrumentation amplifier design

Self-Study: (18 hours)

1. Study op-amp datasheets (e.g., 741, TL072, AD620) and key performance specs
2. Design a basic ECG amplifier circuit and present the design choices
   Building and testing instrumentation amplifiers for biosignal acquisition
3. Review real ECG amplifier designs (with schematic examples) and identify critical analog stages
4. Simulate op-amp amplifier circuits and compare ideal vs. real-world behavior using software tools

MODULE III: Filters and Signal Conditioning for Biomedical Signals
(9 hrs(L)+ 3 hrs(T))

Biomedical signal filtering needs: noise sources, interference, motion artifacts. Passive filter design: LPF, HPF, BPF using RC circuits, cutoff frequency calculations, Active filter design: op-amp-based Butterworth and Chebyshev filters, Notch filters for power-line interference rejection (50/60 Hz), Analog-to-digital front-end design: anti-aliasing filters, sample-and-hold, interfacing considerations,

Tutorial: Filter design exercises, Bode plots, frequency response analysis, and real-world filtering case studies

Self-Study: (18 hours)

1. Read application notes on filtering biosignals (e.g., ECG, EMG)
2. Develop and present a filter system for noise reduction in ECG acquisition
3. Lab work designing and testing LPF, HPF, and notch filters applied to biomedical signals
4. Analyze how filtering is implemented in commercial ECG or EMG devices, including before/after signal examples**:**
5. Simulate filter circuits (passive and active) and plot Bode plots, step responses, and signal filtering outcomes

MODULE IV: Power, Protection, and Analog System Integration
(9 hrs(L)+ 3 hrs(T))

Power supply design for biomedical systems: linear regulators, switching supplies, noise control, Circuit protection: overvoltage, ESD, patient leakage currents, safety grounding, Isolation and coupling circuits: capacitive, transformer, optical coupling Integration of analog front-end systems in biomedical devices (e.g., ECG monitor, pulse sensor) Regulatory design constraints (IEC 60601): basics and impact on circuit design.

Tutorial: Design and troubleshoot protection circuits, evaluate system-level analog integration for biomedical use

Self-Study: (18 hours)

1. Study IEC 60601 standards and safety design requirements for biomedical devices
2. Design an isolated analog front-end circuit that meets safety specs and present the solution
3. Lab testing of regulated power supplies, isolation circuits, and protection mechanisms
4. Examine failure cases in biomedical device circuits due to inadequate isolation or protection; discuss lessons learned
5. Simulate power supply circuits, test ripple performance, and simulate fault conditions to evaluate protections

Text Books

1. R. L. Boylestad and L. Nashelsky, Electronic Devices and Circuit Theory, 11th ed.,: Pearson Education, 2015.
2. S. Franco, Design with Operational Amplifiers and Analog Integrated Circuits*, 4th ed.,: Pearson Education, 2015.
3. J. G. Webster, Medical Instrumentation: Application and Design, 4th ed. Hoboken, NJ, USA: Wiley, 2009.

Reference books

1. R.S. Khandpur, Handbook of Biomedical Instrumentation, published by McGraw Hill India,3rd edition,2014
2. R. A. Gayakwad, Op-Amps and Linear Integrated Circuits, 4th ed., Indian ed. New Delhi, India: Pearson Education, 2002.
3. P. Horowitz and W. Hill, The Art of Electronics, 3rd ed. Cambridge, U.K.: Cambridge Univ. Press, 2015.

Additional Tools for Self-Learning (Recommended)

1. Simscape Onramp (MATLAB/Simulink)
2. Circuit Simulation Onramp (MATLAB/Simulink or equivalent tools)

NPTEL/SWAYAM Courses for reference:

1. Analog Electronic Circuits – Prof. S. Srinivasan, IIT Madras
   https://onlinecourses.nptel.ac.in/noc23_ee77/preview
2. Analog Circuits – Prof. Shouribrata Chatterjee, IIT Bombay
   https://onlinecourses.nptel.ac.in/noc21_ee07/preview

No.	COURSE CONTENTS AND LECTURE SCHEDULE	No. of Hours [48 hours]
	MODULE 1 [9 + 3 hours]	
1.1	Overview of analog circuits in biomedical systems: Why analog matters, where it is used	1
1.2	Semiconductor devices in biomedical circuits: review of diodes, Zener diodes, LEDs, photodiodes	2

1.3	Rectifiers and filters in medical power supplies: half-wave, full-wave, bridge rectifiers, capacitor filters	2
1.4	Optical sensors and photodiode circuits: biomedical sensing applications	2
1.5	BJT/FET overview (without biasing details): switching applications in medical electronics.	2
1.6	Problem-solving on diode circuits, photodiode configurations, rectifier ripple calculations	3
MODULE II [9 + 3 hours]		
2.1	Op-amp fundamentals: ideal vs real behaviour, input/output impedance, slew rate	2
2.2	Inverting, non-inverting, summing amplifiers: design and analysis	2
2.3	Instrumentation amplifiers: principles, design, and applications in ECG, EMG circuits	2
2.4	Op-amp-based comparators, Schmitt triggers, and zero-crossing detectors	2
2.5	Troubleshooting standard op-amp circuits: gain errors, offset, bandwidth limitations	1
2.6	Design and analysis problems on op-amp circuits, gain calculations, CMRR, and instrumentation amplifier design	3
MODULE III [9 + 3 hours]		
3.1	Biomedical signal filtering needs: noise sources, interference, motion artifacts	1
3.2	Passive filter design: LPF, HPF, BPF using RC circuits, cutoff frequency calculations	2
3.3	Active filter design: op-amp-based Butterworth and Chebyshev filters	2
3.4	Notch filters for power-line interference rejection (50/60 Hz).	2
3.5	Analog-to-digital front-end design: anti-aliasing filters, sample-and-hold, interfacing considerations	2
3.6	Filter design exercises, Bode plots, frequency response analysis, and real-world filtering case studies	3
MODULE IV [9 + 3 hours]		
4.1	Power supply design for biomedical systems: linear regulators, switching supplies, noise control.	2
4.2	Circuit protection: overvoltage, ESD, patient leakage currents, safety grounding	2
4.3	Isolation and coupling circuits: capacitive, transformer, optical coupling	2
4.4	Integration of analog front-end systems in biomedical devices (e.g., ECG monitor, pulse sensor)	2
4.5	Regulatory design constraints (IEC 60601): basics and impact on circuit design	1
4.6	Design and troubleshoot protection circuits, evaluate system-level analog integration for biomedical use	3

CO Assessment Questions	
CO-1	1. Explain the working of a Zener diode in a voltage regulator circuit. **(Apply)** 2. Draw and label the circuit diagram of a bridge rectifier with capacitor filter**. (Apply)** 3. Explain the working of a photodiode-based optical pulse sensor circuit with a block diagram and key design points. **(Apply)** 4. Calculate the ripple voltage and efficiency of a bridge rectifier supplying 100 mA load at 10 V DC. **(Apply)**
CO-2	**1.** Write the gain expression for an inverting amplifier using an op-amp. **(Apply)** **2.** State two applications of instrumentation amplifiers in biomedical circuits. **(Apply)** **3.** Determine the offset voltage and bias current effects in a biomedical amplifier circuit and propose compensation methods. **(Apply)** 4. Compare inverting and non-inverting amplifier configurations for amplifying EMG signals; include design calculations**. (Apply)**
CO-3	**1.** Define cutoff frequency and bandwidth of a filter. **(Analyze)** **2.** Explain why notch filters are important in biomedical signal conditioning. **(Analyze)** **3.** Design a 50 Hz notch filter to remove power-line interference from a biomedical signal and explain its operation. **(Apply/Analyze)** **4.** Simulate and analyze the Bode plot of a two-stage active bandpass filter designed for EEG signals. (**Analyze)** **5.** In an ECG machine, 50/60 Hz mains hum interferes with signal quality. Design an analog filter to minimize this interference without affecting the heart signal (0.05–150 Hz) **(Create)**
CO-4	**1.** State the purpose of isolation amplifiers in patient-connected biomedical devices. **(Analyze)** **2.** List two types of circuit protection used in biomedical device analog circuits**. (Apply)** **3.** Simulate and evaluate the effect of ESD (electrostatic discharge) on an analog front-end circuit. **(Analyze)** **4.** Compare transformer isolation vs opto-isolation in analog biomedical circuits; include advantages and limitations. **(Analyze)** 5. Design a linear power supply to convert 230V AC to 5V DC for a wearable medical device. Explain how you would manage heat dissipation and regulation. **(Create)**

Prepared By
Dr. Finto Raphel, Associate Professor
Minu C Davis, Assistant Professor
Dept of Biomedical Engineering

24BMT303	DIGITAL ELECTRONICS	L	T	P	R	C	Year of Introduction
		3	1	0	0	4	2024

Preamble:
The course deals with the study of different types of number systems and Boolean expressions. The course is the foundation for designing combinational and sequential circuits. With this knowledge students can self explore the design and development of digital systems.

Prerequisite: Nil

Course Outcomes: After the completion of the course, the student will be able to

CO 1	Understand the fundamental concepts of logic systems and apply Boolean algebra to simplify combinational logic circuits. **[Understand, Apply]**
CO 2	Design and analyze combinational circuits such as adders, subtractors, multiplexers, decoders, and comparators. **[Analyze]**
CO 3	Construct and evaluate sequential circuits using flip-flops, counters, and shift registers. **[Evaluate]**
CO 4	Design and implement digital sequential circuits using finite state machines and familiarise with the logic families. **[Evaluate]**

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	3	2	2		3						2
CO2	3	2	2	2	3		2	2	2	2	2
CO3	3	2	3	2	3		2	2	2	2	2
CO4	3	2	3	2	3		2	2	2	2	2

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember				
Understand	√	√	√	√
Apply	√	√	√	√
Analyze	√	√	√	√
Evaluate	√	√	√	√
Create				

Mark Distribution of CIA

Course Structure [L-T-P-R]	Lecture [L]				Total Marks
	Attendance	Assignment	Test-1	Test-2	
3-1-0-0	5	10	12.5	12.5	40

Total Mark distribution

Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	40	60	2.5 hours

End Semester Examination [ESE]: Pattern			
PATTERN	**PART A**	**PART B**	**ESE Marks**
PATTERN 1	8 Questions (2 Questions from each module), each question carries 3 marks Marks: (3x8 =24 marks)	2 questions will be given from each module, out of which 1 should be answered. Each question can have a maximum of two sub-divisions. Each question carries 9 marks. Marks: (9x4 = 36 marks)	60

SYLLABUS

MODULE I: Fundamentals of Digital Systems [9 + 3 hours]

Number systems: Binary, Octal, Decimal, Hexadecimal, and conversions. Binary codes: BCD, XS-3, Gray code. Binary arithmetic: Addition, subtraction and 1's/2's complement. Logic gates: AND, OR, NOT, NAND, NOR, XOR, XNOR. Boolean algebra: Postulates, theorems, and simplification. Realization of different gates using Universal gates.

Self study (18 hours):

1. Applications of Number Systems in Digital Biomedical Devices: Explore how ADC (Analog-to-Digital Converter) outputs are represented in hexadecimal or binary.
2. Simulating Logic Gates Using Logisim or Multisim**.** Practice building basic circuits (AND, OR, NOT) in simulation tools. Extend to universal gates (NAND, NOR) to build XOR, XNOR.
3. Introduction to Verilog HDL - Writing and simulating a simple AND, OR, NOT gate

MODULE II: Combinational Logic Design [9 + 3 hours]

SOP & POS- minterm and maxterm expansion. Minimization technique: Algebraic and Karnaugh map (up to 4 variables), Don't care conditions. Combinational circuits: Adders, subtractors, comparators, Code Converters, multiplexers, demultiplexers, encoders, decoders.

Self study (18 hours):

1. Application of Boolean algebra, formation of switching function from word statement.
2. Study of the Quin-McCluskey minimization technique.
3. Designing Biomedical Logic Circuits:
    - Study how a digital thermometer can use comparators and decoders.
    - Design a heart rate threshold alert using adders and comparators.
4. Simulation of Combinational Circuits. Use Logisim or Quartus to implement: 4-bit binary adder, BCD to 7-segment decoder, 4-to-1 multiplexer.
5. Verilog language basics: Design Half Adder, Full Adder, 4:1 Multiplexer, Encoder, Decoder

MODULE III: Sequential Logic Circuits and Timing Control [9 + 3 hours]

Sequential logic circuits & design: Latches –SR latch, Flip Flops-SR, JK, T and D Flip flops, master slave JK flip flop, conversion between flip flops. Shift registers: SISO, SIPO, PISO, PIPO shift registers. Counters: Asynchronous Counters – Modulus of a counter, Up/Down Counters.

Self study (18 hours):

1. Study of bidirectional and universal shift register.
2. Demonstrate clocking and timing diagrams using waveform simulation tools (e.g., Model Sim). Study how flip-flops respond to clock signals using timing diagrams.
3. Explore shift registers used in digital signal delay (common in EEG filtering circuits).
4. Designing Ring and Johnson Counters: Study their application in control sequencing (e.g., stepper motor control in medical pumps). Simulate the counters and verify output sequences.
5. Design using Verilog: D Flip-Flop, 4-bit counter (up/down)

MODULE IV: Design of digital sequential circuits [9 + 3 hours]

Asynchronous counters: mod-N counters, Ring counter, Johnson Counter.
Design of Synchronous counters. Sequence detectors and finite state machines. Mealy and Moore machines-state diagram, Comparison. Clocking, timing diagrams, and hazards. Logic families: TTL, CMOS, Voltage levels and interfacing basics- standard logic level, current and voltage parameter fan in & fan out, propagation delay, noise consideration. Comparison of CMOS & TTL.

Self study (18 hours):

1. Practical Differences Between TTL and CMOS Logic Families**.**
2. Read datasheets of popular ICs (e.g., 74LS series for TTL, 4000 series for CMOS).
   Study voltage level compatibility and interfacing techniques between TTL and CMOS.
3. Comparing Verilog and VHDL**:** Study syntax differences and when to use each in industry. Write simple circuits in both languages for practice.
4. Writing FSMs in HDL (Mealy and Moore Machines):
   1. Design a sequence detector using Mealy and Moore approaches in Verilog.
   2. Study how FSMs can be used for arrhythmia detection (pattern of abnormal heartbeats).
5. Explore Verilog applications in digital biomedical devices

Textbooks

1. Thomas L Floyd , *Digital Fundamentals*, 9th edition , pearson
2. Charles. H. Roth, Jr. *Fundamentals of Logic design*, 5th edition,Thomson books /cole
3. A.Anandkumar,*Fundamentals of Digital Circuits*, PHIlearning,2/e 2010.
4. M. Morris Mano & Michael D. Ciletti, *Digital Design with an Introduction to the Verilog HDL,* Pearson, 6th Edition.

Reference books

1. Taub and Schilling,Digital principles and applications,TMH
2. Mano.M.M,Digital design,PHI.
3. Taub and Schilling,Digital principles and applications,TMH
4. Khandpur, R. S, Handbook of Biomedical Instrumentation, McGraw Hill, 3rd Edition
5. R. S. Sedha, A textbook of Digital Electronics S. Chand Publishing

NPTEL/SWAYAM Courses for reference:

1. NPTEL :: Digital Electronic circuits, Prof Goutam Saha, IIT Kharagpur https://archive.nptel.ac.in/courses/108/105/108105132/
2. NPTEL :: Digital Circuits, Prof Santanu Chattopadhyay, IIT Kharagpur https://archive.nptel.ac.in/courses/108/105/108105113/
3. NPTEL :: Digital Design with Verilog, Dr. Aryabhartta Sahu. Dr Chandan Karta, IIT Guwahati https://onlinecourses.nptel.ac.in/noc25_cs25/preview

No.	COURSE CONTENTS AND LECTURE SCHEDULE	No. of Hours [48 hours]
	MODULE 1 [9+3 hours]	
1.1	Number systems and conversions (binary, octal, decimal, hexadecimal)	2
1.2	Binary codes - BCD, XS-3, Gray code	3
1.3	Binary arithmetic and complements	2
1.4	Logic gates and truth tables (AND, OR, NOT, NAND, NOR, XOR, XNOR)	1
1.5	Boolean algebra: Postulates, theorems, and simplification.	2
1.6	Realization of different gates using Universal gates.	2
	MODULE II [9+3 hours]	
2.1	SOP & POS- minterm and maxterm expansion.	2
2.2	Minimization technique: Algebraic and Karnaugh map (up to 4 variables), Don't care conditions.	3
2.3	Combinational circuits: Adders, subtractors.	2
2.4	Comparators, Code Converters, multiplexers, demultiplexers,	3
2.5	Encoders, decoders.	2
	MODULE III [9+3 hours]	
3.1	Sequential logic circuits & design: Latches –SR latch	1
3.2	Flip-flops: SR, D, JK, T; excitation and characteristic tables	3
3.3	Master slave JK flip flop.	2
3.4	Conversion between flip flops	1
3.5	Shift registers: SISO, SIPO, PISO, PIPO shift registers.	2
3.6	Counters: Asynchronous Counters – Modulus of a counter, Up/Down Counters,	3
	MODULE IV [9+3 hours]	
4.1	Asynchronous counters: mod-N counters, Ring counter, Johnson Counter.	3

4.2	Design of Synchronous counters.	2
4.3	Sequence detectors and finite state machines. Mealy and Moore machines - state diagrams, Comparison.	2
4.4	Clocking, timing diagrams, and hazards.	2
4.5	Logic families: TTL, CMOS, Voltage levels and interfacing basics-standard logic level, current and voltage parameter fan in & fan out, propagation delay, noise consideration.	2
4.6	Comparison of CMOS & TTL.	1

CO Assessment Questions	
CO-1	1. Convert the decimal number 156 to its equivalent in binary, octal, and hexadecimal. Then, implement a Boolean function F = A + A'B using only NAND gates and explain your design with a logic diagram. **(Apply)** 2. Convert the following number i) (638)8 =( )2 ii) (3FD)H = ( )2 iii)(25B)H =( )8 **(Apply)** 3. Simplify the expression Y=Σm(1,3,5,7) using algebraic simplification. **(Analyze)** 4. Obtain the minimal SOP expression for the function using kmap. Y=∑m(1,5,7,13,14,15,17,18,21,22,25,29)+∑d(6,9,19,23,30) **(Analyze)**
CO-2	1. Explain about adders and subtractors with diagram and truth tables? **(Understand)** 2. Implement the given function using 8:1 multiplexer **(Apply)** F (A, B, C, D) = ∑ (2, 5, 7, 8, 9, 10, 11, 13,15) 3. Explain the difference between multiplexer and demultiplexer. **(Understand)** 4. Design a 3-to-8 decoder using logic gates. Provide the truth table and logic diagram. **(Create)**
CO-3	1. Describe the procedure for converting one type of flip-flop to another, perform the following conversion. **(Apply)** i) T to JK ii)T to D 2. Draw the logic diagram of a 4 bit Johnson counter and explain the working with truth table and timing diagram. **(Analyze)** 3. What is the difference between serial and parallel data transfer? Draw the circuit diagram of an N bit parallel in serial out shift register using D flipflops.**(Understand)** 4. Design a 4-bit binary synchronous up counter with D FF. **(Create)**
CO-4	1. Compare Mealy and Moore machines with state diagrams. **(Analyze)** 2. Compare the features of TTL and CMOS. **(Analyze)** 3. Explain finite state machines with suitable examples. **(Understand)** 4. What is a state diagram? Explain **(Understand)**

Prepared by:
Ms. Supriya Mary Sunil, Assistant Professor
Dept of Biomedical Engineering

24BMR304	MEDICAL PHYSICS	L	T	P	R	C	Year of Introduction
		3	0	0	1	4	2024

Preamble:

This course introduces students to the physical principles underlying physiological processes and medical technologies. It covers neural communication, radiation interactions with biological tissues, and the analysis of bioelectric signals. Students will also learn techniques to improve the accuracy of biomedical measurements by minimizing noise and artifacts.

Prerequisite:

Course Outcomes: After the completion of the course, the student will be able to

CO 1	Interpret the physiological basis of synaptic transmission and its role in neural communication. **[Understand]**
CO 2	Assess the beneficial and harmful biological effects of various types of radiation in medical contexts. **[Apply]**
CO 3	Analyze the characteristics (amplitude, frequency) of bioelectric signals and relate them to clinical applications. **[Analyze]**
CO 4	Apply appropriate techniques to minimize noise and artifacts in biomedical measurements. **[Apply]**

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO 1	3	2		2							
CO 2	3					3	3				
CO 3	3	3		2	2						
CO 4	3		3		2						

Assessment Pattern for Theory Component

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember				
Understand	√	√		√
Apply	√	√	√	√
Analyze	√		√	√
Evaluate				
Create				

Assessment Pattern for Project Component

Bloom's Category	Continuous Assessment Tools		
	Evaluation 1	Evaluation 2	Report
Remember			
Understand			
Apply			
Analyze			
Evaluate	√	√	√
Create			

Mark Distribution of CIA								
Course Structure [L-T-P-R]	**Attendance**	**Theory [L]**			**Project [R]**			**Total Marks**
		Assignment9	**Test-1**	**Test-2**	**Evaluation-1**	**Evaluation-2**	**Report**	
3-0-0-1	5	5	7.5	7.5	10	10	5	**50**

Total Marks distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	50	50	2 hrs.

End Semester Examination [ESE]: Pattern			
PATTERN	**PART A**	**PART B**	**ESE Marks**
PATTERN 2	2 Questions from each module. Any full 6 Questions, each carrying 3 marks (6x3 =18 marks)	2 questions will be given from each module, of which 1 question should be answered. Each question can have a maximum of 3 subdivisions. Each question carries 8 marks. (4x8 = 32 marks)	50

SYLLABUS

MODULE I: Mechanism of Cell Potentials and Neural Impulses (9 hours)

Resting Membrane Potential: Ionic basis of membrane potential (Na^+, K^+, Cl^-, Ca^{2+}), Nernst and Goldman equations. Action Potential Generation: Threshold, depolarization, repolarization, hyperpolarization, Role of ion channels and the sodium-potassium pump. **Propagation of Neural Impulses**: Saltatory vs. continuous conduction, Refractory periods, Myelinated vs. unmyelinated fibers, **Synaptic Transmission**: Electrical and chemical synapses, Neurotransmitter release and receptor activation. Electrode-tissue interfaces - electrode-electrolyte and electrolyte skin interfaces. Skin contact impedance.

Self-Study topics (18 Hours):

1. Study the Nernst Equation. Compute and compare the equilibrium potentials for various ions.
2. Use a multimeter to measure skin contact impedance at different sites on your body. Compare the impedance values and understand the factors influencing them.
3. Learn about refractory periods and the differences between myelinated and unmyelinated fibers.
4. Set up a simple circuit with a voltage source and resistor to simulate the action potential. Use an oscilloscope to visualize the voltage changes.

MODULE II: Bio-potentials and Their Acquisition Principles (9 hours)

Generation of Bio-potentials: Origin of bioelectric signals: ECG, EEG, EMG, EOG, ERG, Electrical activity in excitable tissues. **Characteristics of Bio-potentials**: Amplitude, frequency, waveform shape, signal-to-noise ratio, **Principles of Bio-signal Acquisition**:

Signal conditioning: amplification, filtering, sampling, Analog-to-digital conversion, Noise sources and reduction techniques, **Basic Instrumentation Systems**: Block diagrams of biomedical recording systems.

Self-Study topics (18 Hours):

1. Understand the characteristics of bioelectric signals: amplitude, frequency, waveform shape, and signal-to-noise ratio.
2. Design and assemble a circuit that includes amplification, filtering, and ADC. Use software tools to analyze the conditioned signals.
3. Use a commercial ECG device or a DIY kit to record your heart's electrical activity. Analyze the electrical activity of the heart, including the P-wave, QRS complex, and T-wave.
4. Expose the eyes to light stimuli and record the retinal response using appropriate equipment.

MODULE III: Skin Impedance and Electrodes for Signal Acquisition (9 hours)

Electrical Properties of Skin: Skin impedance, frequency dependency, variability across individuals, Factors affecting skin impedance (hydration, temperature, electrode placement), **Types of Electrodes**: Surface electrodes: disc, gel, dry electrodes, Needle and microelectrodes, Electrode materials (silver/silver chloride, gold, platinum), **Electrode-Skin Interface**: Polarizable vs. non-polarizable electrodes, Electrode preparation and placement techniques, **Artifacts and Mitigation**: Motion artifacts, baseline drift, contact noise.

Self-Study topics (18 Hours):

1. Learn about skin impedance and frequency dependence, variability across individuals and actors affecting skin impedance.
2. Investigate how varying skin hydration levels affect impedance. Apply different hydration levels and measure impedance. Quantify the relationship between hydration and impedance.
3. Evaluate the performance of different electrode types. Record signals using disc, gel, and dry electrodes. Assess signal quality and impedance characteristics.
4. Study the impact of motion on signal quality. Develop strategies to minimize artifacts .

MODULE IV: Radiation Types and Effects on Humans (9 hours)

Types of Radiation: Ionizing radiation: alpha, beta, gamma, X-rays, neutrons, Non-ionizing radiation: UV, visible, infrared, microwave, RF, ultrasound, **Beneficial Applications of Radiation**: Diagnostic imaging (X-ray, CT, nuclear medicine), Therapeutic uses (radiotherapy, cancer treatment), **Harmful Effects of Radiation**: Deterministic vs. stochastic effects, **Long-term effects**: carcinogenesis, genetic mutations, **Radiation Protection and Safety**: Exposure limits (ICRP, NCRP guidelines), Shielding, time-distance-shielding principle, dosimetry and monitoring.

Self-Study topics (18 Hours):

1. Investigate harmful effects of radiation- Deterministic effects, stochastic effects and long-term effects.

2. Read and understand **ICRP Guidelines** (Recommend dose limits for occupational and public exposure) and **NCRP Guidelines** (Provide recommendations for radiation protection).
3. Study the characteristics of ionizing and non-ionizing radiations and their application in medical field including treatment of different types of ailments.
4. Study how different materials absorb and emit infrared radiation to understand thermal properties and insulation effectiveness.

Textbooks

1. 1. Arthur C. Guyton "Textbook of Medical Physiology", Prism Books (Pvt) Ltd & W.B. Saunders Company.1991
2. 2. R S Khandpur" Handbook of Medical Instrumentation", Tata McGraw Hill, New Delhi.2005.
3. John G. Webster: "Medical Instrumentation -Application and Design"; Houghton Mifflin Co., Boston, 1992
1. Geddes & Baker, "Principles of Applied Biomedical Instrumentation", John Wiley 3rd edition 1989

Reference books

1. W.J. Meredith & J.B. Massey, "Fundamental Physics of radiology", Varghese Publishing House, Bombay, 1992
2. D.J. Aidley: "The Physiology of Excitable cells", 3rd Ed., Cambridge University Press. 1998
1. Webb, S. (ed) "The Physics of Medical Imaging", Institute of Physics Publishing, Bristol, 1992.

NPTEL/SWAYAM Courses for reference:

1. Biomedical Instrumentation and Sensors- Dr. Piyush Lotia and Mr. Thaneshwar Kumar Sahu: Chhattisgarh Swami Vivekanand Technical University, Bhilai
https://onlinecourses.swayam2.ac.in/nou25_bt02/preview
2. Biomedical Signal Processing- Sudipta Mukhopadhyay: IIT, Kharagpur
nptel.ac.in/courses/108105101

No.	COURSE CONTENTS AND LECTURE SCHEDULE	No. of Hours (36 hours)
	MODULE I (9 hours)	
1.1	**Resting Membrane Potential**: Ionic basis of membrane potential (Na^+, K^+, Cl^-, Ca^{2+}), Nernst and Goldman equations.	2
1.2	Action Potential Generation: Threshold, depolarization, repolarization, hyperpolarization.	2
1.3	Role of ion channels and the sodium-potassium pump. **Propagation of Neural Impulses**: Saltatory vs. continuous conduction, Refractory periods, Myelinated vs. unmyelinated fibers.	2
1.4	**Synaptic Transmission**: Electrical and chemical synapses, Neurotransmitter release and receptor activation.	2
1.5	Electrode-tissue interfaces - electrode-electrolyte and electrolyte skin interfaces. Skin contact impedance.	1

MODULE II (9 hours)		
2.1	**Generation of Bio-potentials**: Origin of bioelectric signals: ECG, EEG, EMG, EOG, ERG, Electrical activity in excitable tissues.	2
2.2	**Characteristics of Bio-potentials**: Amplitude, frequency, waveform shape, signal-to-noise ratio.	2
2.3	**Principles of Bio-signal Acquisition**: Signal conditioning: amplification, filtering, sampling.	2
2.4	Analog-to-digital conversion, Noise sources and reduction techniques.	2
2.5	**Basic Instrumentation Systems**: Block diagrams of biomedical recording systems.	1
MODULE III (9 hours)		
3.1	**Electrical Properties of Skin**: Skin impedance, frequency dependency, variability across individuals.	2
3.2	Factors affecting skin impedance (hydration, temperature, electrode placement)	2
3.3	**Types of Electrodes**: Surface electrodes: disc, gel, dry electrodes, Needle and microelectrodes, Electrode materials (silver/silver chloride, gold, platinum).	2
3.4	**Electrode-Skin Interface**: Polarizable vs. non-polarizable electrodes, Electrode preparation and placement techniques.	
3.5	**Artifacts and Mitigation**: Motion artifacts, baseline drift, contact noise.	1
MODULE IV (9 hours)		
4.1	**Types of Radiation**: Ionizing radiation: alpha, beta, gamma, X-rays, neutrons, Non-ionizing radiation: UV, visible, infrared, microwave, RF, ultrasound.	2
4.2	**Beneficial Applications of Radiation**: Diagnostic imaging (X-ray, CT, nuclear medicine), Therapeutic uses (radiotherapy, cancer treatment).	2
4.3	**Harmful Effects of Radiation**: Deterministic vs. stochastic effects, **Long-term effects**: carcinogenesis, genetic mutations.	2
4.4	**Radiation Protection and Safety**: Exposure limits (ICRP, NCRP guidelines), Shielding, time-distance-shielding principle.	
4.5	Dosimetry and monitoring.	1

PROJECT

Description:

1.ECG Acquisition System

- Build a 3-lead ECG acquisition circuit using instrumentation amplifiers (e.g., AD620).
- Include analog filtering (low-pass, high-pass), and digitize the signal using an Arduino or similar microcontroller.
- Display waveform via serial plotter or a basic GUI in Python/MATLAB.

2.ECG Conditioning and Plotting.

- Use a simulated ECG signal (from MATLAB or online databases like PhysioNet) and apply digital filtering.
- Signal conditioning, noise reduction, plotting waveform shapes using MATLAB / Python / Octave

3.**EMG Signal Detection with Dry Electrodes**

- Measure basic muscle activity using dry electrodes and an instrumentation amplifier (like AD620).
- Signal amplification, identifying voluntary muscle contractions using Breadboard circuit + oscilloscope or Arduino

4. **EOG-Based Eye Movement Tracking (Two-Electrode Setup)**

- Capture basic horizontal eye movements using a two-electrode EOG setup.
- Detect saccades/blinks, analyze waveform shifts using Instrumentation amplifier and Arduino.

LESSON PLAN FOR PROJECT COMPONENT

No. Topic	Topic	No. of Hours (12)
1	Preliminary Design of the Project	2
2	Zeroth presentation (4th week)	2
3	Project work - First Phase	2
4	Interim Presentation	2
5	Project work - Final Phase & Report writing (discussions in class during project hours)	2
6	Final Evaluation, Presentation and Exhibition (11th and 12th weeks)	2
CO Assessment Questions		
CO1	1. Differentiate between electrical and chemical synapses. **[Understand]** 2. Derive the Nernst equation and use it to calculate the equilibrium potential for K^+. **[Analyze]** 3. Describe the sequence of ionic movements during depolarization and repolarization. **[Apply]** 4. How does the electrolyte-skin interface impact signal quality in ECG or EEG recordings? **[Analyze]**	
CO2	1. List the advantages and disadvantages of using dry electrodes versus gel-based electrodes. [Understand] 2. Compare the electrical properties of gold, platinum, and Ag/AgCl electrodes in clinical settings. [Analyze] 3. Explain the cause of baseline drift in bio-signal recording and suggest a solution. **[Apply]** 4. Differentiate between polarizable and non-polarizable electrodes with examples. **[Apply]**	

CO3	1. Explain the term "signal-to-noise ratio" (SNR) and its significance in biomedical signal analysis. **[Apply]** **2.** What is the role of a differential amplifier in a biomedical recording system? **[Apply]** **3.** List the main types of bioelectric signals (ECG, EEG, EMG, EOG, ERG) and mention their physiological origins. **[Understand]** 4. List common noise sources in bio-signal acquisition and suggest methods to reduce them. **[Understand]**
CO4	1. Differentiate between deterministic and stochastic effects of radiation exposure with examples. **[Apply]** 2. What are the exposure limits for occupational workers and the general public as per ICRP/NCRP guidelines? **[Apply]** 3. Explain the potential long-term health effects of repeated low-dose exposure to ionizing radiation. **[Understand]** 4. Explain how X-rays and CT scans differ in terms of image acquisition and diagnostic use. **[Apply]**

Prepared By
Dr. Reshma Jose, Assistant Professor
Dept of Biomedical Engineering

24HUT005	ENGINEERING ECONOMICS	L	T	P	R	C	Year of Introduction
		2	0	0	0	2	2024

Preamble:

To provide students with a fundamental concept of economics related to engineering industry, understanding of how price and output determined in different markets, macroeconomic concepts and to deliver the basic concepts of value engineering.

Prerequisite: None

Course Outcomes: After the completion of the course, the student will be able to

CO 1	To learn the basic economic concepts and to understand the fundamentals of various economic issues. **[Understand]**
CO 2	To acquire knowledge regarding the functioning of firms in different market situations and to develop decision making capability by applying concepts relating to cost and revenue. **[Apply]**
CO 3	To demarcate the macro-economic principles of monetary and fiscal systems, national income and stock market. **[understand]**
CO 4	To solve simple business problems using break -even analysis, capital budgeting techniques, and bring to bear the possibilities of value analysis and value engineering. **[Analyze]**

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO 1					1	2		2		3	3
CO 2					1	2		2		3	3
CO 3					1	2		2		3	3
CO 4					1	2		2		3	3

Assessment Pattern for Theory Component

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	√	√	√	√
Understand	√	√	√	√
Apply	√	√	√	√
Analyze	√	√	√	√
Evaluate				
Create				

Mark Distribution of CIA

Course Structure [L-T-P-R]	Theory [L]					Total Marks
	Attendance	Assignment	Test1	Test 2	Case study	
2-0-0-0	5	5	10	10	20	**50**

Total Marks distribution

Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	50	50	2 hrs.

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN	2 Questions from each module. Any full 6 Questions, each carrying 3 marks (6x3 =18 marks)	2 questions will be given from each module, of which 1 question should be answered. Each question can have a maximum of 3 subdivisions. Each question carries 8 marks. (4x8 = 32 marks)	50

MODULE I: DEMAND AND SUPPLY ANALYSIS (7 hours)

Basic Economic Concepts- Central problems of an economy -Production Possibility Curve-Utility-Law of diminishing marginal utility-Law of equi marginal utility- Law of Demand and Supply-Elasticity of Demand-Measurement of elasticity and its applications-Market Equilibrium-Changes in demand and Supply- its effects-Consumer surplus and producer surplus-Production functions in the short and Long run-Economies of scale-Internal and External economies-Cobb-Douglas Production Function. Taxation-Direct and indirect tax-Value Added Tax -Goods and Service Tax-Deadweight Loss. Case study on discounts for products in E-commerce.

Self-Study:(8 Hours)

1. Read and summarise what is economy and economics.
2. Read and make note on how does a consumers utility change when their income increases? Explain with the help of normal and inferior goods?
3. Explain the factors affecting the market demand of a commodity?
4. Study and make report on Impact of GST on small business in your city**.**

MODULE II: MARKET STRUCTURE (7 hours)

Costs Concepts- Social cost ,Private cost-Explicit and Implicit cost-Sunk cost- Opportunity cost-Short run and long run cost curves-Revenue concepts- shut down point-Markets-Perfect competition- Monopoly-Monopolistic Competition-Oligopoly (price and output determination)-Non- price competition-Product pricing-Methods of product pricing. Case study on Monopolistic competition (Industry- consumer electronics).

Self Study: (8 Hours)

1. Explain cost estimation techniques for engineering projects?
2. Read and summarise fixed and variable cost?
3. With real life example explain opportunity cost?
4. Explain the importance and methods of product pricing?

MODULE III: MACRO ECONOMIC CONCEPTS (9 hours)

National income -Concepts-Methods of estimating National income -Circular flow of income in two and four sector economy-Business financing -Bonds and shares- Financial Market-Stock market -Functions-Problems faced by the Indian stock market-Demat Account and Trading Account-Stock market indicators-SENSEX And NIFTY. Meaning and functions of Money-Central Banking-Inflation-Causes and effects -Measures to control inflation- Monetary and fiscal policies-Deflation-Case study on ”Impact of rising food prices on middle income house holds in your city”.

Self Study: (8 Hours)

1. Read and Summarise how the national income of India is calculated?
2. Explain the causes of inflation?
3. Study and make report on :"A New Investor's Journey in Stock Market Trading"
4. Explain the impact of deflation in an economy?

MODULE IV:VALUE ANALYSIS AND VALUE ENGINEERING (7 hours)

Value Analysis and Value Engineering-Cost value, -Exchange value, -Use value-, Esteem value-Aims, Advantages and Application areas of value engineering-Value Engineering Procedure-Break-even-Analysis -Capital Budgeting-Time value of money-Net Present Value Method-Benefit Cost Ratio-Internal Rate of Return-Payback-Accounting Rate of Return-Decision tree analysis-Game theory application in engineering. Case study on Value addition in food processing industry.

Self -study:(8 Hours)

1. Explain the Time value of money in project evaluation?
2. Read and summarise the importance of cost benefit analysis?
3. Explain engineering decision- making under uncertainity ?
4. Study and make report on" The rise of Gig economy and its impact on engineers".
5. Explain Nash equilibrium?

Textbooks

1. Managerial Economics- Geetika, Piyali Gosh and Choudry-Tata McGrawHill-2015.
2. Engineering Economy- H.G.Thuesen, W.JFabrycky-PHI-1966.
1. Engineering Economics -R.Paneerselvam-PHI-2012

Reference books

1. Leland Blank.P.E,Anthony Tarquin P.E-,Engineering Economy– *Mc Graw Hill* – 7th Edition.
2. Khan.M.Y-,IndianFinancialSystem– Tata Mc Graw Hill –2011
3. Donald .G.Newman,Jerome.p.Lavelle-Engineering Economics And Analysis-Enginerring pressTexas-2002
4. Chan.S.Park-Contemporary Engineering Economics-Prentice Hall of India Ltd-2001

NPTEL/SWAYAM Courses for reference:

1. Principles of Economics – Prof. V. Anantha Nageswaran, IIT Madras https://onlinecourses.nptel.ac.in/noc23_ec06/preview
2. Engineering Economic Analysis – Prof. Inderdeep Singh, IIT Roorkee https://nptel.ac.in/courses/110107141

No.	COURSE CONTENTS AND LECTURE SCHEDULE	No. of Hours (28 hours)
	MODULE I (7 hours)	
1.1	Basic Economic Concepts-Central Problems of an economy-Production possibility curve-Utility -Law of Diminishing Marginal Utility.	2
1.2	Law of Demand and Supply-Elasticity-Measurement of Elasticity and its applications.	1

1.3	Market Equilibrium - Changes in demand and supply-its effects- Consumer Surplus and Producer Surplus.	2
1.4	Production function in the short and Long run.	1
1.5	Economies of Scale-Internal and external economies-Cobb -Douglas production function, Taxation, Dead weight loss	1
MODULE II (7hours)		
2.1	Cost Concepts- Social cost -Private cost -Explicit and implicit cost-Sunk cost- Opportunity cost.	1
2.2	Short run and Long run cost Curves-Revenue Concepts. Shut down point	1
2.3	Markets-Perfect competition - Monopoly	2
2.4	Monopolistic competition - Oligopoly	2
2.5	Non-price Competition - Product pricing- Methods of Product Pricing.	1
MODULE III (7 hours)		
3.1	National Income-Concepts-Methods of estimating national income and difficulties.	2
3.2	Circular flow of income in two and four sector economy.	1
3.3	Business Financing	1
3.4	Financial market-Money market and capital market.	1
3.5	Stock Market-Functions-Problems faced by the Indian Stock Market	1
3.6	Meaning and functions of money, Inflation and Deflation.	1
MODULE IV (7 hours)		
4.1	Value analysis and value engineering-Cost value-Exchange value- Use value-Esteem value-Aims, Advantages and its Application- Areas of Value Engineering.	1
4.2	Value Engineering Procedure.	1
4.3	Break- even- analysis.	1
4.4	Capital Budgeting-Time value of money-Net Present Value Method-Benefit Cost Ratio-Internal Rate of Return-Payback-Accounting Rate Of Return.	2
4.5	Decision tree analysis.	2
CO Assessment Questions		
CO1	1.Examine why the problem of choice arise? **(Apply)** 2.Explain central economic problems? **(Analyze)** 3.Outline how do we solve the basic economic problems? **(Apply)** 4.Interpret the relation between price and demand? **(Apply)**	

CO2	1.Explain shut down point? **(Analyze)** 2.Explain why monopolist called a price taker? **(Analyze)** 3Examine the equilibrium of a firm under monopolistic competition? **(Apply)** 4.Outline the methods of product pricing? **(Apply)**
CO3	1.Explain the methods of estimating national income? **(Analyze)** 2.Distinguih between bonds and shares? **(Analyze)** 3.Examine the functions of money? **(Apply)** 4.Outline problems faced by Indian stock market? **(Apply)**
CO4	1. Explain break even analysis? **(Analyze)** 2. Examine capital budgeting methods? **(Apply)** 3.Distinguish between exchange value and use-value? **(Analyze**) 4.Digramatically explain decision tree analysis? **(Analyze)**

Prepared By
Ms. Vini Valsan, Assistant Professor
Dept of Applied Science and Humanities

24EST306	APPLIED DATA SCIENCE & ARTIFICIAL INTELLIGENCE	L	T	P	R	C	Year of Introduction
		3	1	0	0	4	2024

Preamble:
This course covers the fundamentals of data analysis, including essential concepts in statistics and linear algebra, which form the basis for working with real-world data. Students will learn how to clean, transform, and visualize data, as well as handle missing values and detect outliers. The course provides hands-on experience with Python programming and data science libraries such as Pandas, NumPy, and Matplotlib. Additionally, it introduces the basics of machine learning and explores how these techniques are applied in engineering and industrial contexts..

Prerequisite: Problem Solving and Algorithmic Thinking with Python(24ESR105)

Course Outcomes: After the completion of the course the student will be able to

CO1	Apply advanced mathematical concepts such as matrix operations, singular values, and principal component analysis to analyze and solve engineering problems. **[Apply]**
CO2	Interpret data using statistical methods including descriptive statistics, correlation, and regression analysis to derive meaningful insights and make informed decisions. **[Apply]**
CO3	Carry out exploratory data analysis (EDA), including data collection, cleaning, visualization, and statistical summarization **[Apply]**
CO4	Demonstrate foundational knowledge of machine learning paradigms and apply selected algorithms for classification and regression problems using Python **[Analyze]**

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO 1	3	3	3	3	2						
CO 2	3	3	3	3	3						2
CO 3	2	3	3	3	3				2		
CO 4	3	3	2	3	3			2			2

Assessment Pattern for Theory Component

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	✓	✓	✓	✓
Understand	✓	✓	✓	✓
Apply	✓	✓	✓	✓

Analyse		✓	✓	✓
Evaluate				
Create				

Assessment Pattern for the Lab component

Bloom's Category	**Continuous Assessment Tools**	
	Class work	**Test1**
Remember	✓	✓
Understand	✓	✓
Apply	✓	✓
Analyze	✓	✓
Evaluate		
Create		

Mark Distribution of CIA

Course Structure [L-T-P-R]	**Attendance**	**Assignment**	**Theory [L- T]**		**Total Marks**
			Test-1	**Test-2**	
3-1-0-0	5	10	12.5	12.5	40

Total Mark distribution

Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	40	60	2.5 hours

End Semester Examination [ESE]: Pattern

PATTERN	**PART A**	**PART B**	**ESE Marks**
PATTERN 1	8 Questions, each question carries 3 marks Marks: (3x8 =24 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 subdivisions. Each question carries 9 marks. Marks: (9x4 = 36 marks)	60

SYLLABUS

MODULE I: Linear Algebra for Data Science and AI (11 Hours)

Role of Linear Algebra in Data Representation and Analysis, Introduction to vectors: properties, vector addition and subtraction, scalar multiplication. Vector norms and distance metrics. Interpretation and computation. Matrix Decomposition- Singular Value Decomposition (SVD): concept and applications. Dimensionality Reduction, Principal Component Analysis.

Tutorial Questions:

- Vector addition, subtraction, and scalar multiplication
- Singular Value Decomposition

Self Study:(16 Hours)

- Principal Component Analysis (PCA) using Eigenvectors
- Orthogonality and Orthogonal Vectors
- Matrix Rank and Its Significance
- Vector and Matrix Broadcasting in NumPy.

MODULE II: Applied Probability and Statistics for AI and Data Science(11 Hours)

Basics of probability-random variables and statistical measures - rules in probability- Bayes theorem and its applications- statistical estimation Maximum Likelihood Estimator (MLE) - statistical summaries Correlation analysis- linear correlation - regression analysis- linear regression (using least square method)

Types of Analytics: Descriptive Analytics, Diagnostic Analytics, Predictive Analytics, Prescriptive Analytics, Big Data Analytics, Web Analytics, Social Media Analytics, Business Intelligence.

Tutorial Questions:

- Problems on Probability
- Measures of Dispersion
- Covariance and Correlation
- Linear Regression

Self Study:(16 Hours)

- Difference Between Classical and Empirical Probability
- Understanding Conditional Probability with Real-Life Applications
- Bayes' Theorem and Its Applications in Decision Making
- Real world case study on Social Media Analytics
- Application of Business Intelligence.

MODULE III: Exploratory Data Analysis (EDA) (14 Hours)

Introduction to data analysis and the EDA process. Types of data: structured, unstructured, categorical, numerical. Data collection techniques and sources (CSV files, APIs, databases). Data cleaning: fixing rows and columns, handling missing data, standardizing values, treating invalid entries, removing duplicates. Univariate analysis: distribution of individual variables. Bivariate analysis: relationships between two variables. Data visualization: histograms, box plots, scatterplots, pair plots, heatmaps.

Tutorial Questions:

- Data Cleaning
- Bivariate Analysis
- Boxplots

Self Study:(18 hours)

- Feature engineering techniques
- Outlier detection and treatment methods
- Advanced data visualization with Plotly and Bokeh
- Time series data analysis basics, Introduction to big data tools for EDA (e.g., Apache Spark)
- Introduction to clustering for exploratory analysis
- Data quality assessment metrics and frameworks

MODULE IV: Machine Learning and Python for Data Science (12 Hours)

Introduction to libraries: NumPy for numerical operations, Pandas for data manipulation, Matplotlib for visualization, SciPy for scientific computation. Introduction to machine learning: overview of supervised, unsupervised, and reinforcement learning. Key algorithms: regression, classification (logistic, Naïve Bayes), clustering (K-means). Model training and testing using scikit-learn. Evaluation metrics: accuracy, precision, recall, F1 score, confusion matrix. End-to-end implementation of a basic machine learning pipeline with real-world datasets.

Tutorial Questions:

1. K-Nearest Neighbors (KNN) algorithm.
2. Classification Examples
3. Data Structure Applications

Self Study:(18 Hours)

- Ensemble learning basics (Random Forest, Gradient Boosting)
- Basics of neural networks and deep learning frameworks (TensorFlow, PyTorch)
- Introduction to unsupervised learning beyond K-means (DBSCAN, hierarchical clustering)
- Project Title: "Customer Segmentation and Purchase Prediction using Machine Learning"

Textbooks

1. Jake VanderPlas,
2. Python Data Science Handbook. Essential Tools for Working with Data,O'Reilly Media, Year: 2016,First Edition
3. Peter Bruce, Andrew Bruce, Practical Statistics for Data Scientists: 50 Essential Concepts,O'Reilly Media, Year: 2017,Second Edition

Reference books

1. Mike X Cohen,Practical Linear Algebra for Data Science,O'Reilly Media, Inc,September 2022,First Edition
2. Joel Grus,Data Science from Scratch , O'Reilly Media, Inc.,April 2015,Second Edition
3. Suresh Kumar Mukhiya, Usman Ahmed,Hands-On Exploratory Data Analysis with Python,Packt Publishing,March 2020,First Edition

NPTEL/SWAYAM Courses for reference:

1. Probability Theory for Data Science, Prof. Ishapathik Das, IIT Tirupati https://onlinecourses.nptel.ac.in/noc24_ma64/preview
2. Python for Data Science (Python-based), Prof. Ragunathan Rengasamy, IIT Madras, https://onlinecourses.nptel.ac.in/noc22_cs32/preview
3. Fundamentals of Artificial Intelligence, Prof. Shyamanta M. Hazarika, IIT Guwahati, https://onlinecourses.nptel.ac.in/noc24_ge47/preview

No.	COURSE CONTENTS AND LECTURE SCHEDULE	No. of Hours [48 hours]
	MODULE 1 [11 hours]	
1.1	Role of Linear Algebra in Data Representation and Analysis,	1
1.2	Introduction to vectors: properties, vector addition and subtraction, scalar multiplication.	2
1.3	Vector norms and distance metrics.	2
1.4	Interpretation and computation.	1
1.5	Matrix Decomposition- Singular Value Decomposition (SVD): concept and applications.	1
1.6	Singular Value Decomposition (SVD): concept and applications.	1
1.7	Dimensionality Reduction,	2
1.8	Principal Component Analysis.	1
	MODULE II [11 hours]	
2.1	Basics of probability-random variables and statistical measures -	1
2.2	rules in probability	1
2.3	Bayes theorem and its applications- statistical estimation	1

2.4	Maximum Likelihood Estimator (MLE) - statistical summaries	1
2.5	Correlation analysis- linear correlation - regression analysis- .	1
2.6	linear regression (using least square method)	2
2.7	Types of Analytics: Descriptive Analytics, Diagnostic Analytics, Predictive Analytics,	2
2.8	Prescriptive Analytics, Big Data Analytics, Web Analytics,	1
2.9	Social Media Analytics, Business Intelligence	1
MODULE III [14 hours]		
3.1	Introduction to data analysis and the EDA process.	1
3.2	Types of data: structured, unstructured, categorical, numerical.	1
3.3	Data collection techniques and sources (CSV files, APIs, databases).	2
3.4	Data cleaning: fixing rows and columns, handling missing data,	2
3.5	Data cleaning: standardizing values, treating invalid entries, removing duplicates.	2
3.6	Univariate analysis: distribution of individual variables.	1
3.7	Bivariate analysis: relationships between two variables.	2
3.8	Data visualization: histograms, box plots, scatterplots	2
3.9	Data visualization: pair plots, heatmaps.	1
MODULE IV [12 hours]		
4.1	Introduction to libraries: NumPy for numerical operations	1
4.2	Pandas for data manipulation, Matplotlib for visualization	2
4.3	SciPy for scientific computation.	1
4.4	Introduction to machine learning: overview of supervised, unsupervised, and reinforcement learning.	2
4.5	Key algorithms: regression, classification (logistic, Naïve Bayes), clustering (K-means).	2
4.6	Model training and testing using scikit-learn.	1
4.7	Evaluation metrics: accuracy, precision, recall, F1 score, confusion matrix.	1
4.8	End-to-end implementation of a basic machine learning pipeline with real-world datasets.	2

CO Assessment Questions	
CO 1	1. Define conditional probability and solve a problem involving Bayes' Theorem using real-world data.(6 marks) **[Remember and Apply]** 2. A dataset contains exam scores of 100 students. Calculate the mean, median, mode, variance, and standard deviation. Interpret your results. (6 marks)**[Apply]** 3. Compare and contrast population and sample distributions. Provide examples where sampling distribution plays a critical role.(5 marks)**[Apply]**
CO 2	1. Given two vectors, compute their dot product, norm, and the distance between them.(5 marks) **[Apply]** 2. For a given 3×3 matrix, calculate its determinant, inverse, and eigenvalues using NumPy(6 marks). **[Apply]** 3. Explain the role of Singular Value Decomposition (SVD) in dimensionality reduction and demonstrate with a sample dataset.(6 marks**)[Remember and Apply]**
CO 3	1. Collect a small dataset from a public source (e.g., Kaggle or UCI), identify missing values, and demonstrate how to handle them using Pandas.(5 marks) **[Apply and Analyze]** 2. Perform univariate and bivariate analysis on a dataset. Include visualizations (boxplots, histograms, scatterplots) and interpret the patterns.(6 marks)**[Apply and Analyze]** 3. Discuss the role of outlier detection in data cleaning. Use a boxplot to identify outliers in a numeric feature and explain your treatment method.(5 marks)**[Apply and Analyze]**
CO 4	1. Write Python code to read a CSV file, display summary statistics, and plot a histogram using Pandas and Matplotlib.(6 marks) **[Apply and Analyze]** 2. Using NumPy, create two matrices and perform operations: addition, multiplication, transpose, and trace.(6 marks)**[Apply]** 3. Use Seaborn to create a heatmap showing correlation between features in a dataset. Interpret the visual result.(6 marks).**[Analyze]**

Prepared By

Dr. Sreeraj R
Professor, CSE

Dr. Krishnadas J
Associate Professor, CSE

Dr. Asha S
Associate Professor, CSE

24BML307	ANALOG ELECTRONICS LAB	L	T	P	R	C	Year of Introduction
		0	0	3	0	2	2024

Preamble: This laboratory is designed to bridge the gap between theoretical knowledge and real-world applications, providing students with hands-on experience in the realm of analog electronics.

Prerequisite: Basic knowledge on Electronic components and measuring instruments.

Course Outcomes: After the completion of the course, the student will be able to

CO1	Analyze the current-voltage characteristics and working principles of semiconductor devices such as diodes, transistors under different operating conditions. **[Analyze]**
CO2	Design and simulate basic operational amplifier (op-amp) circuits and analyze its output in response to multiple inputs. **[Apply]**
CO3	Assess the frequency response of analog circuits, including bandwidth, gain, and phase characteristics. **[Evaluate]**
CO4	Interpret measurement data to assess circuit behavior and troubleshoot issues effectively. **[Apply]**

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	3	3	2	3	2				2	2	
CO2	3	3	3	2	3				2	3	2
CO3	3	3	2	3	3				2	2	
CO4	3	3	2	3	3				2	2	

Assessment Pattern

Bloom's Category	Continuous Assessment Tools	
	Classwork	Test
Remember		
Understand	√	√
Apply	√	√
Analyze	√	
Evaluate	√	
Create		

Mark Distribution of CIA

Attendance	Classwork *(Preparation/Pre-Lab Work experiments, Viva and Timely completion of Lab Reports / Record)*	Internal Lab Exam	Total Marks
5	25	20	50

Mark Distribution of ESE

Procedure/ Preparatory work/Design/ Algorithm	Conduct of experiment/ Execution of work/ troubleshooting/ Programming	Result with valid inference/ Quality of Output	Viva voce	Record	Total
10	15	10	10	5	50

Total Mark distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	50	50	2 hours

End semester Examination Pattern

The following guidelines should be followed regarding award of marks
(a) Preliminary Work (10 Marks)
(b) Execution of Work (15 Marks)
(c) Quality of Work (10 Marks)
(d) Viva Voce (10 Marks)
(e) Record (5 Marks)

SYLLABUS- DETAILS OF EXPERIMENTS

1. Zener Diode characteristics (Forward and Reverse Characteristics)
- Take the readings of voltage and current in both forward and reverse biased conditions.
- Plot the values in normal graph
- Find the cut-in and break-down voltages

2. Full wave and Bridge Rectifier (With and Without Capacitor)
- Connect the circuit and note down the parameters of both input and output waveforms.
- Find the Ripple factor of filtered and non-filtered output

3. Power Supply Unit using 78XX and 79XX fixed voltage regulators
- Measure the output voltage with respect to the input voltage
- Plot the Vin –Vout graph.

4. Transistor as a switch
- Connect the circuit and note down the values of Delay time, Rise time, Storage time and Fall time.
- Plot the input –output waveforms.

5. Photo diode
- Take the readings of voltage and current readings with different conditions
- Plot the values in normal graph

6. Passive LP and HP filters (R&C Circuits)
- Take the output voltages by varying the input frequency.
- Calculate the gain and plot it against frequency

7. RC coupled Common Emitter amplifier with Voltage Divider Bias
- Note down the output voltages by varying the input frequency.
- Calculate the gain and plot it against frequency
- Calculate the bandwidth.

8. Basic OPAMP circuits inverting and non-inverting, Voltage follower, etc
- Measure the output voltage and find out the gain.
- Plot the frequency response graph

9. RC differentiator and integrator using Op-amps
- Measure the peak-to-peak voltage of output waveform
- Ploth both input and output waveforms

10. Summing and difference amplifiers using Op-amps

- Measure the parameters of output waveform
- Plot the waveforms in graph

11. Voltage comparator and Schmitt Trigger using Op-amps

- Measure the parameters of output waveform
- Plot the waveforms in graph

12. Opto Coupler using IC MCT2E

- Note down the base current and collector current.
- Plot the graph with I_B and I_C

13. Simulate inverting, non-inverting, and voltage follower configurations using P spice/ Multisim/ Tina

- Design the circuit and simulate the circuit
- Plot the frequency response

14. Simulate frequency response and gain of an RC-coupled amplifier using P spice/ Multisim/ Tina

- Design the circuit and simulate the circuit
- Plot the frequency response

Note: *A minimum of 12 experiments are to be completed.*

Self-Study (24 hrs.)

1. **Diode Basics**: Definition and function of a diode, Structure of a p-n junction, Forward and reverse bias conditions, Threshold voltage (cut-in voltage), Diode equation, Reverse saturation current, Breakdown voltage.
2. **Fundamentals of Rectifiers**: Half-Wave Rectifier, Full-Wave- Bridge Rectifier & Center-Tapped Rectifier, Capacitor Filter in Rectifiers, Ripple Factor, Efficiency, Peak Inverse Voltage (PIV).
3. Overview of 78XX and 79XX Regulators, Heat Dissipation, Heat Sinks, Transformer Rating, Capacitor Selection, Decoupling Capacitors
4. **Transistor as a Switch: Operating Regions**- Cut-Off Region (OFF State), Saturation Region (ON State), Active Region. **Working as a switch**: Base Drive, Saturation, Cut-Off, On- Time, Off- Time.
5. **Photodiode Fundamentals**- Structure, Working Principle and Dark Current, Modes of Operation: Photovoltaic Mode, Photoconductive Mode, Avalanche Mode,
6. Fundamental concepts and classifications of passive filters, types of filters, cut-off frequency (f_0), time constant (τ), phase shift, transfer function, frequency response.
7. Biasing and load conditions, coupling and by pass capacitors, transistor amplification, voltage divider biasing, advantages of voltage divider biasing.
8. Op-amp datasheets of IC 741, understand the fundamental concepts and characteristics of operational amplifiers.
9. Working of RC differentiator and integrator circuit, configuration and operation, Ideal Differentiator and Integrator, Frequency Response, Practical Considerations.
10. Inverting and Non-Inverting Summing Amplifier, Unity Gain and Scaling Summing Amplifier. Difference Amplifier: Differential Gain, Common-Mode Rejection Ratio (CMRR), Input and Output Impedance.
11. Fundamental concepts and configurations of voltage comparators, zero crossing detector, basic operation, key equations, open-loop gain, bandwidth, practical applications. **Schmitt Trigger**: Upper Threshold Voltage (V_1), Lower Threshold Voltage (V_2), Non-Inverting and Inverting Schmitt Trigger.
12. MCT2E datasheet, Opto coupler Basics, Electrical Isolation Techniques, applications in electronic circuits.

13. Learn to simulate inverting and non-inverting amplifiers, components, procedure and expected outcome.
14. Learn to simulate frequency response and gain of an RC-coupled amplifier, components, procedure and expected outcome.

List of Experiments

1. Zener Diode characteristics (Forward and Reverse Characteristics)
2. Full wave and Bridge Rectifier (With and Without Capacitor)
3. Power Supply Unit using 78XX and 79XX fixed voltage regulators
4. Transistor as a switch
5. Photo diode
6. Passive LP and HP filters (R&C Circuits)
7. RC coupled Common Emitter amplifier with Voltage Divider Bias
8. Basic OPAMP circuits inverting and non-inverting, Voltage follower, etc
9. RC differentiator and integrator using Op-amps
10. Summing and difference amplifiers using Op-amps
11. Voltage comparator and Schmitt Trigger using Op-amps
12. Optocoupler using IC MCT2E
13. Simulate inverting, non-inverting, and voltage follower configurations using P spice/ Multisim/ Tina
14. Simulate frequency response and gain of an RC-coupled amplifier using P spice/ Multisim/ Tina

Reference books

1. Chinmoy Saha, Arindham Halder and Debarati Ganguly, Basic Electronics – Principles and Applications, Cambridge University Press, 2018.
2. R L Boylestad and Nachelsky: Electronic Devices & Circuit Theory, 10thEd.Pearson.
3. David A. Bell: Electronic Devices and Circuits, 5th Edition.
4. Adel S. Sedra, Kenneth C. Smith: Microelectronics Circuits, 5th Ed., Oxford University Press, 2004
5. Jacob Milman, Christos C Halkias and SatyabrataJit: Millman's Electronic Devices & Ciruits, 4th Edition

NPTEL/SWAYAM

1. Analog Electronic Circuits- Prof. Pradip Mandal: IIT, Kharagpur
NPTEL :: Electrical Engineering - NOC:Analog Electronic Circuits
2. Analog Electronic Circuits- Prof. Shanthi Pavan: IIT, Madras
https://onlinecourses.nptel.ac.in/noc25_ee05/preview

CO Assessment Questions	
CO1	1. Explain the forward and reverse bias characteristics of a PN junction diode. **(Understand)** 2. What are the mechanisms of reverse breakdown in diodes? Differentiate between avalanche breakdown and Zener breakdown. **(Analyze)** 3. Compare the I-V characteristics of a Silicon diode with a standard PN junction diode. **(Evaluate)**

	4. Describe the three operating regions of a BJT: active, saturation, and cutoff. How do the collector-emitter and base-emitter voltages define these regions?**(Analyze)**
CO2	1. Design a summing amplifier circuit that adds two input voltages, V_1 and V_2, with equal weighting. Choose appropriate resistor values and explain your selection. **(Apply}** 2. Design a circuit using an op-amp that accepts three input voltages and provides an output that is the weighted sum of these inputs. Choose appropriate resistor values to achieve the desired weighting and simulate the circuit. **(Apply}** 3. Design a non-inverting amplifier circuit with a voltage gain of 5. **(Apply}** 4. Simulate the designed inverting amplifier circuit using a simulation tool like Multisim or TINA. Apply a 1 kHz sine wave input and observe the output waveform. What is the phase shift between the input and output? **(Analyze)**
CO3	1. Given a two-stage amplifier with individual bandwidths of 10 kHz and 20 kHz, calculate the overall bandwidth. **(Apply)** 2. Design a band-pass filter for a radio receiver with a center frequency of 100 MHz and a bandwidth of 5 MHz. **(Apply)** 3. Analyze how introducing negative feedback into an amplifier circuit affects its bandwidth. **(Analyze)** 4. Design a high-pass filter with a cutoff frequency of 500 Hz and a phase margin of 45°. **(Apply)**
CO4	1. An oscillator circuit is not producing the expected waveform. An oscillator circuit is not producing the expected waveform. **(Analyze)** 2. You measure the input and output power of a power amplifier and find that the efficiency is lower than expected. What factors could contribute to the observed inefficiency (e.g., thermal losses, component mismatches)? **(Analyze)** 3. You apply a sine wave input to a filter circuit and observe the output using an oscilloscope. The amplitude decreases significantly at higher frequencies. How would you determine the cutoff frequency of the filter? **(Apply)** 4. Using a multimeter, you measure the output voltage of a power supply and find it to be 5% below the expected value. What are the possible reasons for this voltage drop? **(Analyze)**

Prepared by:
Dr. Reshma Jose, Assistant Professor,
Dept of Biomedical Engineering

24BML308	DIGITAL ELECTRONICS LAB	L	T	P	R	C	Year of Introduction
		0	0	3	0	2	2024

Preamble: The course deals with the study of different digital ICs. The laboratory course gives hands-on experience to perform the experiments. Students will be able to design the circuits.

Prerequisite: Basic knowledge of Digital Electronics is expected.

Course Outcomes: After the completion of the course, the student will be able to

CO1	Understand the logic gates and study of the different ICs used in combinational and sequential circuits. **[Understand]**
CO2	Design and implement combinational circuits. **[Create]**
CO3	Design and implement sequential circuits. **[Create]**
CO4	Evaluate the performance of digital electronic circuits using simulators. **[Evaluate]**

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	3	3	2		3	2	2	3	3	2	2
CO2	3	3	2	2	3	2	2	3	3	2	2
CO3	3	3	3	2	3	2	2	3	3	2	2
CO4	2	2	3	2	3	2	2	3	3	2	2

Assessment Pattern

Bloom's Category	Continuous Assessment Tools	
	Classwork	Test
Remember		
Understand	√	√
Apply	√	√
Analyze	√	√
Evaluate	√	
Create	√	

Mark Distribution of CIA

Attendance	Classwork *(Preparation/Pre-Lab Work experiments, Viva and Timely completion of Lab Reports / Record)*	Internal Lab Exam	Total Marks
5	25	20	50

Mark Distribution of ESE

Procedure/ Preparatory work/Design/ Algorithm	Conduct of experiment/ Execution of work/ troubleshooting/ Programming	Result with valid inference/ Quality of Output	Viva voce	Record	Total
10	15	10	10	5	50

Total Mark distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	50	50	2 hours

End Semester Examination Pattern:

The following guidelines should be followed regarding award of marks
(a) Procedure/Preliminary Work/Design/Algorithm (10 Marks)
(b) Conduct of Experiment/Execution of Work/Programming (15 Marks)
(c) Result with Valid Inference/Quality of Output (10 Marks)
(d) Viva Voce (10 Marks)
(e) Record (5 Marks)

SYLLABUS- DETAILS OF EXPERIMENTS

Study of basic logic gates and realization of logic gates using universal gates.

- Verify the truth tables of basic logic gates: AND, OR, NOT, NAND, NOR, XOR, and XNOR.
- Realize basic gates (AND, OR, NOT, XOR, XNOR) using only universal gates (NAND and NOR).

Half adder, full adder, half subtractor and full subtractor using basic gates and universal gates.

- Design and verify the truth tables of half adder, full adder, half subtractor, and full subtractor using basic gates (AND, OR, XOR, NOT).
- Implement the same circuits using only universal gates (NAND and NOR).
- Analyze and compare the circuit behavior and outputs for different input combinations.
- Understand how arithmetic logic circuits can be built from fundamental digital components.

Design and implementation of code converters.

- Design and implement various code converters such as Binary to Gray, Gray to Binary, BCD to Excess-3, and Excess-3 to BCD using logic gates.
- Verify the truth tables for each conversion and observe the correctness of output for all valid input combinations.

Realization of simple multiplexer and demultiplexer using basic gates and study of their IC's .

- Design and implement a multiplexer and demultiplexer using basic logic gates.
- Verify their truth tables and switching functions based on select inputs and data lines.
- Study standard MUX/DEMUX ICs (e.g., IC 74153, IC 74139) and observe their pin configuration and operation.

Realization of decoder and encoder using basic gates and study of their IC's.

- Design and implement a 2-to-4 line decoder and a 4-to-2 line encoder using basic logic gates.
- Verify the truth tables and logic operation of each circuit for all valid input combinations.
- Study standard decoder and encoder ICs (e.g., IC 7442, IC 74147), including their pin configuration and functionality.

Design and implementation of comparators.

- Design and implement a digital comparator using basic logic gates.

- Verify the output for conditions A > B, A = B, and A < B by applying various input combinations.
- Understand the working principle of magnitude comparison between binary numbers.

Flip-flop circuits (SR,JK,T,D & Master slave) and their IC's.

- Design and implement SR, JK, T, and D flip-flops using basic gates and verify their truth tables.
- Observe the characteristic behavior and state transitions of each flip-flop type.
- Implement and analyze the working of a Master-Slave JK flip-flop to understand clocking and edge triggering.

Design and implementation of asynchronous counters.

- Design and implement asynchronous (ripple) counters such as 4-bit binary up, down, up/down counter using T or JK flip-flops.
- Verify the counting sequence and observe the pattern

Design and implementation of Johnson and ring counters.

- Design and implement **4-bit Johnson counter** and **4-bit Ring counter** using D flip-flops.
- Verify the **state sequence** and observe the number of unique states for each counter type.
- Understand the feedback mechanism in Johnson counters and circular shifting in Ring counters.

Design and implementation of synchronous counters.

- Design and implement a 4-bit synchronous up, down, up/down counter using D or JK flip-flops.
- Apply a common clock to all flip-flops and verify the counting sequence with no ripple delay.

Design and implement a sequence generator circuit.

- Design a sequence generator using flip-flops and logic gates to produce a predefined binary sequence (e.g., 1010, 1101).
- Use state diagrams and state tables to determine the required transitions and logic expressions.
- Implement the circuit using D or JK flip-flops and verify the output sequence using timing diagrams.

Familiarization of Simulators for Digital electronics circuits.

- Learn to use digital circuit simulators like Multisim, Logisim, Proteus, Tinkercad, or Digital Works for designing and testing digital circuits.
- Hands-on Practice: Simulate basic circuits such as logic gates, adders, flip-flops, and counters, and observe their real-time behavior.

Self study hours (24 hrs):

1. Simplify Boolean expressions using K-map and implement them using logic gates and universal gates.
2. Writing and simulating a simple AND, OR, NOT gate in Verilog HDL
3. Simplify Boolean expressions using K-map and implement them using logic gates and universal gates.
4. Study how binary, BCD, and Gray codes are used in digital sensors (e.g., thermometers, digital ECG).
5. Understand how multiplexers are used in medical signal routing (e.g., ECG leads).

6. Study of BCD to 7-segment display decoder.
7. Explore use of encoders in medical imaging and sensor data acquisition.
8. Applications of comparators in digital systems (e.g., memory addressing, sorting circuits, digital instrumentation).
9. Study applications of flip-flops in digital memory and biosignal edge detection.
10. Use pulse detection or waveform gating (common in ECG/EEG circuits) as case studies for counters and shift registers. Implement a pulse counter to measure heartbeats per minute.
11. Simulate the counters and verify output sequences.
12. Compare asynchronous vs synchronous counters in terms of speed and reliability.
13. Design a synchronous sequence generator that generates a specific sequence (e.g., 1011), using flip-flops and combinational logic.
14. Simulate a basic digital circuit (e.g., full adder or counter) using VHDL/Verilog on software like Xilinx or Quartus.

Textbooks

1. CHARLES H ROTH,Jr.Fundamentals of Logic Design,5th edition,Thomson books/cole.
2. A.Anandkumar,fundamentals of digital circuits,PHI learning ,2/e,2010
3. Thomas L Floyd, Digital Fundamentals, Pearson, 10/e,(2011)

Reference books

1. Taub & Schilling, Digital Integrated Electronics, Tata Mc Graw Hill,(2008), ISBN-13: 978-007-026508
2. R P Jain, Modern Digital Electronics, Tata Mc Graw Hill, 4/e, (2009).

NPTEL/SWAYAM

1. NPTEL :: Digital Electronic circuits, Prof Goutam Saha, IIT Kharagpur https://archive.nptel.ac.in/courses/108/105/108105132/
2. NPTEL :: Digital Circuits, Prof Santanu Chattopadhyay, IIT Kharagpur https://archive.nptel.ac.in/courses/108/105/108105113/
3. NPTEL :: Digital Design with Verilog, Dr. Aryabhartta Sahu. Dr Chandan Karta, IIT Guwahati https://onlinecourses.nptel.ac.in/noc25_cs25/preview

LIST OF EXPERIMENTS

No.	Experiments
1	Study of basic logic gates and realization of logic gates using universal gates.
2	Half adder, full adder, half subtractor and full subtractor using basic gates and universal gates.
3	Design and implementation of code converters.
4	Realization of simple multiplexer and demultiplexer using basic gates and study of their IC's .
5	Realization of decoder and encoder using basic gates and study of their IC's.

6	Design and implementation of comparators.
7	Flip-flop circuits (SR,JK,T,D & Master slave) and their IC's.
8	Design and implementation of asynchronous counters.
9	Design and implementation of Johnson and ring counters.
10	Design and implementation of synchronous counters.
11	Design and implement a sequence generator circuit.
12	Familiarization of Simulators for Digital electronics circuits.
**A minimum of 10 experiments must be performed compulsorily.*	
CO Assessment Questions	
CO1	1. Implement NOT using NOR gate. **(Apply)** 2. Verify the equation for A XOR B using the truth table. **(Understand)** 3. Verify the truth table of XOR and XNOR gates using IC 7486 and 7400-based configurations. **(Understand)** 4. Implement OR gate using universal gates. **(Apply)**
CO2	1. Implement a half adder circuit using universal gates. **(Apply)** 2. Design and set up binary to grey code converters. **(Create)** 3. Set up a 2 bit comparator circuit. **(Apply)** 4. Implement a 4:1 multiplexer using logic gates and ICs (e.g., IC 74153) and verify the output for all selection lines. **(Evaluate)**
CO3	1. Design and set up 3 bit asynchronous up counter. **(Apply)** 2. Generate the sequence 1-3-4-6 **(Evaluate)** 3. Design and set up 3 bit synchronous down counter using T-FF . **(Create)** 4. Construct and test a JK flip-flop using IC 7476. Verify the output for all input conditions (J, K, Clock). **(Create)**
CO4	1. Implement a decade counter in simulation software. **(Evaluate)** 2. Implement a Full adder circuit using half adders in simulation circuit. **(Evaluate)** 3. Simulate a ring counter and analyse the output sequence. **(Analyze)** 4. Analyse how JK flip flop is different from SR flip flop. Verify their output sequence in any simulation software. **(Analyze)**

Prepared by:
Ms. Supriya Mary Sunil, Assistant Professor
Dept of Biomedical Engineering

SEMESTER-IV
SYLLABUS

		L	T	P	R	C	Year of

24MAT421	**PROBABILITY DISTRIBUTIONS, NUMERICAL METHODS & TRANSFORMS**	**3**	**0**	**0**	**0**	**3**	**Introduction 2024**

Preamble: This course lays a strong foundation in probabilistic modelling, statistical inference, numerical methods, and transforms, equipping students with the tools to tackle complex real-world problems with confidence and precision. These concepts enable engineers to analyse data, model uncertainties, and design reliable, efficient systems across diverse engineering domains.

Prerequisite: Basics of statistics and probability laws, Fundamentals of differentiation and integration

Course Outcomes: After the completion of the course, the student will be able to

CO 1	Develop the ability to model and analyse real-world situations involving uncertainty using discrete and continuous probability distributions. **[Apply]**
CO 2	Apply statistical inferences concerning characteristics of a population based on attributes of samples drawn from the population.**[Apply]**
CO 3	Utilise numerical methods to differentiate and integrate multivariable functions, extending their application to advanced engineering models. **[Apply]**
CO 4	Determine the transforms of functions and understand their properties. **[Apply]**

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO 1	3	2	2	2							
CO 2	3	2	2	2							
CO 3	3	2	2	2	2						
CO 4	3	2	3								

Assessment Pattern

Bloom's Category	**Continuous Assessment Tools**			**End Semester Examination**
	Test1	**Test 2**	**Other tools**	
Remember	√	√	√	√
Understand	√	√	√	√
Apply	√	√	√	√
Analyze				
Evaluate				
Create				

Mark Distribution of CIA

Course Structure [L-T-P-R]	**Attendance**	**Theory [L-T]**			**Total Marks**
		Assignment	**Test-1**	**Test-2**	
3-0-0-0	5	10	12.5	12.5	40

Total Mark distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	40	60	2.5 hours

End Semester Examination [ESE]: Pattern			
PATTERN	**PART A**	**PART B**	**ESE Marks**
PATTERN 1	8 Questions, each question carries 3 marks Marks: (3x8 =24 marks)	2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 2 subdivisions. Each question carries 9 marks. Marks: (9x4 = 36 marks)	60

SYLLABUS

MODULE I: (Probability Distributions)[9 Hrs]

(Text 1: Relevant topics from sections 3.1,3.2,3.3,3.4,3.6,4.1,4.2,4.3,4.4)

Discrete and continuous random variables and their probability distributions, Expectation, mean and variance, Binomial distribution, Poisson distribution, Poisson approximation to the Binomial distribution, exponential and normal distributions.

Self-Study(14 hours):

1. Explain the probability mass function (PMF). Can you give an example of a discrete random variable?
2. Write down the significance of the expectation and variance in real-life contexts.
3. Under what conditions is a random variable said to follow a binomial distribution?
4. Derivation of the mean and variance of a Poisson distribution? Are they always equal?
5. Explain the Central Limit Theorem, and how does it relates to the normal distribution.
6. Identify which distribution to apply in real-life problems such as machine failures, survey results, or traffic patterns.

MODULE II: (Statistical Inference) [8 Hours]

(Text 1: Relevant topics from sections 1.1,7.1,7.2,8.1,8.2,8.3)

Population and samples, Sampling distribution of the mean and proportion (for large samples only), Confidence interval for single mean and single proportions (for large samples only). Test of hypotheses: Large sample test for single mean and single proportion, small sample t-tests for single mean and equality of means of normal population.

Self-Study (13 hours):

1. Write a short note on the difference between a population and a sample in statistics.
2. Identify the population and sample in a given real-world example (e.g., survey of college students).
3. Explain the difference between the standard deviation and the standard error.
4. Under what conditions can you apply the normal approximation for proportions?
5. When do you use the t-test instead of the Z-test? Explain with examples.
6. Relevance of probability and statistics in your branch of study.

MODULE III: (Numerical Differentiation and Integration)[9 Hours]

(Text 2: Relevant topics from sections 19.3,19.5,21.1)

Newton's forward and backwards interpolation method, Lagrange's interpolation method, Solution of ordinary differential Equations-Euler and Classical Runge-Kutta method of second and fourth order, Numerical Integration- Trapezoidal rule and Simpson's rule.

Self-Study (13 hours):

1. How do you identify whether to use forward or backwards interpolation for a given data set with an example?
2. Explain the situations in which Lagrange's interpolation formula and Newton's methods can be applied.
3. What are the assumptions and limitations of Euler's method?
4. Review the motivation for using the Runge-Kutta methods over Euler's method.
5. Identify real-world problems where these numerical methods are applicable (e.g., physics, engineering, finance).

MODULE IV: (Transforms)[10 Hours]

(Text 2: Relevant topics from sections 11.8,11.9)

(Text3: Relevant topics from sections 23.1,23.2,23.3,23.4,23.5,23.6,23.7,23.8,23.15)

Fourier transform and inverse Fourier transform, basic properties (without proof), Fourier sine and cosine transforms, inverse Fourier sine and cosine transform transforms, Z transform

Self-Study (14 hours):

1. Explain the types of functions that are suitable for applying the Fourier transform.
2. When do we prefer to use the sine or cosine transform over the general Fourier transform? Verify with examples.
3. Importance of Transforms in Your Branch of Study.
4. Write a note on the properties of the Z-transform.
5. How do the Fourier and Z-transforms differ in terms of domain (continuous vs. discrete)?

Text books

1. Devore J.L., "Probability and Statistics for Engineering and Sciences", Cengage learning, 9th edition.
2. Kreyszig, Advanced Engineering Mathematics, 10th Edition, John Wiley & Sons, 2016.
3. B.S. Grewal, Higher Engineering Mathematics, Khanna Publishers, 44th Edition, 2017.

Reference books

1. N.P. Bali,Dr.Manish Goyal,Goyal Laxmi publication,8th Edition,2011
2. Steven C Chapra, Raymond P.Canale, Numerical methods for Engineers, McGraw-Hill education ,8th Edition,2021
3. Papoulis, A. & Pillai, S.U., Probability, Random Variables and Stochastic Processes, McGraw Hill. 4th edition,2002
4. Ross, S. M., Introduction to Probability and Statistics for Engineers and Scientists, Academic Press, 6th edition,2020
5. Dr.Sudhir kumar Pundir,Integral Transform methods in Science and Engg.,CBS Publishers & Distributors, 1st edition,2017.

NPTEL/SWAYAM Courses for reference:

1.Dharmaraja, S. (2022). *Introduction to Probability Theory and Statistics* [Video course]. National Programme on Technology Enhanced Learning (NPTEL), IIT Delhi. https://archive.nptel.ac.in/courses/111/102/111102160/

2. Numerical Methods By Prof. Ameeya Kumar Nayak, Prof. Sanjeev Kumar, IIT Roorkee NPTEL :: Mathematics - NOC:Numerical methods

No.	COURSE CONTENTS AND LECTURE SCHEDULE	No. of Hours [36 hours]
	MODULE 1 [9 hours]	
1.1	Discrete random variables, Probability distributions of Discrete random variables	1
1.2	Expectation, Mean, Variance	1
1.3	Binomial Distribution	2
1.4	Poisson Distribution, Poisson approximation to the binomial distribution	1
1.5	Continuous random variables, Probability distributions of Discrete random variables	1
1.6	Exponential Distribution	1
1.7	Normal distribution	2
	MODULE II [8 hours]	
2.1	Population and samples, Sampling distribution of the mean and proportion (for large samples only)	1
2.2	Confidence interval for single mean (for large samples only)	1
2.3	Confidence interval for single proportions (for large samples only)	1
2.4	Test of hypotheses:	1
2.5	Large sample test for single mean	1
2.6	Large sample test for the single proportion	1
2.7	small sample t-tests for single mean and equality of means of normal population	2
	MODULE III [9 hours]	
3.1	Newton's forward & backwards interpolation method	2
3.2	Lagrange's interpolation method	1
3.3	Solution of ordinary differential equations-Euler method	1
3.4	Solution of ordinary differential equations- Classical Runge-Kutta method of second order	1

3.5	Solution of ordinary differential equations- Kutta method of fourth order	2
3.6	Numerical integration-Trapezoidal rule	1
3.7	Numerical integration- Simpson's rule	1
MODULE IV [10 hours]		
4.1	Fourier transform and inverse Fourier transform	2
4.2	Basic properties(without proof)	1
4.3	Fourier sine and cosine transforms	2
4.4	Inverse sine and cosine Fourier transform.	1
4.5	z transform	2
4.6	Properties of Z transform.	2
CO Assessment Questions		
CO1	1. A problem in Mechanics is given to three students A, B, C whose chances of solving it are ½ , 1/3 and ¼, respectively. What is the probability that the problem will be solved.**[Apply]** 2. If a random variable has a Poisson distribution such that P(1) = P(2) then find mean of the distribution and P(4).**[Analyze]** 3. The lifetime (in hours) of a water pump used at a construction site follows an exponential distribution with a mean lifetime of 2000 hours. (i) What is the probability that a pump fails before 1000 hours? (ii) What is the probability that a pump operates for more than 3000 hours without failure?**[Apply]** **Team Work**: 1. A company launches a new email marketing campaign. Based on past data, there's a 20% chance that any given customer will respond positively to the email. If the company sends the email to 15 customers: What is the probability that exactly 3 customers respond positively? What is the probability that at most 2 customers respond positively? How would the probability change if the success rate increased to 30%? 2. The amount of rainfall (in cm) during a storm at a construction site is modeled as a continuous random variable X with the following probability density function (PDF): $f(x) = \begin{cases} \frac{1}{5}, & 0 \le x \le 5 \\ 0, & \text{otherwise} \end{cases}$ (i) Verify whether f(x) is a valid probability density function. (ii) What is the probability that the rainfall during a storm is less than,2 cm? (iii) What is the probability that the rainfall is between 1 cm and 3 cm? Compare the answer of (ii) when rainfall is less than 3cm. and compare the answer of (iii) when rainfall is between 1.5cm and 3.5cm.	

CO2	1. Two independent samples of students from two colleges give the following heights (in cm): a. College A (n = 8): Mean = 170, SD = 6 b. College B (n = 10): Mean = 174, SD = 5 2. Test at 5% level whether the mean heights differ significantly.?**.[Apply]** 3. Explain the importance of random sampling in statistical inference.**[Understanding]** 4. In a survey of 600 people, 360 support a proposed law. Can we conclude at 1% significance level that the true proportion exceeds 0.55??**.[Apply]** **Team Work**: 1.Discuss and list examples of **Type I and Type II errors** in practical scenarios (e.g., drug approval, quality control, court verdicts). 2.Debate: Larger samples always give more accurate results in statistics."
CO3	1. Using Newton's method of interpolation find sin 52^0 from the data given below,when sin 45^0 = 0.7071, sin 50^0 = 0.7660, sin 55^0 = 0.8192, sin 60^0 = 0.8660?**[Apply]** 2. From the following data find log 656 No. : 654 658 659 661 Log : 2.8156 2.8182 2.8189 2.8202 **[Apply]** 3. Use Trapezoidal rule to estimate the integral 02ex2dx taking intervals.**[Apply]** **Team Work**: Solve the ODE dydt= -2y+ e-t , y 0=1 , t ∈[0 , 5] using Runga Kutta method of 4^{th} order (step size= h = 0.1) and compare the answer obtained using MATLAB's ordinary differential equation solver.
CO4	1.Use the time-shifting property to find the Fourier transform of f(x – x_0) given the transform of f(x).**[Apply]** 2.Explain how the convolution theorem simplifies the process of solving differential equations using Fourier transforms. **[Apply]** **Team Work**: 1. Each team discusses and presents one **property** of Fourier or Z-transform (e.g., time shift, linearity, scaling). 2. Each team researches an application of Fourier or Z-transform in engineering (e.g., image compression, signal filtering).

Prepared by,
Ms.Swapna Joseph,Ms.Rani Thomas
Department of Applied Sceince and Humanities

24BMT402	MICROCONTROLLERS AND INTERFACING	L	T	P	R	C	Year of Introduction
		3	1	0	0	4	2024

Preamble:
The course on *Microcontrollers and Interfacing* is designed to provide a comprehensive understanding of embedded systems through the study of microcontrollers—compact, efficient computing units widely used in modern electronic applications. This course aims to develop students' foundational knowledge of microcontroller architecture, programming, and peripheral interfacing techniques.

Prerequisite: Digital Electronics

Course Outcomes: After the completion of the course, the student will be able to

CO 1	Explain the architectural features and functional units of the Intel 8051 microcontroller to develop basic embedded applications involving interrupts, timers, ports, and memory organization.**[Understand]**
CO 2	Apply 8051 assembly language programming skills and instruction set knowledge to interface peripheral devices such as stepper motors, keyboards, rolling displays, ADCs, and DACs for embedded system applications. **[Apply]**
CO 3	Apply the principles of RISC and ARM design philosophy to develop basic programs using ARM instruction sets and to analyze the functioning of ARM processor components including pipelines, exceptions, and core extensions.**[Apply]**
CO 4	Apply the programming structure of Arduino and ESP32 boards to interface sensors such as LM35, PIR, and MPU6050, and to implement basic motor control using PWM techniques. **[Apply]**

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	3	2	3		2			2	2		3
CO2	3	2	3		3			3	3		3
CO3	3	2	2	3	3			3	3		3
CO4	3	2	3		3			3	3		3

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember				
Understand	√	√	√	√
Apply	√	√	√	√
Analyze				
Evaluate				
Create				

Mark Distribution of CIA

Course Structure [L-T-P-R]	Lecture [L]				Total Marks
	Attendance	Assignment	Test-1	Test-2	
3-1-0-0	5	10	12.5	12.5	40

Total Mark distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	40	60	2.5 hours

End Semester Examination [ESE]: Pattern			
PATTERN	**PART A**	**PART B**	**ESE Marks**
PATTERN 1	8 Questions (2 Questions from each module), each question carries 3 marks Marks: (3x8 =24 marks)	2 questions will be given from each module, out of which 1 should be answered. Each question can have a maximum of two sub-divisions. Each question carries 9 marks. Marks: (9x4 = 36 marks)	60

SYLLABUS

MODULE I: Intel 8051 (12 hours)

Architecture, Special Function Registers, Pin description, Interrupts, Stack and stack pointer, Addressing modes, Port organization and dual operations of 8051 ports, Instruction format, and Counter and Timer operation, Memory organization of 8051.

Tutorial Topics:Addresing modes, Timer & Counter programs

Self-study topics(18 hours) :

1. Create a pin diagram of 8051 using **any mind mapping tools**
2. Reading research articles about 8051 and write a review paper based on that

MODULE II: Instruction sets of 8051: (12 hours)

Data transfer instructions, Arithmetic, logical, compare and rotate instructions- Bit processing instructions- Program flow control instructions. Assembly language programming of 8051, Interfacing with 8051- stepper motor, keyboard& rolling display, ADC & DAC interfacing.

Tutorial Topics: Programming of 8051

Self-study topics(18 hours) :

1. Basis of Keil Programming,
2. Course study : 8051 Microcontroller - Embedded C and Assembly Language | Udemy(10 hour)

MODULE III: ARM Embedded Systems (12hours)

Introduction, RISC design philosophy, ARM design philosophy, ARM Processor Fundamentals, ARM core dataflow model, registers, current program status register, Pipeline, Exceptions, Interrupts and Vector Table, Core extensions. Introduction, Data processing instructions, Load - Store instruction, Software interrupt instructions, Program status register instructions, Loading constants, ARMv5E extensions, Conditional Execution.

Tutorial Topics: Programming of ARM controller

Self-study topics(18 hours) :

1. Basis of micro phyton programming for STM32 series and comparison of arm family
2. Course study : MicroPython Primer | Government of India : National Institute of Electronics & Information Technology (10 hour)

MODULE IV: Arduino UNO (12 hours)

Overview, Board description, Program structure - Elements of programming, Interfacing sensors-LM35, PIR Sensors, motor control - PWM. Overview of ESP32, Board description and programming structure of ESP32, Interfacing: analog sensors, MPU6050

Tutorial Topics: Programming of Arduino UNO & Interfacing

Self-study topics(18 hours) :

1. Basis of Proteus platform
2. Course project using Arduino UNO boards

Textbooks

1. The 8051 Microcontroller and Embedded Systems using Assembly and C : Muhammed Ali Mazidi and Janice GillispieMazidi
2. Andrew N Sloss, Dominic System and Chris Wright, "ARM System Developers Guide", Elsevier, Morgan Kaufman publisher, 1st Edition, 2008.
3. Arduino Programming: Step by-Step Guide to Master Arduino Hardware and Software: ISBN-13: 978 1976097713: Mark Torvalds
4. ESP32 Programming for the Internet of Things: A step-by step guide to the ESP32: Sever Spanulescu: CRC Press

Reference books

1. The 8051 Microcontroller: Kenneth J Ayala
2. Arduino Programming From Beginning to Advanced: Muhammad Ali Mazidi, Shujen Chen, EshraghGhaemi.
3. Internet of Things Projects with ESP32: Build exciting and powerful IoT projects using the all-new Espressif ESP32: Agus Kurniawan
4. Arduino 101 Beginners Guide: How to Get Started with Your Arduino: Erik Savasgard

NPTEL/SWAYAM Courses for reference:

1. NPTEL: Microprocessors and Microcontrollers: IIT Kharagpur, Prof. Santanu Chattopadhyay, https://nptel.ac.in/courses/108105102
2. NPTEL: Embedded System Design with ARM: IIT Kharagpur, Prof. Indranil Sengupta, Prof. Kamalika Datta, https://nptel.ac.in/courses/106105193
3. NPTEL: Introduction to Arduino: IIT Kharagpur, Prof. Sudip Misra ,https://nptel.ac.in/courses/106105166
4. Learn ESP32 with Arduino IDE (Random Nerd Tutorials): https://randomnerdtutorials.com/learn-esp32-with-arduino-ide/

No.	COURSE CONTENTS AND LECTURE SCHEDULE	No. of Hours [36 hours]
MODULE 1 [9 hours]		
1.1	Architecture	1
1.2	Special Function Registers	1
1.3	Pin description	1
1.4	Interrupts, Stack and stack pointer	1
1.5	Addressing modes, Port organization and dual operations of 8051 ports	1
1.6	Instruction format, and Counter and Timer operation	2
1.7	Memory organization of 8051.	2
MODULE II [9 hours]		
2.1	Data transfer instructions, Arithmetic, logical, compare and rotate instructions	1
2.2	Bit processing instructions- Program flow control instructions.	1
2.3	Assembly language programming of 8051	2
2.4	Interfacing with 8051- stepper motor, keyboard& rolling display, ADC & DAC interfacing	5
MODULE III [9 hours]		
3.1	Introduction, RISC design philosophy, ARM design philosophy,	1
3.2	ARM Processor Fundamentals, ARM core dataflow model, registers	2
3.3	current program status register, Pipeline, Exceptions, Interrupts and Vector Table	1
3.4	Core extensions. Introduction, Data processing instructions, Load - Store instruction	2
3.5	Software interrupt instructions, Program status register instructions	2
3.6	Loading constants, ARMv5E extensions, Conditional Execution.	1
MODULE IV [9 hours]		
4.1	Overview, Board description, Program structure	1
4.2	Elements of programming, Interfacing sensors-LM35	2
4.3	PIR Sensors, motor control - PWM.	2
4.4	Overview of ESP32, Board description and programming structure of ESP32	2
4.5	Interfacing: analog sensors, MPU6050	2

CO Assessment Questions	
CO-1	1. List any six salient features of the 8051 microcontroller.**[Understand]** 2. Differentiate between immediate and direct addressing modes in the 8051.**[Understand]** 3. Write an assembly language program to generate a 1-second delay using Timer 1 in mode 1 of the 8051 microcontroller.**[Apply]** 4. Explain the dual functionality of Port 0 in the 8051 microcontroller and how it is utilized in external memory interfacing.**[Apply]**
CO-2	1. List any three data transfer instructions in 8051 and explain their functions.**[Understand]** 2. Differentiate between logical and arithmetic instructions in 8051 with one example each.**[Understand]** **3.** Write an 8051 assembly language program to interface a stepper motor for rotating it 90 degrees clockwise using suitable port pins. Explain the role of data transfer and bit processing instructions used in your program.**[Apply]** **4.** Explain the different types of addressing modes in 8051 with suitable examples.**[Understand]**
CO-3	1. List any three key principles of the RISC design philosophy. **[Understand]** 2. Differentiate between ARM and traditional RISC design philosophies.**[Understand]** 3. Write an ARM assembly program to perform a simple arithmetic operation using data processing instructions. Explain each instruction used.**[Apply]** 4. Elaborate on ARMv5E core extensions and their significance in enhancing processor capabilities.**[Apply]**
CO-4	1. List the steps involved in interfacing an LM35 temperature sensor with an ESP32 board.**[Understand]** 2. Explain how the ESP32's ADC converts the analog voltage from the LM35 sensor into a digital value. .**[Understand]** 3. What is the role of PWM in controlling the speed of a DC motor using an ESP32.**[Understand]** 4. Describe how temperature readings from the LM35 sensor can be mapped to PWM values for motor speed control. .**[Apply]**

Prepared by
Ms. Jayalakshmi P K, Assistant Professor,
Dept of Biomedical Engineering

24BMT403	ELECTRONIC INSTRUMENTATION AND COMMUNICATION SYSTEMS	L	T	P	R	C	Year of Introduction
		4	0	0	0	4	2024

Preamble: This course introduces the fundamental principles and advanced techniques used in biomedical instrumentation. It focuses on the analysis of measurement systems, error sources, and sensor characteristics critical to accurate physiological monitoring. Students will gain practical skills in electrical parameter measurement, signal acquisition, and interpretation using various bridge methods and sensors. The course also explores the integration of digital interfaces and wireless technologies for efficient biomedical data acquisition and transmission.

Prerequisite: Basics of Electronics and Electrical Engineering, Analog Electronics

Course Outcomes: After the completion of the course, the student will be able to

CO 1	Analyze the functional elements, static/dynamic characteristics, and error sources in biomedical measurement systems to improve accuracy and reliability. **[Analyze]**
CO 2	Apply DC and AC bridge methods to measure electrical parameters and evaluate the sensitivity and accuracy of null balance techniques in biomedical applications. **[Apply]**
CO 3	Apply appropriate sensors and electrical measurement techniques to acquire and interpret physiological signals relevant to biomedical engineering **[Apply]**
CO 4	Analyze the role of digital interfaces and wireless technologies in biomedical instrumentation systems, focusing on data acquisition, transmission, and system performance. **[Analyze]**

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	3	3	2		2						2
CO2	3	3	3	2	2			2	2	2	2
CO3	3	3	3	2	2			2	2	2	2
CO4	3	3	3	3	2	3	2	2	2	2	2

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember				
Understand				
Apply	√	√	√	√
Analyze	√	√	√	√
Evaluate				
Create				

Course Structure [L-T-P-R]	Lecture [L]				
	Attendance	Assignment	Test-1	Test-2	Total Marks
4-0-0-0	5	10	12.5	12.5	40

Total Mark distribution

Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	40	60	2.5 hours

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	8 Questions (2 Questions from each module), each question carries 3 marks Marks: (3x8 =24 marks)	2 questions will be given from each module, out of which 1 should be answered. Each question can have a maximum of two sub-divisions. Each question carries 9 marks. Marks: (9x4 = 36 marks)	60

SYLLABUS

MODULE I: Measurement Systems (12 hours)

Introduction to Measurement: Importance and role of measurement in engineering, Functional elements of a measurement system, Static characteristics: accuracy, precision, resolution, sensitivity, reproducibility, Dynamic characteristics: speed of response, fidelity, lag, dynamic error.

Error and Uncertainty in Measurement: Sources and types of errors: systematic, random, gross errors, Statistical treatment of data, Uncertainty analysis and error propagation, Calibration procedures and importance of standards

Self-Study:(18 hours)

1. Review of basic electrical quantities (current, voltage, resistance), International standards for medical device calibration (e.g., ISO 13485, IEC 60601)
2. Analyze the measurement system of a hospital device (e.g., sphygmomanometer, thermometer) and identify each functional element.
3. Visit the biomedical instrumentation lab or hospital equipment room to observe the use of ECG, pulse oximeter, or BP monitor. Record the system characteristics and discuss in class.
4. Analyze a real-world case where measurement errors led to patient safety issues (e.g., BP monitor calibration error, faulty glucose meter).

MODULE II: DC and AC Null Methods of Measurement (12 hours)

DC Bridge Methods: Wheatstone bridge, Kelvin double bridge: principle and applications for resistance measurement

AC Bridge Methods: Maxwell's bridge, Hay's bridge: inductance measurement, Schering bridge: capacitance and dielectric loss measurement, Wien bridge: frequency measurement

Null Balance Principles, Concept and advantages of null balance methods, Factors affecting sensitivity and accuracy

Self-Study:(18 hours)

1. Read about bioimpedance measurement principles and explore practical issues in impedance measurement in living tissues.
2. Design and present a simple DC bridge circuit using resistors, simulate in software, and explain its biomedical application.
3. Build and test a Wheatstone bridge to measure an unknown resistor; extend the concept to skin-electrode resistance measurement.
4. Investigate the use of AC bridges in tissue impedance analysis and dielectric property measurement for cancer detection.

MODULE III : Sensors and Basic Electrical Measurements (12 hours)

Sensors for Physical Measurements: Measurement of Acceleration, Velocity, and Displacement, Measurement of Force and Torque, Pressure Measurements, Piezoelectric and optical sensors

Basic Electrical Measurements: Ammeter, voltmeter, wattmeter, energy meter: construction, principle, and applications, Measurement of power (single-phase, three-phase), energy, frequency, and phase angle, Magnetic Field Measurements, Measurement of Resistance, Capacitance, and Inductance

Self-Study:(18 hours)

1. Read about sensor principles (strain gauge, piezoelectric, optical) used in prosthetics and rehabilitation.
2. Work in teams to propose a sensor-based solution to monitor a physiological parameter (e.g., posture monitoring for patients, gait analysis).
3. Measure pulse or respiration rate using a piezoelectric sensor and analyze the recorded waveform.
4. Study the failure of a sensor system in a medical device (e.g., infusion pump occlusion detection) and how proper calibration could prevent it.

MODULE IV: Digital Interfaces and Wireless Instrumentation (12 hours)

Digital Techniques in Measurement Systems

ADC and DAC principles: Successive-Approximation ADCs Tracking or Servo ADCs Dual-Slope Integrating ADCs Flash (Parallel) Delta–Sigma ADCs, R-2R DAC, Multiplexing in measurement systems

Wireless Instrumentation: Introduction to wireless sensors and wireless transducers, Wireless Patient Monitoring Systems, Wireless communication protocols: Bluetooth, ZigBee, Wi-Fi for measurement systems

Self-Study:(18 hours)

1. Study ADC/DAC architectures and their impact on biomedical signal quality.
2. Read about Bluetooth, ZigBee, Wi-Fi use in healthcare devices.
3. Design a conceptual wireless monitoring system (e.g., for ECG, SpO_2, or temperature) and present the choice of protocol, power management, and data security.

4. Set up a simple wireless system (Arduino with Bluetooth or Wi-Fi module) to collect and transmit temperature or heart rate data.
5. Analyze a remote patient monitoring system (e.g., COVID-19 home monitoring) for its hardware, communication protocols, and challenges.

Text books

1. A.K. Sawhney, *Electrical and Electronic Measurements and Instrumentation* , published by Dhanpat Rai & Co, 19th Edition, 2020
2. D.V.S. Murty, *Transducers and Instrumentation* published by PHI Learning, 2nd Edition, 2022
3. H.S. Kalsi, *Electronic Instrumentation* published by McGraw-Hill Education India, 3rd Edition, 2018

Reference books

1. Ernest O. Doebelin, *Measurement Systems: Application and Design* , published by McGraw-Hill , 5th Edition, 2004
2. Relevant datasheets, application notes, and wireless module manuals

NPTEL/SWAYAM Courses for reference:

1. NPTEL :: Biomedical instruments (IIT Madras) https://nptel.ac.in/courses/108105101
2. NPTEL :: Electrical Measurement and Electronic Instruments (IIT Kharagpur) https://nptel.ac.in/courses/108105153

No.	COURSE CONTENTS AND LECTURE SCHEDULE	No. of Hours [48 hours]
	MODULE 1 [12 hours]	
1.1	Importance and role of measurement in engineering, Functional elements of a measurement system	3
1.2	Static characteristics: accuracy, precision, resolution, sensitivity, reproducibility	3
1.3	Dynamic characteristics: speed of response, fidelity, lag, dynamic error	3
1.4	Sources and types of errors: systematic, random, gross errors, Statistical treatment of data	2
1.5	Uncertainty analysis and error propagation, Calibration procedures and importance of standards	1
	MODULE II [12 hours]	
2.1	DC Bridge Methods: Wheatstone bridge, Kelvin double bridge: principle and applications for resistance measurement	4
2.2	AC Bridge Methods: Maxwell's bridge, Hay's bridge: inductance measurement, Schering bridge: capacitance and dielectric loss measurement, Wien bridge: frequency measurement	4
2.3	Null Balance Principles, Concept and advantages of null balance methods, Factors affecting sensitivity and accuracy	4

MODULE III [12 hours]		
3.1	Sensors for Physical Measurements: Measurement of Acceleration, Velocity, and Displacement, Measurement of Force and Torque, Pressure Measurements, Piezoelectric and optical sensors	4
3.2	Basic Electrical Measurements: Ammeter, voltmeter, wattmeter, energy meter: construction, principle, and applications	4
3.3	Measurement of power (single-phase, three-phase), energy, frequency, and phase angle	2
3.4	Magnetic Field Measurements, Measurement of Resistance, Capacitance, and Inductance	2
MODULE IV [12 hours]		
4.1	ADC and DAC principles: Successive-Approximation ADCs Tracking or Servo ADCs Dual-Slope Integrating ADCs Flash (Parallel)	2
4.2	Delta–Sigma ADCs, R-2R DAC, Multiplexing in measurement systems.	2
4.3	Introduction to wireless sensors and wireless transducers, Wireless Patient Monitoring Systems	4
4.4	Wireless communication protocols: Bluetooth, ZigBee, Wi-Fi for measurement systems	4
CO Assessment Questions		
CO-1	1. Analyze the measurement system of a hospital device like a sphygmomanometer. Identify and explain each functional element.**(Analyze)** **2.** Analyze how measurement errors, such as a BP monitor calibration error, will lead to a patient safety issue. Discuss the impact on the diagnosis and how it could have been prevented. **(Analyze)** **3.** Explain the role of dynamic characteristics such as fidelity, lag, and dynamic error in the functioning of instruments. Give examples from ECG or pulse oximeter systems**. (Apply)** **4.** Discuss the importance of statistical data treatment in reducing measurement errors. Illustrate with an example of data processing from a physiological signal. **(Apply)**	
CO-2	**1.** State the Wheatstone bridge principle and describe its application in biomedical measurements. **(Apply)** **2.** What is the advantage of using null balance methods in electrical measurements? Explain its significance in medical device calibration.**(Apply)**	

	3. Compare the principles and applications of the different AC bridges, such as Hay's bridge and Schering bridge **(Analyze)** **4.** Discuss the null balance principle and explain how it enhances the sensitivity and accuracy of electrical measurements in instrumentation systems**. (Analyze)**
CO-3	**1.** Explain the working principle of a piezoelectric sensor and its applications. **(Apply)** 2. Describe how an ammeter and a voltmeter are used to measure electrical quantities in a measurement system**. (Apply)** 3. Examine the failure of a sensor system in a device. How can proper calibration prevent such failures? **(Analyze)** 4. Explain the construction, principle, and application of a wattmeter in measurement systems. Discuss the challenges in measuring power in medical devices**.(Analyze)**
CO-4	1. Explain the working principle of an ADC and its importance in digital signal processing for instrumentation**.(Analyze)** 2. What are the advantages of using wireless communication protocols like Bluetooth and Wi-Fi in patient monitoring systems? **(Analyze)** 3. Describe a simple wireless measurement system setup using Arduino and Bluetooth or Wi-Fi to collect and transmit data such as temperature **(Apply & Create)** 4. Compare the various wireless communication protocols (Bluetooth, ZigBee, Wi-Fi) in the context of their suitability for medical device applications in terms of range, power consumption, and data transmission speed **(Analyze)**

Prepared By
Dr. Finto Raphel, Associate Professor
Ms. Minu C Davis, Assistant Professor
Dept of Biomedical Engineering

24BMR404	BIOSENSORS AND TRANSDUCERS	L	T	P	R	C	Year of Introduction
		3	0	0	1	4	2024

Preamble: To enable students to understand the principles, design, and applications of biosensors and transducers through a problem-based learning approach. This approach encourages critical thinking and collaboration by engaging students in solving real-world biomedical sensing problems.

Prerequisite: Basic knowledge of physics, chemistry, anatomy, and physiology principles.

Course Outcomes: After the completion of the course, the student will be able to

CO 1	Classify transducers and biosensors based on type, bio-recognition element, and signal transduction, and describe key biomolecule immobilization techniques.**[Understand]**
CO 2	Implement the principles of chemical bio-sensing to detect blood gases, pH, and glucose using electrochemical and lab-on-chip systems. **[Apply]**
CO 3	Examine the principles and characteristics of temperature sensors and blood flow measurement techniques, and blood pressure measurement, analyze their applicability in biomedical diagnostics. **[Analyze]**
CO 4	Analyze the aspects of design, materials, and fabrication processes involved in MEMS, NEMS, and nano-biosensor-based biomedical applications. **[Apply]**

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO 1	3	3	1	2	2				3	3	1
CO 2	3	3	3	2	2	1			3	3	3
CO 3	3	3	1	2	1	1			3	3	3
CO 4	3	3	3	2	2	1			3	3	3

Assessment Pattern for Theory Component

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	√	√	√	√
Understand	√	√	√	√
Apply	√	√	√	√
Analyze	√		√	√
Evaluate				
Create				

Assessment Pattern for Project Component

Bloom's Category	Continuous Assessment Tools		
	Evaluation 1	Evaluation 2	Report
Remember			
Understand			
Apply			
Analyze			
Evaluate			
Create	√	√	√

Mark Distribution of CIA								
Course Structure [L-T-P-R]	**Theory [L]**				**Project [R]**			**Total Marks**
	Attendance	**Assignment**	**Test-1**	**Test-2**	**Evaluation-1**	**Evaluation-2**	**Assignment**	
3-0-0-1	5	5	7.5	7.5	10	10	5	**50**

Total Marks distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	50	50	2 hrs.

End Semester Examination [ESE]: Pattern			
PATTERN	**PART A**	**PART B**	**ESE Marks**
PATTERN 2	2 Questions from each module. Any full 6 Questions, each carrying 3 marks (6x3 =18 marks)	2 questions will be given from each module, of which 1 question should be answered. Each question can have a maximum of 3 subdivisions. Each question carries 8 marks. (4x8 = 32 marks)	50

SYLLABUS

MODULE I: Biosensors and Transducers (9 hours)

Overview on basic Sensors and Transducers–types and classification –primary (Thermocouples, Photocells) and secondary (Amplifiers Analog-to-Digital Converters, Display units,), Active Transducers- Thermocouples, Photovoltaic cells, Piezoelectric crystals, Strain gauges, Passive: Resistance-Capacitive-Inductive-LVDT-Pressure transducers. Introduction to biosensor-classification based on bio recognition element. Immobilization techniques-Enzymatic, DNA, and antigen-antibody. Classification based on signal transduction–electrochemical, optical, colorimetric, piezoelectric.

Self-study1: (Design) (18 hours)
Use breadboard kits (or simulator like Tinker cad) to test:
1.Thermocouple**:** Read temperature and observe voltage using a multimeter.
2. Photocell**:** Measure voltage changes with varying light.
3. Piezoelectric: Generate voltage using mechanical pressure and submit a report.

MODULE II: Chemical Biosensors (9 hours)

Chemical Biosensors: Blood–Gas and Acid –Based-Electrochemical Sensors-Ion selective Field effect transistor –Reference Electrodes-Hydrogen Electrodes-Silver/silver chloride Electrodes-Calomel electrodes. Measurement of pH-Glass pH electrodes-oxygen electrodes-CO2 electrodes- Blood –Glucose sensor –Electronic Nose-Lab on Chip.

Self-study2 (Literature survey): (18 hours)

1.Identify a bio recognition element (bio sample) and using ISFET/electrochemical sensing technology.

2. Propose an idea in biomedical applications along with a literature review from minimum 10 research papers

MODULE III: Temperature sensors, blood flow, velocity measurement ,blood pressure(9 hours)

Temperature sensors - principle of operation- characteristics of thermo-resistive transducers, RTD-thermistor, thermoelectric transducers - thermocouple, Blood flow and velocity measurement-: Electromagnetic blood flowmeter and its Types- Ultrasonic blood flowmeters-Doppler shift flow velocity meters. Measurement of blood pressure: Sphygmomanometer-Indirect method, based on Korotkoff sound, oscillometric method.

Self-study 3 (Hospital visit): (18 hours)

Visit a hospital regionally,

1.Identify the principle behind temperature sensor, blood flow and velocity measurements.

2.Evaluate the instruments incorporating these sensors, tabulate its model, purpose, departments accommodating along with its clinical working procedure as a poster display.

MODULE IV: Sensor fabrication, MEMS, Nano biosensors (9 hours)

Introduction to MEMS: Micro fabricated devices with mechanical & electrical parts- BioMEMS overview - MEMS Based Biomedical Devices Pressure sensors for catheters, MEMS accelerometers in fall detection, Micro-needles for drug delivery, Advantages and Challenges of MEMS in Healthcare, Miniaturization, low power, integration with electronics, Cleaning, clogging, calibration(concepts only) , Overview of sensor design and fabrication: Substrate selection -Deposition –Patterning-Thick and Thin Film Sensors, Nano Biosensors: Definition-types of nano biosensors-Application in disease diagnosis(overview).

Self- study 4: (18 hours)

1.Design a prototype model for a non-invasive wearable sensor based on a biomedical application in a simulation environment (ex: ANSYS, COMSOL, MATLAB),

2.Physically Extract the varying electrical characteristics proportional to that noninvasive sample identified and applied (urine, sweat etc.).

Textbooks:

1. Brindley, Keith. Sensors and transducers. CRC Press ILlc, 1988.
2. Cromwell, Leslie, Fred J. Weibel, and Erich A. Pfeiffer. *Biomedical Instrumentation and Measurements*. Pearson Education, 2011.
3. Banica, Florinel-Gabriel. *Chemical Sensors and Biosensors: Fundamentals and Applications*. John Wiley & Sons, 2012.
4. Wang, Wanjun, and Steven A. Soper (Eds). *Bio-MEMS: Technologies and Applications*. CRC Press, 2006.

Reference books:

1. Turner, Anthony P. F., and P. N. Bartlett. *Biosensors: Fundamentals and Applications*. Oxford University Press, 1987.Geddes Becker, Principles of Applied Biomedical Instrumentation, John Wiley,1989.
2. Enderle, John D., and Joseph D. Bronzino. *Introduction to Biomedical Engineering*. Elsevier Academic Press, 2012.Chang Liu, Foundations of MEMS, Prentice Hall (2006)

3. Dally, James W., and William F. Riley. *Instrumentation for Engineering Measurements*. John Wiley & Sons, 1993.Albert Folch, Introduction to BioMEMS CRC (2012)
4. Wu, Aiguo, and Waheed S. Khan (Eds). *Nano biosensors: From Design to Applications*. Elsevier, 2020.

NPTEL/SWAYAM Courses for reference:

1. Sensors and Actuators :: Prof. Hardik Jeetendra Pandya || IISc Bangalore https://onlinecourses.nptel.ac.in/noc25_ee76/preview
2. Sensor Technologies: Physics, Fabrication, and Circuits :: Prof. Mitradip Bhattacharjee || IISER Bhopal https://onlinecourses.nptel.ac.in/noc24_ee83/preview
3. Master COMSOL Multiphysics® Simulation Software:: Bhibatsu Kuiri || UDEMY

No.	COURSE CONTENTS AND LECTURE SCHEDULE	No. of Hours (36 hours)
	MODULE I (9 hours)	
1.1	Transducers–types and classification –primary, and secondary	2
1.2	Transducers–types and classification- active and passive	2
1.3	Introduction to biosensor classification based on bio recognition element	2
1.4	Immobilization techniques- Enzymatic, DNA, antigen-antibody	1
1.5	Classification based on signal transduction–electrochemical, optical, colorimetric, piezoelectric.	2
	MODULE II (9 hours)	
2.1	Chemical Biosensors: Blood–Gas and Acid–Based	2
2.2	Electrochemical Sensors-Ion selective Field Effect Transistor	2
2.3	Reference Electrodes-Hydrogen Electrodes-Silver/silver chloride Electrodes-Calomel electrodes	2
2.4	Measurement of pH-Glass pH electrodes-oxygen electrodes-CO2 electrodes- Blood –Glucose sensor	2
2.5	Electronic Nose-Lab on Chip.	1
	MODULE III (9 hours)	
3.1	Temperature sensors-principle of operation--characteristics of thermo resistive transducers.	2
3.2	RTD-thermistor, thermoelectric transducers- thermocouple	2
3.3	Blood flow Electromagnetic blood flowmeter and its types-Ultrasonic blood flowmeters	1

3.4	Velocity measurement - Doppler shift flow velocity meters.	2
3.5	Sphygmomanometer- Indirect method, based on Korotkoff sound, oscillometric method	2
MODULE IV (9 hours)		
4.1	Introduction to MEMS: Micro fabricated devices with mechanical & electrical parts	1
4.2	MEMS Based Biomedical Devices Pressure sensors for catheters, MEMS accelerometers in fall detection, Micro-needles for drug delivery, Advantages and Challenges of MEMS in Healthcare	3
4.3	Miniaturization, low power, integration with electronics, Cleaning, clogging, calibration(concepts only)	1
4.4	Overview of sensor design and fabrication: Substrate selection - Deposition –Patterning-Thick and Thin Film Sensors	2
4.5	Nano Biosensors: Definition- types of nano biosensors-Application in disease diagnosis(overview).	2
	PROJECT	
Description: To immerse students in applying biosensing/transduction theory through project-based assignments. Students will gain practical experience analyzing bio-recognition elements, designing sensors, and optimizing Input-output characteristics. Emphasis will be placed on integrating sensing-transduction principles and methodologies with real-world biomedical applications.		
LESSON PLAN FOR PROJECT COMPONENT		
No. Topic	**Topic**	**No. of Hours (12)**
1	Preliminary Design of the Project	2
2	Zeroth presentation (4th week)	2
3	Project work - First Phase	2
4	Interim Presentation	2
5	Project work - Final Phase & Report writing (discussions in class during project hours)	2
6	Final Evaluation, Presentation and Exhibition (11th and 12th weeks)	2
CO Assessment Questions		
CO1	1. Define a transducer. How are transducers classified based on energy conversion? Give one example for each type. **(Remember)** 2. Classify biosensors based on the type of bio recognition element. Give one example for each category. **(Apply)** 3. Explain the role and types of display units and ADCs as secondary transducer components in biosensors. **(Understand)** 4. A biosensor is designed to detect a specific protein using antigen-antibody binding. Identify the type of biosensor and explain the role of the immobilization method and signal transduction technique. **(Analyze)**	

CO2	1. Demonstrate how a glass pH electrode is used to measure the acidity of a biological sample. **(Remember)** 2. Outline how oxygen electrodes function in detecting dissolved oxygen in blood samples. **(Apply)** 3. biosensor and relate it to clinical pH monitoring. **(Understand)** 4. Design a simple experimental setup using a glass pH electrode and a reference electrode to measure the pH of a buffered solution. **(Analyze)**
CO3	1. Explain the working principle of Resistance Temperature Detectors (RTDs) and compare them with thermistors. **(Remember)** 2. Differentiate between electromagnetic and ultrasonic blood flow measurement methods in biomedical applications. **(Understand)** 3. A patient-monitoring device uses both a thermistor and a Doppler ultrasound sensor. Justify the selection of these sensors. **(Apply)** 4. Propose suitable sensors for measuring temperature, blood pressure, and blood flow in a non-invasive diagnostic system. Justify their use in terms of clinical accuracy and safety. **(Analyze)**
CO4	1. Explain the working principle of a MEMS-based pressure sensor used in catheterization. **(Remember)** 2. Discuss the differences between thick film and thin film sensor fabrication techniques with relevant biomedical examples. **(Understand)** 3. Design a basic MEMS accelerometer-based system for patient fall detection. Illustrate the functional components involved. **(Analyze)** 4. Prepare a conceptual layout or schematic for a biomedical diagnostic tool that integrates MEMS sensors and nano-biosensing elements. Mention the purpose of each component. **(Apply)**

Prepared by
Mr. Jayakrishnan S, Asstistant Professor
Dept of Biomedical Engineering

24BML406	MICROCONTROLLERS AND INTERFACING LAB	L	T	P	R	C	Year of Introduction
		0	0	2	0	1	2024

Preamble: The *Microcontrollers and Interfacing Lab* is designed to provide hands-on experience in programming and interfacing microcontrollers for embedded system applications. This course aims to bridge the gap between theoretical concepts and practical implementation by enabling students to develop, test, and debug programs for popular microcontrollers such as the Intel 8051, Arduino, and ESP32.

Prerequisite: 24BMT402 Microcontrollers and Interfacing

Course Outcomes: After the completion of the course, the student will be able to

CO1	Apply 8051 assembly programming techniques to perform arithmetic, logical, and bit-level operations, and to interface basic I/O devices such as LEDs, displays, and keyboards. **[Apply]**
CO2	Analyze memory operations, code conversions, and data manipulation using 8051 for applications like matrix processing, array evaluations, and peripheral communication. **[Analyze]**
CO3	Apply Arduino-based interfacing concepts to control analog and digital devices such as ADCs, DACs, and stepper motors for signal processing and automation tasks. **[Apply]**
CO4	Evaluate embedded control strategies using ARM microcontroller simulations to implement GPIO-based applications like LED blinking and condition-triggered buzzer control. **[Evaluate]**

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	3	3	3	3	2					2	2
CO2	3	3	3	3	3					2	2
CO3	3	3	3	3	3					2	2
CO4	3	3	3	3	3					2	2

Assessment Pattern

Bloom's Category	Continuous Assessment Tools	
	Classwork	Test
Remember		
Understand	√	√
Apply	√	√
Analyze	√	
Evaluate	√	
Create		

Mark Distribution of CIA

Attendance	Classwork *(Preparation/Pre-Lab Work experiments, Viva and Timely completion of Lab Reports / Record)*	Internal Lab Exam	Total Marks
5	25	20	50

Mark Distribution of ESE					
Procedure/ Preparatory work/Design/ Algorithm	**Conduct of experiment/ Execution of work/ troubleshooting/ Programming**	**Result with valid inference/ Quality of Output**	**Viva voce**	**Record**	**Total**
10	**15**	**10**	**10**	**5**	**50**

Total Mark distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	50	50	2 hours 30 minutes

End Semester Examination Pattern:

The following guidelines should be followed regarding award of marks
(a) Procedure/Preliminary Work/Design/Algorithm (10 Marks)
(b) Conduct of Experiment/Execution of Work/Programming (15 Marks)
(c) Result with Valid Inference/Quality of Output (10 Marks)
(d) Viva Voce (10 Marks)
(e) Record (5 Marks)

SYLLABUS- DETAILS OF EXPERIMENTS

Familiarization with 8051 based kit, programming

8051 - arithmetic operations/ logical operations
- Basic arithmetic Operations like addition
- Logical operations like And,Or

8051 - Bit manipulation & Data format conversion
- Write assembly code to set, clear, toggle bits in SFRs or ports.
- Convert a binary number to BCD or ASCII and vice versa.

8051 - Finding largest/ smallest elements in an array
- Store an array in internal RAM.
- Use loops and conditional jumps (CJNE) to compare each element.
- Store the maximum/minimum.

8051- Matrix addition.
- Store two matrices in memory.
- Add corresponding elements.
- Store result in new memory locations.

8051- Data transfer/exchange between specified memory locations.
1. Use internal and external RAM.
2. Swap contents between two arrays.

8051- Code conversion – Hex to Decimal/ASCII to Decimal and vice versa.
Take input in HEX.
- Convert to BCD or ASCII for display.
- Output on a port or serial terminal.

Time delay generation and relay interface.
- Write timer-based delay subroutine.

- Use delay to switch relay ON/OFF.

Display (LED/Seven segments/LCD) and keyboard interface

- Connect LED/LCD to port pins.
- Write code to display character, number.
- Scan a keypad matrix and display key pressed.

ADC & DAC interface with wave form generation with Arduino

- Use Arduino analog input pins to read sensor signal.
- Output waveform using DAC or PWM.

Stepper motor interfacing

- Write code to energize coils in sequence.
- Rotate stepper motor forward/backward.

Realization of Boolean expression through port.

- Implement simple Boolean logic (AND, OR, NOT) using port pins.
- Connect switches as inputs, LEDs as outputs.

LED Blinking using GPIO (ARM Microcontroller Simulation)

- Use ARM simulator (Keil MDK) or STM32CubeIDE.
- Write C program to toggle GPIO pin.

Buzzer Simulation with Condition-Based Trigger (ARM Microcontroller)

- Simulate a condition (e.g., button press or sensor reading).
- Activate buzzer via GPIO.

Note: A minimum of 10 experiments are to be completed.

Self-study hours (24 hrs.):

- 8051 Architecture and Pin Diagram
- Memory Organization in 8051 (Code vs Data Memory)
- Special Function Registers (SFRs) in 8051
- Data transfer instructions
- Arithmetic, logical, compare and rotate instructions
- Bit processing instructions
- Timers and Counters in 8051
- Basis of Keil Programming: Free ARM Cortex-M Tutorial - ARM Cortex-M : Modular Embedded Systems Design
- Basis of Keil Programming
- Basics of Boolean Algebra and Karnaugh Maps
- Introduction to ARM Architecture
- Arduino Basics and Pin Mapping

Textbooks

1. The 8051 Microcontroller and Embedded Systems using Assembly and C : Muhammed Ali Mazidi and Janice GillispieMazidi
2. Andrew N Sloss, Dominic System and Chris Wright, "ARM System Developers Guide", Elsevier, Morgan Kaufman publisher, 1st Edition, 2008.
3. Arduino Programming: Step by-Step Guide to Master Arduino Hardware and Software: ISBN-13: 978 1976097713: Mark Torvalds
4. ESP32 Programming for the Internet of Things: A step-by step guide to the ESP32: Sever Spanulescu: CRC Press.

Reference books

1. The 8051 Microcontroller: Kenneth J Ayala
2. Arduino Programming From Beginning to Advanced: Muhammad Ali Mazidi, Shujen Chen, EshraghGhaemi.

3. Internet of Things Projects with ESP32: Build exciting and powerful IoT projects using the all-new Espressif ESP32: Agus Kurniawan
4. Arduino 101 Beginners Guide: How to Get Started with Your Arduino: Erik Savasgard

NPTEL/SWAYAM

1. NPTEL :: Microprocessors And Microcontrollers, Prof Santanu Chattopadhyay IIT Kharagpur nptel.ac.in/courses/108105102
2. NPTEL :: Embedded System Design with ARM, Prof. Indranil Sengupta, Prof. Kamalika Datta , IIT Kharagpur nptel.ac.in/courses/106105193
3. NPTEL :: Introduction to internet of things, Prof. Sudip Misra, IIT Kharagpur https://nptel.ac.in/courses/106105166
4. Learn ESP32 with Arduino IDE (Random Nerd Tutorials): https://randomnerdtutorials.com/learn-esp32-with-arduino-ide/

LIST OF EXPERIMENTS

No.	Experiments
1	Familiarization with 8051 based kit, programming
2	8051 - arithmetic operations/ logical operations
3	8051 - Bit manipulation & Data format conversion
4	8051 - Finding largest/ smallest elements in an array
5	8051- Matrix addition.
6	8051- Data transfer/exchange between specified memory locations.
7	8051- Code conversion – Hex to Decimal/ASCII to Decimal and vice versa.
8	Time delay generation and relay interface
9	Display (LED/Seven segments/LCD) and keyboard interface
10	ADC & DAC interface with wave form generation with Arduino
11	Stepper motor interfacing
12	Realization of Boolean expression through port.
13	LED Blinking using GPIO (ARM Microcontroller Simulation)
14	Buzzer Simulation with Condition-Based Trigger (ARM Microcontroller)

**A minimum of 10 experiments must be performed compulsorily.*

CO Assessment Questions	
CO1	Develop an 8051 assembly program to toggle specific bits of Port 1 continuously with a delay. **(Apply)**
CO2	Analyze how internal and external memory is accessed by the 8051 in a mixed code-data scenario. **(Analyze)**
CO3	Interface a DAC with Arduino and write code to generate a triangular waveform. **(Apply)**
CO4	Design and evaluate a condition-triggered alert system using GPIO interrupts on an ARM controller. **(Create)**

Prepared by,
Ms. Jayalakshmi P K , Assistant Professor
Dept of Biomedical Engineering

24BML407	Medical Electronics Lab	L	T	P	R	C	Year of Introduction
		0	0	3	0	2	2024

Preamble: This provides hands-on experience with electronic circuits and biomedical devices, helping students understand, design, and analyze systems used in medical diagnostics and monitoring.

Prerequisite: Basic knowledge of analog and digital electronics, operational amplifiers, and biomedical instrumentation principles, electronic components such as resistors, capacitors and inductors and functioning of electronic measuring equipment, power supplies and bread board are expected.

Course Outcomes: After the completion of the course, the student will be able to

CO1	Familiarize with the working and application of basic biomedical instruments such as stethoscope and sphygmomanometer.**[Understand]**
CO2	Design and implement analog and digital circuits using operational amplifiers and specialized ICs for biomedical signal processing.**[Create]**
CO3	Integrate biomedical transducers like thermistors, LDRs, and optocouplers into functional circuits for physiological signal detection and conversion.**[Create]**
CO4	Effectively measure, analyze, and troubleshoot biomedical electronic circuits using standard laboratory instruments and testing procedures.**[Apply]**

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1							2	3	3		2
CO2	2	2	3	3		2	3	3	3	3	3
CO3	2	2	3	3		2	3	3	3	3	3
CO4	2	2						3	3		3

Assessment Pattern

Bloom's Category	Continuous Assessment Tools	
	Classwork	Test
Remember		
Understand	√	√
Apply	√	√
Analyze	√	√
Evaluate	√	
Create	√	√

Mark Distribution of CIA

Attendance	Classwork *(Preparation/Pre-Lab Work experiments, Viva and Timely completion of Lab Reports / Record)*	Internal Lab Exam	Total Marks
5	25	20	50

Mark Distribution of ESE					
Procedure/ Preparatory work/Design/ Algorithm	**Conduct of experiment/ Execution of work/ troubleshooting/ Programming**	**Result with valid inference/ Quality of Output**	**Viva voce**	**Record**	**Total**
10	**15**	**10**	**10**	**5**	**50**

Total Mark distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	50	50	2 hours 30 minutes

End Semester Examination Pattern:

The following guidelines should be followed regarding award of marks
(a) Procedure/Preliminary Work/Design/Algorithm (10 Marks)
(b) Conduct of Experiment/Execution of Work/Programming (15 Marks)
(c) Result with Valid Inference/Quality of Output (10 Marks)
(d) Viva Voce (10 Marks)
(e) Record (5 Marks)

SYLLABUS- DETAILS OF EXPERIMENTS

Bio-amplifier
- Take the readings of peak to peak voltage for both common mode and differential mode of AC input and DC input
- Calculate the CMRR

Active Filters – Lpf, Hpf
- Take the readings peak to peak voltage of output by varying the frequency of the input
- Calculate the gain and plot the frequency response graph
- Find out the lower cut off and higher cut off frequencies

Frequency to Voltage Converters
- Take down the output voltage by varying the input frequency
- Plot the graph and find the sensitivity

Voltage to Frequency Converters
- Take down the output frequency by varying the input voltage
- Plot the graph and find the sensitivity

Basic principles of biotelemetry using IC 4046
- Connect the first part of circuit and make the free running frequency to 2.5 KHz
- Feed the input wave and observe the modulated wave form.
- Connect the second part and observe the demodulated waveform
- Draw the input and output waveforms

Flash ADC
- Vary the input voltage and note the voltage at which the corresponding LED glows.
- Plot the graph and find out the step size voltage

R-2R Ladder DAC
- Note down the output voltage with respect to binary input.

- Plot the graph and find out the theoretical sensitivity and practical sensitivity

MUX & DEMUX using IC4051

- Connect the circuit and note down the values in tabulation table.

Pacemaker circuit

- Note down the time period and voltages of output waveforms.
- Draw the output waveforms and find out the beats per minute.

Thermistor Characteristics

- Set up the experiment and start boiling the water
- Note down the output voltage and current with respect to the temperature
- Plot the graph and calculate the temperature coefficient and thermistor constant.

Study of LDR and Its Characteristics

- Set up the experiment and note down the values of voltage current and resistance.
- Plot the graph and calculate the sensitivity

Study of IC 723- Low voltage and High voltage regulation.

- Vary the input voltage and note the corresponding output voltage.
- Plot the graph

Astable and monostable using IC741

- Observe the output waveforms
- Plot the graph

Astable and monostable using IC555

- Observe the waveforms of output and capacitor voltage
- Plot the graph

Study of Medical Equipments

1. Stethoscope
2. Sphygmomanometer

- Identify its major parts and learn to use the equipment properly

Self study hours (24 hrs):

1. Study the differential amplifier configuration, common mode rejection ratio (CMRR), and applications in ECG signal acquisition.
2. Study Different types of filters and its frequency response(Notch & Bandpass Filters), and relevance in biomedical signal filtering.
3. Explore how F-V converters are used in heart rate monitoring, pulse frequency sensing, and respiratory signal analysis.
4. Study V-F converter circuits, linearity considerations, and applications in instrumentation.
5. Research FM modulation/demodulation, PLL operation using IC4046, and biomedical telemetry systems.
6. Understand comparator ladder networks, priority encoders, and timing analysis in high-speed ADCs.
7. Study binary-weighted and R-2R DAC design, digital-to-analog conversion process, and sensitivity.
8. Review digital multiplexing/demultiplexing, truth tables, and use in data acquisition systems.
9. Learn heart pacing principles,need of pacemaker,different types of pacemaker, and safety considerations.
10. Explore thermistor types, temperature-resistance behavior, and biomedical temperature sensing.

11. Review LDR working principle, photoresistance, and light-dependent sensing applications.
12. Learn about voltage regulation concepts, Difference between line and load regulations
13. Understand multivibrator principles, timing calculations, and waveform generation,Study schmitt trigger circuit and its working
14. Study IC555 internal diagram,working, pulse width calculation and simulate the circuit with 50% duty cycle.
15. Research acoustic stethoscope principles, electronic enhancements, and auscultation techniques.
16. Study non-invasive blood pressure measurement techniques and clinical usage.

Textbooks

1. Boylestead&Neshelsky, Electronic Devices & Circuit Theory, Prentice Hall of India.2003
2. Millman&Halkias, Electronic Devices & Circuits, Tata McGraw Hill, New Delhi.1996

Reference books

1.K.A. Navas,Electronics Lab Manual, Volume 2,PHI Learning
2.Ramakant A. Gayakwad, Op-Amp and Linear Integrated Circuits", Pearson Education Asia. 4thed.

NPTEL/SWAYAM

NPTEL: Biomedical Instrumentation & Sensors, Dr. Piyush Lotia & Mr. Thaneshwar Kumar Sahu
https://onlinecourses.swayam2.ac.in/nou23_bt05/preview

**A minimum of 10 experiments must be performed compulsorily.*

CO Assessment Questions

CO1	1. Explain the working principle of a stethoscope. **[Understand]** 2. Explain the working principle of sphygmomanometer . **[Understand]**
CO2	1. Design 4-Bit R-2R Ladder DAC **[Create]** 2. Design a Multiplexer and Demultiplexer circuit **[Create]** 3. Design a circuit for transmit and receive a biosignal. **[Create]**
CO3	1. Design a circuit for sensing the temperature and glow an LED if the temperature goes above 50 degree celsius. **[Create]** 2. Design a circuit for obtain the P-I Characteristics of LDR. **[Analyze]** 3. Design an 2-bit ADC **[Create]**
CO4	1. Design a pacemaker circuit with 80 beats per minute **[Create]** 2. Design a circuit for generating a squarewave with 80% Duty Cycle. **[Create]**

Prepared By
Ms.Lavina Joseph, Assistant Professor
Dept of Biomedical Engineering

24PWT208	UHV II, Life skills and community work	L	T	P	R	C	Year of Introduction
		1	0	0	0	1	2024

Preamble: This course aims to foster holistic development by integrating Universal Human Values (UHV II), essential life skills, and community engagement. Through self-reflection, discussion, and experiential learning, students will develop ethical awareness, emotional intelligence, and a sense of social responsibility. The course encourages active citizenship by engaging students in real-life community work, enabling them to apply values and skills for societal transformation.

Prerequisite: NIL

Course Outcomes: After the completion of the course the student will be able to

CO1	Demonstrate an understanding of harmony in the self, family, society, nature, and existence by applying the principles of universal human values to reflect on ethical living, responsible relationships, ecological balance, and professional conduct. **[Evaluate]**
CO2	Apply principles of emotional intelligence, effective communication, and critical thinking to personal and professional contexts, and demonstrate the ability to manage time, solve problems, and interact empathetically and assertively. **[Apply]**
CO3	Demonstrate leadership, teamwork, and social responsibility by planning and implementing community-based initiatives that integrate human values, sustainable development principles, and participatory approaches, and critically reflect on their societal impact. **[Evaluate]**

CO – PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	3	2				3	3	3		2	
CO2	2	3	2	2				3	3	3	2
CO3		3	3	2	2	3	3	3	3	3	3

Assessment Pattern

Blooms Category	Continuous Assessment Tools			
	Test 1	Test 2	Assignment	Field Work
Remember	✓	✓		

Understand	✓	✓	✓	
Apply	✓	✓	✓	✓
Analyze	✓	✓	✓	✓
Evaluate			✓	✓
Create				✓

Mark Distribution of CIA

Course Structure [L-T-P-R]	Attendance	Theory [L]				Total Marks
		Assignment /Activity	Test-1	Test-2	Field Work	
1-0-0-0	**5**	**20**	**12.5**	**12.5**	**50**	**100**

The assignments shall be evaluated as part of the activities under Modules 1, 2, and 3. Field work shall constitute the self-study component of Module 4.

SYLLABUS

MODULE 1: Understanding the Self, Relationships, and Society (3 Hours)

Session 1: Course Introduction and Self-Exploration (1 hour)
Course Purpose & Motivation, Recap of UHV-I, What is Self-Exploration?, Natural Acceptance & Experiential Validation, Human Aspirations: Continuous Happiness & Prosperity

Activities:

- *Reflection Exercise:* "Who am I?" – Write 5 statements about self and categorize as physical/sentient
- *Group Discussion:* Share experiences validating a value (e.g., truthfulness) through personal observation

Session 2: Understanding the Human Being and Prosperity (1 hour)
Co-existence of 'I' and Body, Needs of 'Self' vs 'Body', Body as Instrument of 'I', Sanyam (self-regulation) & Health, True Prosperity vs Accumulation

Activities:

- *Case Study:* "A Day in My Life" – Identify physical vs happiness-based needs
- *Role Play:* "Balanced Lifestyle vs Overconsumption"

Session 3: Harmony in Relationships and Society (1 hour)
Justice in Human Relationships, Trust vs Competence, Respect vs Differentiation,

Visualizing Undivided Society, Universal Order, Gratitude in Relationships

Activities:

- *Circle Discussion:* Role of gratitude in student-teacher relationships
- *Scenario Analysis:* Interpersonal conflict – analyze based on values of trust and respect
- *Exercise:* Map your relationship network and reflect on mutual happiness

MODULE 2: Harmony with Nature and Professional Ethics (3 Hours)

Session 1: Harmony in Nature and Existence (1 hour)

Harmony in Nature: Four Orders, Mutual Fulfilment, Recyclability, Self-regulation, Existence as Co-existence, Holistic Perception of Harmony

Activities:

- *Film Screening & Discussion:* "Home" – Reflection on human impact on environment
- *Group Task:* Trace a natural cycle (e.g., water or carbon) and discuss its harmony

Session 2: Human Values and Professional Ethics (1 hour)

Ethical Human Conduct: Definitiveness & Natural Acceptance, Professional Competence & Responsibility, Humanistic Education, Constitution, and Universal Order

Activities:

- *Debate:* "Technology – Boon or Bane for Nature?"
- *Reflective Writing:* "What does it mean to be an ethical engineer?"

Session 3: Path to Universal Human Order (1 hour)

Transition Strategy: Individual & Societal Level, People- & Eco-friendly Systems, Case Studies of Holistic Models

Activities:

- *Case Study Discussion:* Amul Cooperative Model / Barefoot College
- *Action Plan Activity:* Create a personal code of ethics and action plan as a future professional

MODULE 3 Life Skills for Personal and Professional Growth (3 Hours)

Emotional intelligence: Self-regulation, empathy, Communication: Listening, assertiveness, empathy-based interaction; Problem-solving, decision-making, and critical thinking, Time management, goal setting, and personal productivity

Activity 1: Empathy Circle – "Walking in Their Shoes"

Objective: To practice empathetic listening and perspective-taking.

Instructions:

- Students form groups of 4–5.
- Each member shares a brief real-life or imagined story involving emotional difficulty or a moral dilemma (max. 3 mins).
- Other members respond with only empathetic reflections (no advice or judgment).

- Debrief as a class: How does it feel to be truly heard? What makes listening difficult?

Activity 2: Communication Styles Role-Play
Objective: To differentiate between passive, aggressive, and assertive communication.
Instructions:

- In pairs or small groups, students enact 3 short scenarios (e.g., refusing extra work, asking for help, handling group conflict) using each style.
- Each group presents one version to the class, followed by reflection:
  - What was the impact of each style?
  - When is assertiveness most effective?

Activity 3: Critical Thinking Puzzle – "What's the Real Problem?"
Objective: To strengthen problem-identification and decision-making skills.
Instructions:

- Present a real-world case (e.g., project failure, peer conflict, missed deadline).
- In groups, students:
  - Identify the root cause(s),
  - Propose at least two solutions,
  - Discuss possible consequences.
- Each group shares findings with the class.

Activity 4: Time Audit and Productivity Planning
Objective: To improve time management through self-awareness and planning.
Instructions:

- Students reflect on and write down how they spent the previous day (hour by hour).
- Identify time wasters and productivity blocks.
- Using the SMART method, each student sets 1 academic and 1 personal goal with an action plan.

Activity 5: Emotional Regulation Check-In
Objective: To raise awareness of emotional triggers and calming strategies.
Instructions:

- Students list 3 situations that trigger frustration or anxiety.
- For each, they note:
  - Physical/emotional reactions,
  - Current coping strategies,
  - One new strategy (e.g., deep breathing, journaling, re-framing thoughts).
- Optionally, share coping ideas in small groups.

(Any three activities to be completed)

MODULE 4: Community Engagement and Social Responsibility (5 Hours)

Values, Leadership, and Social Responsibility: Leadership, initiative, and teamwork as personal and social values, Community service as a form of experiential value education, Civic sense and responsibilities of educated citizens

Gandhian Vision and Community Empowerment:Introduction to Gandhian concept of Village Republics, Rural self-sufficiency and non-violence in development, Institutional role in community upliftment

Tools for Sustainable Community Engagement: Importance of eco-friendly, decentralized development, Science and technology for rural empowerment, Participatory planning, implementation, and monitoring, Knowledge, fund, and stakeholder convergence in development

Application through Service Learning: Integrating learning from values and life skills into community work, Designing small student-led interventions, Reflecting on leadership, empathy, and impact

Self -Study/Field Work: 16 hours

Students will identify a local community need and engage in a minimum 16-hour field project (individually or in small teams) aligned with the values studied.

Examples:

- Environmental awareness campaign
- Literacy or peer mentoring program
- Senior care/home visits with structured reflection
- Water/energy conservation drive
- Organic Farming
- Artisans, Industries and Livelihood
- Basic Amenities

Text Book

1. R R Gaur, R Asthana, G P Bagaria, 2019 (2nd Revised Edition), A Foundation Course in Human Values and Professional Ethics. ISBN 978-93-87034-47-1, Excel Books, New Delhi.
2. Premvir Kapoor, Professional Ethics and Human Values, Khanna Book Publishing, New Delhi, 2022.
3. Goleman, D. (1995). Emotional Intelligence. New Delhi: Bloomsbury Publishing India Private Limited
4. B. K. Mitra, Personality Development and Soft Skills, 3rd ed. New Delhi, India: Oxford Univ. Press, 2019.
5. K.G. Balakrishnan, *Unnat Bharat Abhiyan: Transforming India through Village Empowerment*, 1st ed., Ministry of Education, Govt. of India, 2022.

Reference books

1. Ivan Illich, 1974, Energy & Equity, The Trinity Press, Worcester, and Harper Collins, USA
2. E.F. Schumacher, 1973, Small is Beautiful: a study of economics as if people mattered, Blond & Briggs, Britain.
3. S. R. Covey, *The 7 Habits of Highly Effective People*. New York, NY, USA: Free Press, 2004.
4. A. Kumar, *Youth and Social Transformation*. Jaipur, India: Rawat Publications, 2012.

NPTEL Course

1. Exploring human values: Visions of happiness of perfect Societies, Prof. A.K. Sharma, IIT Kanpur https://nptel.ac.in/courses/109104068
2. Developing Soft Skills and Personality, Prof. T. Ravichandran, IIT Kanpur https://onlinecourses.nptel.ac.in/noc22_hs77/preview
3. Corporate social responsibility, By Prof. Aradhna Malik, IIT Kharagpur, https://onlinecourses.nptel.ac.in/noc21_mg54/preview

No.	COURSE CONTENTS AND LECTURE SCHEDULE	No. of Hours (14 hours)
	MODULE 1 (3 Hours)	
1.1	Course Introduction and Self-Exploration	1
1.2	Understanding the Human Being and Prosperity	1
1.3	Harmony in Relationships and Society	1
	MODULE 2 (3 Hours)	
2.1	Harmony in Nature and Existence	1
2.2	Human Values and Professional Ethics	1
2.3	Path to Universal Human Order	1
	MODULE 3 (3 Hours)	
3.1	Emotional intelligence	1
3.2	Communication:	1
3.3	Problem-solving, decision-making, and critical thinking, Time management, goal setting, and personal productivity	1
	MODULE 4 (5 Hours)	
4.1	Values, Leadership, and Social Responsibility	1

4.2	Gandhian Vision and Community Empowerment:	1
4.3	Tools for Sustainable Community Engagement	1
4.4	Application through Service Learning	2
LESSON PLAN FOR FIELD WORK		
No.	**Topic**	**No. of Hours (16)**
1	Orientation & Need Identification	1
2	Proposal Submission:	1
3	Field Implementation	9
4	Reflection Session:	3
5	Final Submission	2
No.	**Field Work Assessment**	**50 marks**
1	Problem identification	5
2	Planning and organization	5
3	Execution and teamwork	15
4	Reflection and learning outcomes	10
5	Report and presentation	15
CO Assessment Questions		
CO1	1. What is the meaning of natural acceptance? 2. List the four levels of harmony discussed in the course. 3. Explain the difference between prosperity and accumulation. 4. How do trust and respect influence human relationships? 5. Apply the principle of Sanyam to your daily routine. What changes would you make? 6. How can you promote harmony in your classroom or hostel? 7. Analyze the current societal model in terms of human aspirations and values. 8. How does imbalance in nature reflect the lack of harmony at the human level?	
CO2	1. What are the key components of emotional intelligence, and why are they important in both personal and professional life? 2. Explain the difference between assertive and aggressive communication. How can this distinction improve interpersonal relationships?	

	3. Describe a situation where you faced a communication challenge. How would you apply assertiveness and empathy to handle it differently now? 4. Given a tight academic schedule and personal responsibilities, how would you apply time management techniques to maintain productivity and well-being?
CO3	1. What are the core values promoted through Gandhian principles of rural development? 2. List the essential elements of participatory planning in a community project. 3. Explain how eco-friendly, decentralized development contributes to rural sustainability. 4. Describe the relationship between civic responsibility and community engagement for students. 5. How would you apply leadership and teamwork skills in organizing a community-based awareness campaign on environmental sustainability? 6. Devise a plan to involve your peers in a service-learning activity that addresses a local issue. 7. Analyze the roles of different stakeholders (educational institutions, local governance, NGOs) in the successful execution of community projects. 8. Compare two community interventions and identify the factors that led to the success or limitations of each.

Prepared By
Ms. Vini Valsan, Assistant Professor
Dept of Applied Science and Humanities

PROGRAM ELECTIVES – I

24BMT411	SIGNALS AND SYSTEMS	L	T	P	R	C	Year of Introduction
		3	0	0	0	3	2024

Preamble:
This course introduces the fundamental principles of signal representation, system behavior, time and frequency domain analysis, and transforms such as Fourier, Laplace, and Z-transform. By exploring both theoretical insights and practical applications, the course aims to build a strong mathematical and conceptual framework that underpins modern signal processing in biomedical applications and beyond.

Prerequisite: Basics of Linear Algebra, Differential Equations & Laplace Transforms

Course Outcomes: After the completion of the course, the student will be able to

CO 1	Classify and represent continuous-time and discrete-time signals and systems, perform fundamental signal operations **[Understand]**
CO 2	Analyze Linear Time-Invariant (LTI) systems using impulse response and convolution techniques in both continuous and discrete domains, and determine system properties . **[Analyze]**
CO 3	Interpret the frequency-domain representation of signals using Fourier Series, CTFT, DTFS, and DTFT, and apply their properties in system analysis.**[Analyze]**
CO 4	Analyze aliasing and reconstruction, and understand the role of A/D and D/A conversion and filter design. **[Analyze]**

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	3	2			3						2
CO2	3	3			3						2
CO3	3	3		2	3						2
CO4	3	3	2	2	3						2

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember				
Understand	√	√	√	
Apply	√	√	√	√
Analyze	√	√	√	√
Evaluate				
Create				

Course Structure [L-T-P-R]	Lecture [L]				
	Attendance	Assignment	Test-1	Test-2	Total Marks
3-0-0-0	5	10	12.5	12.5	40

Total Mark distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	40	60	2.5 hours

End Semester Examination [ESE]: Pattern

PATTERN	**PART A**	**PART B**	**ESE Marks**
PATTERN 1	8 Questions (2 Questions from each module), each question carries 3 marks Marks: (3x8 =24 marks)	2 questions will be given from each module, out of which 1 should be answered. Each question can have a maximum of two sub-divisions. Each question carries 9 marks. Marks: (9x4 = 36 marks)	60

SYLLABUS

MODULE I: Fundamentals of Signals and Systems (9 hours)

Classification and representation of continuous time and discrete time signals, Basic operations on signals: time-shifting, scaling, and reversal, Elementary signals: unit step, ramp, exponential, and sinusoidal signals, Classification of Systems: LTI, causal, stable, static/dynamic. Representation of systems - Differential equation representation of continuous time systems. Difference equation representation of discrete systems.

Self Study: (15 hours)

1)Signal Generation in MATLAB (Continuous and Discrete)

2)NPTEL :: Principles of Signals and Systems:

Mathematical Preliminaries, Introduction to Signals, Signal Classification, Continuous/ Discrete Time Signals, Types of Signals and Transformations

MODULE II: Time-Domain Analysis of LTI Systems (9 hours)

Introduction to Linear Time-Invariant (LTI) systems , Impulse response and system behavior, Convolution: Integral (continuous) and sum (discrete), System properties via convolution. Continuous time LTI systems and convolution integral. Discrete time LTI systems and linear convolution. Stability and causality of LTI systems

Self study(15 hours)

1. Case Study: Convolution exercises (manual and using Python/MATLAB)
2. NPTEL :: Principles of Signals and Systems : Properties of LTI Systems, Impulse Response, Convolution, Causality, Stability

MODULE III : Transform Techniques (9 hours)

Concept of frequency representation, Fourier Series (concept and simple examples)
Continuous-Time Fourier Transform(Definition, basic properties), Introduction to Laplace and Z transform, ROC, Inverse transform, properties, Unilateral Z transform.
Discrete time Fourier series for discrete periodic signals. Properties of DTFS.Discrete Time Fourier Transform (DTFT) and its properties.

Self study(15 hours)

1. MATLAB/Python: Fourier transform of basic signals, Linear Convolution of Signals, Computation and Plotting of Fourier Series.
2. Compare the utility of DTFT vs. DFT when analyzing short segments of real-time EMG signals
3. NPTEL:: Introduction to z-Transform, Properties of z-Transform, Region of Convergence, Inverse z-Transform

MODULE IV: Sampling theorem and Filters (9 hours)

Sampling of continuous time signals, Sampling theorem for low pass signals, aliasing & reconstruction. Signal Reconstruction: Analog-to-Digital Conversion(ADC) and Digital-to-Analog Conversion (DAC), Filters – Basics and Applications: Low-pass, High-pass, Band-pass, Band-stop, IIR/ FIR Filters, Direct Form Realization

Self Study: (15 hours)

1. MATLAB for Signals and Systems
2. Design a basic anti-aliasing filter for digitizing EEG signals. Specify its cutoff frequency and order
3. Analyze aliasing and reconstruction, and understand the role of A/D and D/A conversion and filter design

Textbooks

1. Simon Haykin , Signals & Systems, John Wiley, 2/e, 2003
2. Anand Kumar, Signals and Systems, PHI, 3/e, 2013

Reference books

1. B P. Lathi, Principles of Signal Processing & Linear systems, Oxford University Press.
2. P Ramakrishna Rao, Shankar Prakriya, Signals and System, MCGraw Hill Edn 2013
3. Rodger E. Ziemer, Signals & Systems - Continuous and Discrete, Pearson, 4/e, 2013
4. Schaum's Outline of Signals and Systems by Hwei P. Hsu

NPTEL/SWAYAM Courses for reference:

1. NPTEL :: Signals and Systems- IISER Bhopal
   https://onlinecourses.nptel.ac.in/noc25_ee78/preview
2. NPTEL :: Principles of Signals and Systems-IIT Kanpur
   https://onlinecourses.nptel.ac.in/noc20_ee15/preview

No.	COURSE CONTENTS AND LECTURE SCHEDULE	No. of Hours [36 hours]
	MODULE 1 [9 hours]	
1.1	Classification and representation of continuous time and discrete time signals	2
1.2	Basic operations on signals: time-shifting, scaling, and reversal Elementary signals: unit step, ramp, exponential, and sinusoidal signals	2
1.3	Classification of Systems: LTI, causal, stable, static/dynamic	2

1.4	Representation of systems - Differential equation representation of continuous time systems. Difference equation representation of discrete systems	3
MODULE II [9 hours]		
2.1	Introduction to Linear Time-Invariant (LTI) systems, Impulse response and system behavior	2
2.2	Convolution: Integral (continuous) and sum (discrete)	2
2.3	System properties via convolution	1
2.4	Continuous time LTI systems and convolution integral. Discrete time LTI systems and linear convolution. Stability and causality of LTI systems	4
MODULE III [9 hours]		
3.1	Concept of frequency representation, Fourier Series (concept and simple examples)	2
3.2	Continuous-Time Fourier Transform(Definition, basic properties)	2
3.3	Introduction to Laplace and Z transform, ROC, Inverse transform, properties, Unilateral Z transform.	2
3.4	Discrete time Fourier series for discrete periodic signals. Properties of DTFS. Discrete Time Fourier Transform (DTFT) and its properties.	3
MODULE IV [9 hours]		
4.1	Sampling of continuous time signals, Sampling theorem for low pass signals, aliasing & reconstruction.	3
4.2	Signal Reconstruction: Analog-to-Digital Conversion(ADC) and Digital-to-Analog Conversion (DAC)	2
4.3	Filters – Basics and Applications: Low-pass, High-pass, Band-pass, Band-stop	2
4.4	IIR/ FIR Filters, Direct Form Realization	2
CO Assessment Questions		
CO-1	1. Sketch and mathematically represent the following elementary signals:(i) Unit step,(ii) Ramp, (iii) Exponential $e^{-2t}u(t)$ **(Applying).** 2. A discrete time sequence is given by x(n) = (1,1,1,1,2,2). Sketch (i) x(n) – x(n-2) (ii) x(n) u(n+2) **(Applying).** 3. Classify the following signal as continuous-time or discrete-time, deterministic or random, periodic or aperiodic . Given $x(t) = 3\cos(2\pi t) + e^{-t}u(t)$ **(Apply).** 4. Derive the differential equation that represents a continuous-time system described by the following input-output relationship $y''(t) + 3y'(t) + 2y(t) = x(t)$ **(Apply).**	
	1. A continuous-time LTI system has impulse response $h(t)=e^{-2t}u(t)$. Determine the output y(t) when the input is x(t)=u(t) using convolution. **(Apply).**	

CO-2	2. Given a discrete-time system with input x[n]={1,2,1} and impulse response h[n]={1,−1,2} compute the output using linear convolution. Also, comment on the length of the output signal. **(Apply).** 3. Given the impulse response h(t)=δ(t−1)−δ(t−3), determine if the continuous-time system is causal and stable. Justify your answer. **(Apply).** 4. For a discrete-time LTI system defined by h[n]=(0.5)nu[n] determines whether the system is causal and BIBO (Bounded Input Bounded Output) stable. **(Apply).**
CO-3	1. State and explain any two properties of the Discrete-Time Fourier Transform (DTFT), and show how these properties help in simplifying system analysis**(Apply).** 2. Determine the DTFT of the signal $x[n]$ as given below. $x\,[n] = 3, -10 \le n < 0$ $-3, 0 \le n \le 10$ $0, elsewhere$ **(Apply).** 3. Find the exponential Fourier series coefficients for the periodic signal: $x(t) = \begin{cases} 1, & 0 \le t < T/2 \\ 0, & T/2 \le t < T \end{cases}, \quad x(t+T) = x(t)$ **(Apply).** 4. An ECG signal is corrupted by 50 Hz power line noise. Propose a method to remove this using frequency domain techniques. **(Apply).**
CO-4	1. State and explain the Sampling Theorem. Derive the condition for perfect signal reconstruction and discuss the consequences of violating the Nyquist criterion. (**Understand)** 2. With neat block diagrams, explain the working of ADC and DAC.(**Understand)** 3. Compare different types of ADCs and mention the significance of resolution and sampling rate. **(Apply).** 4. Differentiate between ideal and practical filters. Design a basic RC low-pass filter and discuss how it can be used to remove aliasing before A/D conversion**(Apply).**

Prepared By
Ms Minu C Davis, Assistantt Professor
Department of Biomedical Engineering

24BME412	IOT & BIOMEDICAL APPLICATIONS	L	T	P	R	C	Year of Introduction
		3	0	0	0	3	2024

Preamble:
The course introduces students to the integration of Internet of Things (IoT) technologies with biomedical systems, enabling the design and deployment of intelligent, connected healthcare solutions. Covering key areas such as biomedical sensors, embedded platforms, wireless communication, cloud integration, and healthcare data security, the course equips learners with the foundational knowledge and practical skills needed to build and analyze IoT-enabled biomedical applications.

Prerequisite: Basic concepts of human physiology - Data types, data storage, and basic data processing - Understanding of analog and digital signals - Knowledge of sensors and actuators

Course Outcomes: After the completion of the course, the student will be able to

CO 1	Explain the architecture and components of IoT systems and their relevance to biomedical applications. **(Understand)**
CO 2	Identify appropriate biomedical sensors and microcontrollers to acquire, process, and transmit physiological signals **(Understand)**
CO 3	Analyze the handling of biomedical data in IoT systems with respect to storage, cloud integration, security, and privacy. **(Analyze)**
CO 4	Evaluate and interpret the performance, reliability, and compliance of biomedical IoT systems based on existing healthcare standards. **(Evaluate)**

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	2	2	1	2	1		1			1	1
CO2	2	2	1		2						1
CO3	2	2	2	2	1		2			1	1
CO4	2	1	2	1	1		2			1	1

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	√	√	√	√
Understand	√	√	√	√
Apply	√		√	√
Analyze		√		
Evaluate				
Create				

Mark Distribution of CIA

Course Structure [L-T-P-R]	Lecture [L]				
	Attendance	Assignment	Test-1	Test-2	Total Marks
3-0-0-0	5	10	12.5	12.5	40

Total Mark distribution

Total Marks	CIA (Marks)	ESE (Marks)	ESE Duration
100	40	60	2.5 hours

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	8 Questions (2 Questions from each module), each question carries 3 marks Marks: (3x8 =24 marks)	2 questions will be given from each module, out of which 1 should be answered. Each question can have a maximum of two sub-divisions. Each question carries 9 marks. Marks: (9x4 = 36 marks)	60

SYLLABUS

MODULE I: Fundamentals of IoT and Biomedical Systems (9 hours)

Introduction to IoT - IoT Architecture, Ecosystem, and Design Principles - Components: Sensors, Gateways, Networks, Cloud, Applications
Introduction to Human Physiology and Vital Parameters - Common Biomedical Signals (ECG, EEG, EMG, SpO_2, etc.)
IoT in Healthcare - Use Cases: Wearables, Smart Devices, Telemedicine

Self Study (15 hours):

1. IoT overview and history. List key application domains.
2. Prepare a concept map linking each IoT component to a real-world example in healthcare.
3. Study two case studies of IoT in Healthcare (e.g., wearable ECG monitor, telemedicine app). Reflect on benefits and challenges.

MODULE II: Biomedical Sensors, Devices, and Communication (9 hours)

Biomedical Sensors and Actuators - Types, Characteristics, Selection Criteria
Interfacing and Signal Conditioning - Analog Signal Acquisition, ADCs, Filters, Amplifiers
Communication Protocols for IoT - BLE, ZigBee, Wi-Fi, LoRa, MQTT, and Healthcare Standards
Microcontrollers and Embedded Platforms -Basics of Arduino, ESP32, Raspberry Pi

Self Study (15 hours):

1. Create a classification chart of Biomedical sensors (ECG, temperature, pressure, etc.) with working principles and use-cases.
2. Watch a tutorial on signal conditioning circuits.
3. Prepare a comparison matrix of protocols based on range, power, data rate, and use in healthcare. Include a note on healthcare standards like HL7 and IEEE 11073.

MODULE III: Data Management, Cloud Platforms, and Security (9 hours)

IoT Data Handling - Time-Series Data, Edge vs Cloud Processing
Cloud Integration - Platforms: ThingSpeak, Firebase, AWS IoT – Architecture and Usage
Data Analytics and Visualization - Dashboards, Alert Systems
Security and Privacy in Biomedical IoT - Data Encryption, Authentication, Secure Communication Protocols, Compliance

Self Study (15 hours):

1. Study the structure of time-series data (ECG, temperature) and compare how data is handled at edge vs cloud through a real-time use case.
2. Set up a basic data flow from a simulated sensor (e.g., DHT11) to ThingSpeak or Firebase. Document architecture with screenshots and data samples.
3. Explore how IoT platforms visualize real-time data. Create a basic dashboard (using ThingSpeak or Node-RED) and configure a basic alert

MODULE IV: Standards, Testing, and Real-Time Applications (9 hours)

Healthcare IoT Standards and Interoperability - HL7, FHIR, ISO/IEEE 11073, HIPAA
System Integration and Testing - Interfacing Sensors, Communication Stack Testing, Troubleshooting
Reliability, Accuracy, and Calibration of Biomedical Devices - Validation Techniques, Clinical-Grade vs Consumer-Grade Devices
Real-Time Applications in Healthcare - Smart ICUs, Continuous Monitoring Systems, AI-assisted Diagnosis

Self Study (15 hours):

1. Study the purpose and key features of HL7 and FHIR through case studies. Prepare a summary comparing HL7 vs FHIR and briefly describe HIPAA compliance in data communication. Build a basic test plan for an IoT system.
2. Identify common troubleshooting methods for data transmission or sensor malfunction.
3. Prepare a comparative analysis chart for clinical-grade vs consumer-grade biomedical devices (e.g., pulse oximeter, ECG monitors). Include accuracy benchmarks and calibration requirements.

Textbooks

1. A. Bahga and V. Madisetti, Internet of Things: A Hands-On Approach. Hyderabad, India: Universities Press, 2015.
2. L. Cromwell, F. J. Weibell, and E. A. Pfeiffer, Biomedical Instrumentation and Measurements, Pearson, 2nd ed., 2011.
3. C.-M. Kyung, Ed., Smart Sensors and Systems: Innovations for Medical, Environmental, and IoT Applications, Springer, 2017.
4. R. Buyya, A. V. Dastjerdi, S. N. Srirama, and S. Calheiros, Eds., Internet of Things (IoT): Technologies, Applications, Challenges and Solutions, Springer, 2020.
5. D. Hanes, G. Salgueiro, P. Grossetete, R. Barton, and J. Henry, IoT Fundamentals: Networking Technologies, Protocols, and Use Cases for the Internet of Things, Cisco Press, 2017.

Reference books

1. R. Kamal, Internet of Things: Architecture and Applications, McGraw-Hill Education, 2022.
2. J. Enderle and J. Bronzino, Introduction to Biomedical Engineering, 4th ed., Academic Press, 2012.
3. Y. Zhu, Embedded Systems with ARM Cortex-M Microcontrollers in Assembly Language and C, 3rd ed., E-Man Press LLC, 2023.
4. F. Hu, Security and Privacy in Internet of Things (IoTs): Models, Algorithms, and Implementations, CRC Press, 2020.

NPTEL/SWAYAM Courses for reference:

1. Introduction to Internet of Things - Prof. Sudip Misra, IIT Kharagpur https://nptel.ac.in/courses/106105166
2. Biomedical Signal Processing - Prof. S. Dandapat, IIT Kharagpur https://nptel.ac.in/courses/108105101
3. Embedded System Design with ARM - Prof. S. Chandramouli, IIT Madras https://nptel.ac.in/courses/106105193
4. Cyber Security - Dr. G. Padmavathi, Avinashilingam Institute for Home Science & Higher Education for Women https://onlinecourses.swayam2.ac.in/cec21_cs14/preview

No.	COURSE CONTENTS AND LECTURE SCHEDULE	No. of Hours [36 hours]
	MODULE 1 [9 hours]	
1.1	Introduction to IoT - IoT Architecture, Ecosystem, and Design Principles	2
1.2	Components: Sensors, Gateways, Networks, Cloud, Applications	1
1.3	Introduction to Human Physiology and Vital Parameters -	2
1.4	Common Biomedical Signals (ECG, EEG, EMG, SpO_2, etc.)	2
1.5	IoT in Healthcare - Use Cases: Wearables, Smart Devices, Telemedicine	2
	MODULE II [9 hours]	
2.1	Biomedical Sensors and Actuators- Types	1
2.2	Characteristics, Selection Criteria	1
2.3	Interfacing and Signal Conditioning - Analog Signal Acquisition	1
2.4	ADCs, Filters, Amplifiers	1
2.5	Communication Protocols for IoT - BLE, ZigBee, Wi-Fi, LoRa, MQTT,	1
2.6	Healthcare Standards (HL7, IEEE 11073)	2
2.7	Microcontrollers and Embedded Platforms - Basics of Arduino, ESP32	1
2.8	Raspberry Pi	1
	MODULE III [9 hours]	

3.1	IoT Data Handling - Time-Series Data, Edge vs Cloud Processing	1
3.2	Edge vs Cloud Processing	1
3.3	Cloud Integration - Platforms	1
3.4	ThingSpeak, Firebase, AWS IoT – Architecture and Usage	1
3.5	Data Analytics and Visualization - Dashboards, Alert Systems	2
3.6	Security and Privacy in Biomedical IoT - Data Encryption, Authentication	1
3.7	Secure Communication Protocols, Compliance	2
MODULE IV [9 hours]		
4.1	Healthcare IoT Standards and Interoperability	1
4.2	HL7, FHIR, ISO/IEEE 11073, HIPAA	1
4.3	System Integration and Testing - Interfacing Sensors,	1
4.4	Communication Stack Testing, Troubleshooting	1
4.5	Transform of derivatives	1
4.6	Reliability, Accuracy, and Calibration of Biomedical Devices - Validation Techniques,	2
4.7	Clinical-Grade vs Consumer-Grade Devices	1
4.8	Real-Time Applications in Healthcare - Smart ICUs, Continuous Monitoring Systems,	2
4.9	AI-assisted Diagnosis	1
CO Assessment Questions		
CO-1	1. Describe the layered architecture of an IoT system and explain the role of each layer in the context of a biomedical monitoring application. **(Understand)** 2. Compare and contrast ECG and SpO_2 signals in terms of their origin, physiological significance, and the type of sensors required for IoT-based acquisition. **(Analyze)** 3. Illustrate how an IoT-enabled wearable device captures and transmits real-time heart rate data to a cloud platform for telemedicine. Include all involved components. **(Create)** 4. Explain the importance of gateways and network protocols in an IoT system used for continuous glucose monitoring in diabetic patients. . **(Understand)** **5.** List and explain three real-world healthcare applications of IoT and analyze how each leverages core components of an IoT ecosystem. **(Evaluate)**	
CO-2	1. Given a wearable ECG monitoring application, identify a suitable biosensor and microcontroller, and justify your selection based on signal type, power constraints, and interface capabilities. **(Evaluate)** 2. Design a basic signal conditioning circuit for a pulse oximeter sensor using appropriate amplifiers and filters. Explain the role of each component. **(Create)**	

	3. Compare BLE and LoRa communication protocols in terms of range, power efficiency, and suitability for real-time patient monitoring in remote areas. **(Analyze)** 4. List the key characteristics to consider when selecting a biomedical sensor for EEG acquisition and identify a compatible embedded platform for data processing. **(Analyze)** 5. Explain the process of acquiring analog physiological signals using an ARM Cortex-M based microcontroller. Include steps such as ADC configuration and digital signal transmission using MQTT. **(Understand)**
CO-3	1. Analyze the trade-offs between edge and cloud processing in a real-time biomedical monitoring system. Provide examples where each approach is preferable. **(Analyze)** 2. Given a patient health monitoring use case, compare the cloud integration workflows of ThingSpeak and AWS IoT in terms of scalability, data privacy features, and ease of deployment. **(Analyze)** **3.** Discuss how time-series biomedical data (e.g., ECG, body temperature) can be stored and visualized effectively using IoT dashboards. What considerations affect real-time alert generation? **(Apply)** 4. Examine the role of encryption and secure communication protocols (e.g., TLS, HTTPS) in ensuring patient data privacy during IoT-based remote monitoring. **(Understand)** 5. Identify key compliance standards (e.g., HIPAA, GDPR) applicable to biomedical IoT systems and analyze how they influence system architecture and data governance. **(Analyze)**
CO-4	1. Evaluate how HL7 and FHIR standards enable interoperability in a hospital-based IoT system involving continuous patient monitoring across multiple devices. **(Analyze)** 2. A biomedical IoT device used for heart rate monitoring shows inconsistent readings during field trials. Propose a validation and calibration strategy and evaluate its impact on clinical reliability. **(Create)** 3. Compare and evaluate the testing methodologies used for ensuring reliable wireless communication in IoT-based Smart ICU systems. **(Analyze)** 4. Discuss the ethical and regulatory implications of deploying AI-assisted diagnosis tools within IoT healthcare systems. How does HIPAA compliance shape such deployments? **(Understand)** 5. Evaluate the trade-offs between clinical-grade and consumer-grade biomedical IoT devices in terms of reliability, usability, cost, and regulatory compliance. Provide examples. **(Evaluate)**

Prepared by
Dr. Jis Paul, Associate Professor
Dept of Biomedical Engineering

24BME413	CLINICAL ENGINEERING	L	T	P	R	C	Year of Introduction
		3	0	0	0	3	2024

Preamble:

This course introduces the foundational and advanced roles of Biomedical Engineers in hospital infrastructure, safety systems, and medical technology management. It covers essential topics such as hospital architecture, electrical, central gas & sterilization systems, equipment management, and disaster preparedness. Emphasis is placed on international standards, smart hospital design, and integration of IT systems to improve patient outcomes and healthcare efficiency.

Prerequisite: A basic understanding of human anatomy and physiology, fundamentals of electrical and electronics engineering, and introductory biomedical instrumentation is required to comprehend the clinical applications of medical devices, hospital systems, power infrastructure, equipment safety, and instrumentation.

Course Outcomes: After the completion of the course, the student will be able to

CO 1	Understand the responsibilities of biomedical engineers in the planning, deployment, and management of healthcare technology and infrastructure. **[Understand]**
CO 2	Identify the basic components and functions of hospital infrastructure and support systems essential for safe and efficient healthcare delivery.**[Understand]**
CO 3	Apply safety standards and accreditation protocols (ISO, NABH, AERB, JCI) in evaluating hospital systems and medical equipment. **[Apply]**
CO 4	Analyze disaster preparedness strategies and evaluate healthcare technology management practices, including equipment procurement, maintenance, and IT integration **[Analyze]**

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO 1	2		2	3		3	3	3	3		3
CO 2	2		2	3		3	3	3	3		3
CO 3	2		2	3		3	3	3	3		3
CO 4	2		2	3		3	3	3	3		3

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	√	√	√	√
Understand	√	√	√	√
Apply	√	√	√	√
Analyze	√	√	√	√
Evaluate				
Create				

Mark Distribution of CIA

Course structure [L-T-P-R]	Theory [L]				Total Marks
	Attendance	Assignment	Test-1	Test-2	
3-0-0-0	5	10	12.5	12.5	**40**

Total Marks distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	40	60	2.5 hrs.

End Semester Examination [ESE]: Pattern			
PATTERN	**PART A**	**PART B**	**ESE Marks**
PATTERN 1	8 Questions (2 Questions from each module), each question carries 3 marks Marks: (3x8 =24 marks)	2 questions will be given from each module, out of which 1 should be answered. Each question can have a maximum of two sub-divisions. Each question carries 9 marks. Marks: (9x4 = 36 marks)	60

SYLLABUS

MODULE I: Introduction to Hospital Infrastructure and Engineering Roles (9 hours)

Roles and Responsibilities of Biomedical Engineers in healthcare settings, Overview of Hospital Architecture: Space distribution in hospital buildings and optimal workflow for departments, Planning and design of key departments (Radiology, ICU, Operation Theaters, Central Sterilization), **Introduction to Quality Assurance practices in Healthcare and Medical Device Management**: Accreditation Bodies (Healthcare Facilities) - National Accreditation Board for Hospitals & Healthcare Providers (NABH-India), Joint Commission International (JCI - USA/global); Certification Standards / Standardization Bodies (Medical Equipment) – International Organization for Standardization (ISO 13485), International Electrotechnical Commission (IEC), European conformity (CE Mark) ; Regulatory Authorities (Device Compliance & Safety) - Food and Drug Administration (FDA-USA), Atomic Energy Regulatory Board (AERB –India), World Health Organization (WHO).

Self Study (15 hours):

1. **Experiential Learning Component:** Site visits with professionals from hospital infrastructure design firms or medical equipment manufacturers or disaster response agencies.
2. **Presentation / Report**: Students may give a short group or individual presentation / report summarizing their experience and key takeaways.

MODULE II: Electrical Power Systems and Safety in Hospitals (9 hours)

Design components of **hospital electrical power systems**: substations, stabilized and uninterrupted power supplies, **Protective systems**: Over-voltage protectors, circuit breakers, surge protectors, EMI filters, **Safety Measures**: Electrical safety standards, fire safety, gas safety and radiation safety - surveillance systems, **Impact of Electrical Current on the Human Body**: leakage currents, types and measurements, electrical shocks and hazards, Preventive Measures to Ensure Patient and Operator Safety from Electrical Shock - Grounding and Earthing, Use of Isolation Transformers, Double Insulation, Ground Fault Circuit Interrupters (GFCI), IEC standards for **electrical safety** in hospitals.

Self Study (15 hours):

1. Experiential learning - Ref- 10-13: To understand the practical aspects of how electrical energy is generated, transmitted, and distributed in India by observing real-world infrastructure and gathering data from field visits and secondary sources.
    a. **Field Visit:** Visit the electrical substation / transmission and and distribution system within your own institution to observe the components (such as transformers, circuit breakers, switchgear, busbars, etc.), understand the safety measures in place, and study the voltage levels handled (e.g., 11 kV, 33 kV, etc.).
    b. **Literature Study:** Types of power plants in India (Thermal, Hydro, Solar, Nuclear, Wind), Transmission systems and key players (PGCIL, State Electricity Boards, etc.), Structure of distribution (urban vs. rural), Smart grids and recent innovations.
    c. Submit a brief self-study report (3–5 pages - group work) including visit observations (include photos if allowed), Key learnings and personal reflections.
2. Literature / field visit study on fire safety systems
3. Literature study on radiation safety based on AERB (website): (Ref. 5 to 8)

MODULE III: Hospital Engineering Systems and Medical Equipment Management **(9 hours)**

Hospital Gas Supply Systems: Centralized supply of medical air, nitrous oxide, vacuum, oxygen; and Anesthesia Gas Scavenging System - Central supply Layout and components
Basics of air conditioning and refrigeration systems in hospitals - Refrigerant cycle - components compressor, condenser, expansion valve, and evaporator. Central HVAC System (Heating, Ventilation, and Air Conditioning) in Hospitals - (chilled water-based system)- Overview & Subcomponents - Chillers, Air Handling Units (AHUs), Duct work, Ventilation Systems, Filters (HEPA filters), Cooling Towers, Pumps, Fan Coil Units, Control Systems.
Refrigeration in Hospitals - Applications, Medical-grade refrigerators and freezers, Ultra-low temperature freezers, Walk-in cold rooms
Sterilization Systems: Principles and techniques of steam and Ethylene Oxide (EO) sterilization; autoclaves, incinerators, Work flow in the central sterilization unit
Infection Control: seamless flooring, antibacterial painting, air changes, filtration, sterility and biomedical waste management

Self Study (15 hours):

1. Storage and distribution of liquid medical oxygen (LMO): Cryogenic tank structure and safety
2. Color coding and safety standards for gas cylinders and pipelines (e.g., ISO 7396-1)
3. Safety protocols for handling and aeration after EtO sterilization
4. Difference between sterilization, disinfection, and cleaning
5. Principles of HVAC systems in hospitals (especially OTs and ICUs)
6. Types of HEPA filters and their use in modular OTs and ICUs
7. Clean Room classification and Specifications

MODULE IV: Healthcare Technology Management, IT Integration, and Disaster Preparedness (9 hours)

Medical Equipment management planning: Procedures for procurement, installation, testing, calibration, and maintenance, Preventive and Corrective Maintenance: CMC, AMC contracts, and staff training for proper use and maintenance, Key definitions in medical equipment maintenance as per WHO guidelines.
Healthcare IT Systems and Asset Management: RFID-based asset tracking (Radio Frequency Identification), IT networking, and integration with Hospital Information Systems (HIS), Radiology Information Systems (RIS), and PACS, **Smart Hospital Design**: ITIL framework, dual-use infrastructure, rapid deployment technologies for disaster management.

Disaster Preparedness and Emergency Management: Role of biomedical in disaster preparedness and response. **Emerging Technologies**: AI, Internet of Medical Things (IoMT), predictive analytics, and their applications in disaster management.

Self Study (15 hours): Case Studies and Literature Review (any one of these)

1. Case Study: Hospital Failures During Disasters: Focus on hospital challenges during disasters such as earthquakes, fires, and pandemics. Analyze the failures and identify important learning points.
2. Case Study: Developing and Maintaining Critical Hospital Systems During Emergencies: Explore strategies for ensuring hospital system continuity during emergencies like pandemics and natural disasters. Study the implementation of emergency protocols.

1. Literature Study: Smart Hospital Concept and Prototype - Review literature on the Smart Hospital concept, focusing on the technologies, infrastructure, and strategies involved in the development of smart healthcare facilities.
2. Introduction to Medical Device Rules, 2017 (India) - Study the key features and significance of the Medical Device Rules, 2017 under the Drugs and Cosmetics Act, 1940. Understand the importance of these rules in ensuring the safety and efficacy of medical devices in India.

Textbooks

1. Chan, A. Y. K. (2022). Biomedical device technology: Principles and design (3rd ed.). Springfield, IL: Charles C. Thomas Publisher.
2. Iadanza, E. (Ed.). (2020). Clinical engineering handbook (2nd ed.). Cambridge, MA: Academic Press.

Reference books

1. World Health Organization (WHO). (n.d.). Medical equipment maintenance programme overview [Medical Device Technical Series]. https://www.who.int/publications/i/item/9789241547515
2. National Accreditation Board for Hospitals & Healthcare Providers (NABH). (2020). Hospital accreditation standards (4th ed.). New Delhi, India: Quality Council of India.
3. International Organization for Standardization (ISO). (2016). ISO 13485:2016 – Medical devices – Quality management systems – Requirements for regulatory

purposes. Geneva, Switzerland: ISO.
4. Atomic Energy Regulatory Board (AERB). (2016).
5. Safety guide on radiation protection in the design of radiology facilities.
6. Guidelines for registration and licensing of diagnostic imaging facilities. https://www.aerb.gov.in/images/PDF/CODESGUIDES/SafetyCode-MedicalX-ray.pdf
7. Safety code for nuclear medicine. (PDF via AERB website)
8. eLORA portal – Licensing and regulatory approval. https://elora.aerb.gov.in
9. Association for the Advancement of Medical Instrumentation (AAMI). (n.d.). Standards and resources for HTM professionals. https://www.aami.org/
10. International Electrotechnical Commission (IEC). (2012–2016).
11. IEC 60601 series – Medical electrical equipment.
12. IEC 60601-1 – General requirements for basic safety and essential performance.
13. IEC 60364 – Electrical installations in buildings.
14. IEC 60364-4-44 – Protection against voltage disturbances and electromagnetic disturbances.
15. National Fire Protection Association (NFPA). (2020). NFPA 70: National Electrical Code (NEC). Quincy, MA: NFPA.
16. Medical Gas Systems Training. (n.d.). Learning Task 1 – Block A: Medical gas systems [Training material].
17. Refrigeration Education. (n.d.). Refrigeration cycle and components [Video]. YouTube. https://www.youtube.com

NPTEL/SWAYAM Courses for reference:

1. Regulatory Requirements for Medical Devices Including In Vitro Diagnostics in India (Version 2.0) – Prof. K. Guru Rajesh, NIPER Guwahati https://onlinecourses.nptel.ac.in/noc24_ge06/preview

2. Refrigeration and Air Conditioning – Prof. Ravi Kumar, IIT Roorkee https://nptel.ac.in/courses/112107207
3. Disaster Recovery and Build Back Better – Prof. Rajiv Mishra, IIT Roorkee https://nptel.ac.in/courses/124107010

No.	COURSE CONTENTS AND LECTURE SCHEDULE	No. of Hours (36 hours)
	MODULE I (9 hours)	
1.1	Roles and Responsibilities of Biomedical Engineers in healthcare settings	2
1.2	Overview of Hospital Architecture: Space distribution in hospital buildings and optimal workflow for departments,	2
1.3	Planning and design of key departments (Radiology, ICU, Operation Theaters, Central Sterilization),	2

1.4	**Introduction to Quality Assurance practices in Healthcare and Medical Device Management**: Accreditation Bodies (Healthcare Facilities) - National Accreditation Board for Hospitals & Healthcare Providers (NABH-India), Joint Commission International (JCI - USA/global); Certification Standards / Standardization Bodies (Medical Equipment) – International Organization for Standardization (ISO 13485), International Electrotechnical Commission (IEC), European conformity (CE Mark) ; Regulatory Authorities (Device Compliance & Safety) - Food and Drug Administration (FDA-USA), Atomic Energy Regulatory Board (AERB –India), World Health Organization (WHO).	3
MODULE II (9 hours)		
2.1	Design components of hospital electrical power systems: substations, stabilized and uninterrupted power supplies	1
2.2	Protective systems: Over-voltage protectors, circuit breakers, surge protectors, EMI filters.	2
2.3	Safety Measures: Electrical safety standards, fire safety, gas safety and radiation safety - surveillance systems	2
2.4	Impact of Electrical Current on the Human Body: leakage currents, types and measurements, electrical shocks and hazards,	2
2.5	Preventive Measures to Ensure Patient and Operator Safety from Electrical Shock - Grounding and Earthing,Use of Isolation Transformers, Double Insulation, Ground Fault Circuit Interrupters (GFCI). IEC standards for electrical safety in hospitals.	2
MODULE III (9 hours)		
3.1	**Hospital Gas Supply Systems**: Centralized supply of medical air, nitrous oxide, vacuum, oxygen; and Anaesthesia Gas Scavenging System - Central supply Layout and components	3
3.2	**Basics of air conditioning and refrigeration systems in hospitals** - Refrigerant cycle - components compressor, condenser, expansion valve, and evaporator. Central HVAC System (Heating, Ventilation, and Air Conditioning) in Hospitals - (chilled water-based system)- Overview & Subcomponents - Chillers, Air Handling Units (AHUs), Duct work, Ventilation Systems, Filters (HEPA filters), Cooling Towers, Pumps, Fan Coil Units, Control Systems. Refrigeration in Hospitals - Applications, Medical-grade refrigerators and freezers, Ultra-low temperature freezers, Walk-in cold rooms	4
3.3	**Sterilization Systems**: Principles and techniques of steam and Ethylene Oxide (EO) sterilization; autoclaves, incinerators, Work flow in the central sterilisation unit.	1

3.4	Infection Control: seamless flooring, antibacterial painting, air changes, filtration, sterility. and biomedical waste management	1
MODULE IV (9 hours)		
3.5	**Medical Equipment management planning:** Procedures for procurement, installation, testing, calibration, and maintenanc**e**, Preventive and Corrective Maintenance: CMC, AMC contracts, and staff training for proper use and maintenance, Key definitions in medical equipment maintenance as per WHO guidelines.	2
4.2	**Healthcare IT Systems and Asset Management**: RFID-based asset tracking (Radio Frequency Identification), IT networking, and integration with Hospital Information Systems (HIS), Radiology Information Systems (RIS), and PACS,	2
4.3	**Smart Hospital Design**: ITIL framework, dual-use infrastructure, rapid deployment technologies for disaster management.	2
4.4	**Disaster Preparedness and Emergency Management**: Role of biomedical in **disaster preparedness** and response.	2
4.5	**Emerging Technologies**: AI, IoMT, predictive analytics, and their applications in disaster management.	1
CO Assessment Questions		
CO1	1. Identify the roles and responsibilities of a biomedical engineer in the planning and deployment of medical equipment within the hospital departments such as ICU, Radiology, and Operation Theaters. **(Understand)** 2. How biomedical engineers contribute to compliance with hospital accreditation and certification standards such as NABH, JCI, ISO, AERB, and IEC during the design and management of healthcare infrastructure. **(Understand)** 3. Demonstrate the function of Uninterrupted Power Supplies (UPS) and protective devices such as surge protectors and EMI filters in maintaining electrical safety and reliability in hospital environments. Detail the impact of electrical current on the human body and the role of IEC standards in minimizing electrical hazards in healthcare facilities. **(Apply)** 4. Outline the differences between steam sterilization and Ethylene Oxide (EO) sterilization. **(Understand)**	

CO2	1. Identify the components of a centralized hospital gas supply system and explain the principle of liquid oxygen production used in hospitals. **(Understand)** 2. Identify the major components of a hospital electrical power system and describe their role in ensuring continuous and safe healthcare delivery. **(Understand)** 3. Identify major components of air conditioning systems used in hospitals, and explain how they support infection control. **(Understand)** 4. Discuss the responsibilities of biomedical engineers in integrating HIS, RIS, and PACS with medical devices in a smart hospital setup. **(Understand)**
CO3	1. Apply relevant IEC standards and safety protocols to evaluate the electrical safety compliance of power systems used in hospitals. **(Apply)** 2. Apply relevant IEC or NABH electrical safety standards to evaluate the design of a hospital's power backup system, including UPS and surge protection components. **(Apply)** 3. Using AERB and ISO guidelines, assess the adequacy of radiation safety and electrical protection measures implemented in a diagnostic radiology department. **(Evaluate)**
CO4	1. Analyze the effectiveness of different sterilization techniques (steam vs. EO) in maintaining hospital hygiene, and evaluate how biomedical engineers contribute to equipment planning and maintenance. **(Analyze)** 2. Apply NABH or ISO standards to assess the documentation and maintenance practices followed under CMC or AMC contracts. **(Apply)** 3. Analyze how AI, IoMT, and predictive analytics can be used to evaluate and enhance disaster preparedness strategies in healthcare systems. **(Analyze)** 4. If the insulation resistance of a medical device is measured at 2 MΩ and the supply voltage is 230V, calculate the leakage current according to the standard IEC 60601? - Electrical Safety and Leakage Current Measurement - calculate the leakage current in hospital equipment to evaluate whether it meets safety standards, based on Ohm's law and the specific leakage resistance of the hospital's electrical system **(Evaluate)**

Prepared by
Ms. Sony N S, Assistant Professor
Department of Biomedical Engineering

24BME414	BIOSTATISTICS	L	T	P	R	C	Year of Introduction
		3	0	0	0	3	2024

Preamble:
The course enables the students to understand the fundamental concepts and methods of biostatistics, including data collection, descriptive and inferential statistics, probability distributions, hypothesis testing, and regression analysis. Emphasis is placed on statistical techniques relevant to biological and health sciences. This course equips learners with the ability to analyze and interpret biological data using appropriate statistical tools and software, thereby supporting evidence-based decision-making and research across various domains of biomedical and engineering applications.

Prerequisite: Basic knowledge of algebra and arithmetic, Fundamental concepts of probability and statistics, Basic computer skills, especially using spreadsheets

Course Outcomes: After the completion of the course, the student will be able to

CO 1	Describe the types of biological data and explain appropriate measures of central tendency and dispersion for summarizing them. **[Understand]**
CO 2	Interpret biological phenomena using discrete and continuous probability distributions, and explain their real-life significance. **[Understand]**
CO 3	Apply correlation and regression techniques using statistical tools to examine relationships in biological datasets. **[Apply]**
CO 4	Analyze patterns and relationships in real-world biomedical datasets using regression and correlation techniques with appropriate tools. **[Analyze]**

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	3	3	2	3	2	2					
CO2	3	3	2	3		2					
CO3	3	2	2	3	2	2					
CO4	3	2	2	2		2					

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	√	√	√	√
Understand	√	√	√	√
Apply	√	√	√	√
Analyze				
Evaluate				
Create				

Mark Distribution of CIA

Course Structure [L-T-P-R]	Lecture [L]				
	Attendance	Assignment	Test-1	Test-2	Total Marks
3-0-0-0	5	10	12.5	12.5	40

Total Mark distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	40	60	2.5 hours

End Semester Examination [ESE]: Pattern

PATTERN	**PART A**	**PART B**	**ESE Marks**
PATTERN 1	8 Questions (2 Questions from each module), each question carries 3 marks Marks: (3x8 =24 marks)	2 questions will be given from each module, out of which 1 should be answered. Each question can have a maximum of two sub-divisions. Each question carries 9 marks. Marks: (9x4 = 36 marks)	60

SYLLABUS

MODULE I: Introduction to Biostatistics and Descriptive Statistics (9 hours)

Introduction to Biostatistics: Definition, scope, and relevance in life sciences and engineering.
Types of data: Nominal, ordinal, interval, ratio; primary and secondary data. Sampling methods: Random, stratified, systematic, and cluster sampling. Presentation of data: Frequency distributions, bar charts, histograms, pie charts.
Measures of central tendency: Mean, median, mode. Measures of dispersion: Range, variance, standard deviation, interquartile range, coefficient of variation

Self Study (15 hours):

1. Understand the definition and scope of biostatistics, emphasizing its role in solving problems in life sciences and biomedical engineering.
2. Differentiate between types of data: nominal, ordinal, interval, and ratio, and identify suitable data types for various biological variables.
3. Explore sampling techniques such as simple random, stratified, systematic, and cluster sampling through biological research scenarios.
4. Practice graphical presentation of data using frequency distributions, histograms, bar charts, and pie charts for summarizing datasets.
5. Calculate and interpret central tendency (mean, median, mode) and variability (range, SD, variance, IQR, CV) in biological datasets.

MODULE II: Probability and Probability Distributions (9 hours)

Basic probability theory: Definitions, laws of probability, conditional probability, Bayes' theorem. Random variables: Discrete and continuous.
Discrete distributions: Binomial and Poisson – definition, properties, and applications. Continuous distributions: Normal and Exponential – properties and applications. Z-scores and standard normal distribution.
Biological examples involving probability distributions

Self Study (15 hours):

1. Review the basic definitions and laws of probability, including conditional probability and Bayes' theorem, through biological problem contexts.
2. Differentiate between discrete and continuous random variables and study their roles in modeling biological experiments.
3. Explore the properties and applications of binomial, Poisson, normal, and exponential distributions in biological and health data.
4. Understand Z-scores and the standard normal distribution to assess and interpret biological variation and measurement scales.

MODULE III: Statistical Inference (9 hours)

Sampling distributions and Central Limit Theorem. Estimation: Point and interval estimation (mean and proportion).
Hypothesis testing framework: Steps, errors, significance levels, and power of a test. Parametric tests: t-tests: One-sample, independent two-sample, paired sample - z-test (for large samples).
Non-parametric tests (introduction): Chi-square test for independence and goodness-of-fit. One-way ANOVA: Assumptions, interpretation, and biological applications.

Self Study (15 hours):

1. Understand sampling distributions and the Central Limit Theorem, and explore their role in making inferences about population parameters.
2. Study point and interval estimation for means and proportions, including confidence interval interpretation in biological data.
3. Explore the hypothesis testing framework, including Type I and II errors, significance levels, and perform t-tests and z-tests for various scenarios.
4. Learn about non-parametric tests (Chi-square) and parametric ANOVA methods to evaluate categorical and group differences in biological studies.

MODULE IV: Correlation, Regression, and Data Analysis Tools (9 hours)

Correlation analysis: Pearson's and Spearman's correlation.
Regression: Simple linear regression – model, assumptions, estimation, and interpretation. Introduction to multiple linear regression. Applications in Biomedical and environmental datasets.
Introduction to statistical software (R/SPSS/Excel): Data import, descriptive statistics, charts, regression analysis.
Case studies using real biological data

Self Study (15 hours):

1. Understand the concepts of Pearson's and Spearman's correlation coefficients and their use in identifying relationships in biological data.
2. Learn the formulation, assumptions, and interpretation of simple linear regression, with an introduction to multiple linear regression applications.

3. Practice using statistical software (R/SPSS/Excel) for data import, performing descriptive analysis, visualizations, and regression modeling.
4. Explore real-world biomedical case studies involving correlation and regression to interpret results and draw data-driven conclusions.

Textbooks

1. W. W. Daniel and C. L. Cross, Biostatistics: A Foundation for Analysis in the Health Sciences, 11th ed. Hoboken, NJ, USA: Wiley, 2018.
2. B. K. Mahajan, Methods in Biostatistics for Medical Students and Research Workers, 7th ed. New Delhi, India: Jaypee Brothers Medical Publishers, 2010.
3. M. Pagano and K. Gauvreau, Principles of Biostatistics, 2nd ed. Boca Raton, FL, USA: Chapman & Hall/CRC, 2018.
4. J. H. Zar, Biostatistical Analysis, 5th ed. Upper Saddle River, NJ, USA: Pearson Education, 2010.
5. B. Rosner, Fundamentals of Biostatistics, 8th ed. Boston, MA, USA: Cengage Learning, 2015.
6. R. R. Sokal and F. J. Rohlf, Biometry: The Principles and Practice of Statistics in Biological Research, 4th ed. New York, NY, USA: W.H. Freeman, 2012.

Reference books

1. D. G. Altman, Practical Statistics for Medical Research. London, UK: Chapman & Hall/CRC, 1990.
2. R. J. B. Snedecor and W. G. Cochran, Statistical Methods, 8th ed. Ames, IA, USA: Iowa State University Press, 1989.
3. M. J. Campbell, D. Machin, and S. J. Walters, Medical Statistics: A Textbook for the Health Sciences, 4th ed. Chichester, UK: Wiley, 2007.
4. G. D. Ruxton and N. Colegrave, Experimental Design for the Life Sciences, 4th ed. Oxford, UK: Oxford University Press, 2017.

NPTEL/SWAYAM Courses for reference:

1. Introduction to Biostatistics - Prof. Shamik Sen, IIT Bombay
   https://onlinecourses.nptel.ac.in/noc19_bt19/preview
2. Statistics for Biomedical Engineers - Prof. Shamik Sen, IIT Bombay
   https://onlinecourses.nptel.ac.in/noc24_bt70/preview
3. Probability and Statistics -Prof. Somesh Kumar, IIT Kharagpur
   https://onlinecourses.nptel.ac.in/noc21_ma74/preview
4. Introduction to Probability Theory and Statistics - Prof. Amitabha Bagchi, IIT Delhi
   https://nptel.ac.in/courses/111102160
5. Statistical Inference - Prof. Niladri Chatterjee, IIT Delhi
   https://onlinecourses.nptel.ac.in/noc23_bt13/preview
6. Biostatistics and Design of Experiments - Prof. Mukesh Doble, IIT Madras
   nptel.ac.in/courses/102106051
7. Regression Analysis - Prof. Shalabh, IIT Kanpur
   https://onlinecourses.nptel.ac.in/noc19_ma32/preview
8. Linear Regression Analysis and Forecasting - Prof. Shalabh, IIT Kanpur
   https://archive.nptel.ac.in/courses/111/104/111104098

No.	COURSE CONTENTS AND LECTURE SCHEDULE	No. of Hours [36 hours]
MODULE 1 [9 hours]		
1.1	Introduction to Biostatistics: Definition, scope, and relevance in life sciences and engineering.	1
1.2	Types of data: Nominal, ordinal, interval, ratio; primary and secondary data. Sampling methods: Random, stratified, systematic, and cluster sampling.	2
1.3	Presentation of data: Frequency distributions, bar charts, histograms, pie charts.	2
1.4	Measures of central tendency: Mean, median, mode.	1
1.5	Measures of dispersion: Range, variance, standard deviation, interquartile range, coefficient of variation	2
MODULE II [9 hours]		
2.1	Basic probability theory: Definitions, laws of probability, conditional probability,	1
2.2	Bayes' theorem. Random variables: Discrete and continuous.	1
2.3	Discrete distributions: Binomial and Poisson - – definition, properties, and applications.	2
2.4	Continuous distributions: Normal and Exponential – properties and applications.	2
2.5	Z-scores and standard normal distribution.	2
2.6	Biological examples involving probability distributions	1
MODULE III [9 hours]		
3.1	Sampling distributions and Central Limit Theorem. Estimation: Point and interval estimation (mean and proportion).	2
3.2	Hypothesis testing framework: Steps, errors, significance levels, and power of a test.	1
3.3	Parametric tests: t-tests: One-sample, independent two-sample, paired sample - z-test (for large samples).	2
3.4	Non-parametric tests (introduction): Chi-square test for independence and goodness-of-fit	2
3.5	One-way ANOVA: Assumptions, interpretation, and biological applications.	2
MODULE IV [9 hours]		
4.1	Correlation analysis: Pearson's and Spearman's correlation.	1
4.2	Regression: Simple linear regression – model, assumptions, estimation, and interpretation	2
4.3	Introduction to multiple linear regression. Applications in biomedical and environmental datasets	2
4.4	Introduction to statistical software (R/SPSS/Excel): Data import, descriptive statistics, charts, regression analysis.	2

4.5	Case studies using real biological data	2
CO Assessment Questions		
CO-1	**1.** Differentiate between nominal, ordinal, interval, and ratio scales of measurement with one biological example for each. Explain how the type of data influences the choice of statistical methods. **(Analyzing)** 2. A researcher collects the cholesterol levels of a sample of 40 adults. Construct a frequency distribution and represent the data using a histogram and a cumulative frequency graph. Comment on the shape of the distribution. **(Apply)** 3. Given a data set with the following glucose levels (in mg/dL): 80, 90, 85, 95, 100, 90, 92, 88, 87, and 85, calculate the mean, median, and mode. Which measure is most appropriate for summarizing central tendency in this case, and why? **(Evaluate)** 4. Explain the concepts of variance and standard deviation. Using the data in Q3, compute the variance and standard deviation, and interpret what these values indicate about the data spread. **(Apply)** 5. Discuss the advantages and limitations of different sampling techniques such as simple random sampling, stratified sampling, and cluster sampling in the context of a field study on malaria incidence in a rural area. **(Evaluate)**	
CO-2	1. Define conditional probability and state Bayes' theorem. Illustrate its application with a biological example such as disease screening using diagnostic tests (sensitivity, specificity, and prevalence). **(Understand)** 2. A random variable X follows a binomial distribution with parameters n = 10 and p = 0.3. Calculate the probability that exactly 4 successes occur. Interpret this result in the context of a genetic trait being passed to offspring. **(Apply)** 3. Compare and contrast the binomial and Poisson distributions. Discuss a biological scenario in which the Poisson distribution would be more appropriate than the binomial distribution. **(Analyze)** 4. The systolic blood pressure of a population is normally distributed with a mean of 120 mmHg and a standard deviation of 10 mmHg. Calculate the probability that a randomly selected individual has a systolic pressure greater than 135 mmHg. **(Apply)** 5. Explain the concept of the exponential distribution and provide a real-life biological application, such as modeling the time between successive cell divisions in a tissue sample. **(Apply)**	
CO-3	1. A biologist collected blood pressure readings from a random sample of 36 adults and found a sample mean of 122 mmHg with a standard deviation of 8 mmHg. Construct a 95% confidence interval for the population mean. Interpret the result. **(Evaluate)** 2. State the steps involved in hypothesis testing. A new drug is claimed to reduce blood sugar levels. Design and test a hypothesis using a one-sample t-test based on a dataset of pre- and post-treatment blood sugar values. **(Apply)** 3. A study aims to compare the average hemoglobin levels between two independent groups of individuals: vegetarians and non-vegetarians.	

	Describe the appropriate statistical test and perform the analysis assuming given sample data. **(Apply)** 4. A researcher wants to analyze the relationship between daily protein intake and body mass index (BMI) in a sample of athletes. Describe how Pearson's correlation and linear regression can be used to assess and interpret this relationship. **(Understand)** 5. Three different diets are being tested on weight gain in lab rats. Explain how one-way ANOVA can be used to determine if there are significant differences between the groups. Discuss the assumptions involved and interpret the possible outcomes. **(Evaluate)**
CO-4	1. A study investigates the relationship between blood pressure and sodium intake in adults. Describe how you would apply Pearson's correlation coefficient to evaluate this relationship. What assumptions must be checked, and how would you interpret the result? **(Apply)** 2. Differentiate between Pearson's and Spearman's correlation coefficients. Illustrate with a biomedical dataset where Spearman's rank correlation would be more appropriate than Pearson's. **(Analyze)** 3. Using Excel/SPSS/R, perform a simple linear regression analysis to explore the relationship between BMI and cholesterol level in a sample dataset. Report and interpret the regression coefficients, R^2 value, and significance level. **(Apply)** 4. Explain the concept of multiple linear regression. Describe a scenario in which this model could be used to predict lung capacity based on age, weight, and smoking history. Discuss potential pitfalls in interpreting the coefficients. **(Evaluate)** 5. A case study is presented involving the impact of ambient air pollution levels on respiratory disease incidence in an urban population. Using real environmental health data, outline the steps you would take to clean, explore, and analyze this dataset using R/SPSS, applying appropriate regression techniques**. (Create)**

Prepared by
Dr. Jis Paul, Associate Professor
Department of Biomedical Engineering

24BME415	INTRODUCTION TO POINT-OF-CARE DIAGNOSTIC DEVICES (IVD-1)	L	T	P	R	C	Year of Introduction
		3	0	0	0	3	2024

Preamble:
In Vitro Diagnostics (IVD) plays a crucial role in modern healthcare by providing essential tools for disease detection, monitoring, and treatment decisions. This course offers a comprehensive understanding of IVD devices, covering their design, development, and applications. Learners will explore diverse technologies, including molecular diagnostics, immunoassays, and point-of-care testing**,** with an emphasis on innovation in diagnostics.

Prerequisite: Basic understanding of Biology

Course Outcomes: After the completion of the course, the student will be able to

CO 1	Understand the classification, regulatory aspects, and essential role of In Vitro Diagnostic (IVD) devices in healthcare **[Understand]**
CO 2	Analyze the design, materials, and fabrication of polymeric-based and lateral-flow immunoassay devices for medical diagnostics**. [Analyze]**
CO 3	Analyze the functionality, commercialization challenges, and effectiveness of low-cost microfluidic technologies in clinical applications. **[Analyze]**
CO 4	Evaluate advanced sensor-based diagnostic technologies, including wearable biosensors and glucose monitoring systems for future healthcare innovations. **[Evaluate]**

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	3	3					3				3
CO2	3	3	2				3				3
CO3	3	3	3	3			3				3
CO4	3	3	3	3	3	3	3				3

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember	√	√	√	√
Understand	√	√	√	√
Apply	√	√	√	√
Analyze	√	√	√	√
Evaluate		√		
Create				

Mark Distribution of CIA

Course Structure [L-T-P-R]	Lecture [L]				
	Attendance	Assignment	Test-1	Test-2	Total Marks
3-0-0-0	5	10	12.5	12.5	40

Total Mark distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	40	60	2.5 hours

End Semester Examination [ESE]: Pattern

PATTERN	PART A	PART B	ESE Marks
PATTERN 1	8 Questions (2 Questions from each module), each question carries 3 marks Marks: (3x8 =24 marks)	2 questions will be given from each module, out of which 1 should be answered. Each question can have a maximum of two sub-divisions. Each question carries 9 marks. Marks: (9x4 = 36 marks)	60

SYLLABUS

MODULE I: Basics of In vitro diagnostics (9 hours)

In vitro diagnostics: Definition, Model List of Essential In Vitro Diagnostics, Classification of the main methodology of in vitro diagnostics, Classification of in vitro diagnostic instruments, Systematic Design, Testing and Development Process of In Vitro Diagnostic Instruments

Self Study (15 hours):

1. Reading on "Methods used to establish the List Essential In Vitro Diagnostics, Principles that should guide preparation of the list and
2. Identification of high-priority IVDs for the EDL" by WHO

MODULE II: Lateral-flow immunoassay (LFIA) devices and Polymeric-Based In Vitro Diagnostic Devices (9 hours)

Lateral-flow immunoassay (LFIA) devices: Structure, Advantages, Antibody, Labels, Membranes, Applications.
Overview of Polymeric-Based In Vitro Diagnostic Devices, Selection of Polymer Materials: Polydimethylsiloxane; Cyclic Olefin Copolymer, Fabrication of Polymer Devices : Structure Formation; Device Sealing; World-to-Chip Interface, Fluidic Control Components: Valve; Pump; Mixer, Applications Detection of Metabolites and Small Molecules; DNA- and RNA-Based Diagnosis; Protein-Based Diagnosis; Cell Analysis .

Self Study (15 hours):

1. Analysis of literatures based on development of LFIA and microfluidic devices

MODULE III: Low-cost In Vitro Diagnostic Technologies (9 hours)

Overview of Low-cost In Vitro Diagnostic Technologies, Paper-Based Microfluidic Devices: Benefits of Paper; Fabrication Techniques; Detection Methods; New Functions and Design; Diagnostic Applications, Thread-/Cotton-Based Microfluidics, Basics of optical (Colorimetric) and Electrochemical (Voltametric and Amperometric) Biosensors, Commercialization of low-cost devices for clinical diagnostics.

Self Study (15 hours):

1. Market study on available commercialized low-cost devices for clinical diagnostics.

MODULE IV: Applications and Its Potential Directions (9 hours)

Glucose Sensor and Its Potential Directions; Disposable Screen printed electrodes: design and principles of detection, Design and Fabrication of the Contact Lens-Based Glucose Sensor: Glucose Sensor Design and Fabrication; LED (Red Light) Fabrication; Antenna Design; Wireless Readout Chip Architecture; Fabrication for the Integration of Radio and Sensor with Contact Lens, Other wearable sensors for bimolecular analysis, Potential Directions.

Self Study (15 hours):

1. Reading on Topics: Biosensors for Clinical Diagnostics, Biosensors for Cholesterol Detection, Biosensors for Cancer Detection, Biosensors for Environmental Monitoring, Challenges in Biosensing: Future perspective

Textbooks

1. Cheng, C.-M., Kuan, C.-M., & Chen, C.-F. (2015). In-vitro diagnostic devices: Introduction to current point-of-care diagnostic devices. Cham, Switzerland: Springer.
2. Pandey, C. M., & Malhotra, B. D. (2019). Biosensors: Fundamentals and applications. Berlin, Germany: Walter de Gruyter GmbH & Co KG.

References

1. World Health Organization. (2019). First WHO model list of essential in vitro diagnostics (Vol. 1017). Geneva, Switzerland: World Health Organization. https://www.who.int/publications/i/item/9789241210266
2. Wang, L., Zhang, Y., Chen, Z., Li, J., & Huang, Y. (2023). Methods and advances in the design, testing and development of in vitro diagnostic instruments. Processes, 11(2), 403. https://doi.org/10.3390/pr11020403

NPTEL/SWAYAM Courses for reference:

1. Optical Sensors – Prof. Sachin Kumar Srivastava, IIT Roorkee https://onlinecourses.nptel.ac.in/noc20_ph13/preview
2. Nanobio Technology–Enabled Point-of-Care Devices – Prof. Gorachand Dutta, IIT Kharagpur https://onlinecourses.nptel.ac.in/noc24_ge23/preview
3. Bioelectrochemistry – Prof. Mainak Das, IIT Kanpur https://onlinecourses.nptel.ac.in/noc22_bt26/preview
4. Interactomics: Protein Arrays and Label-Free Biosensors – Prof. Sanjeeva Srivastava, IIT Bombay https://archive.nptel.ac.in/noc16-bt06

No.	COURSE CONTENTS AND LECTURE SCHEDULE	No. of Hours [36 hours]
MODULE 1 [9 hours]		
1.1	In vitro diagnostics: Definition, Model List of Essential In Vitro Diagnostics	2
1.2	Classification of the main methodology of in vitro diagnostics	2
1.3	Classification of in vitro diagnostic instruments	2
1.4	Systematic Design, Testing and Development Process of In Vitro Diagnostic Instruments	3
MODULE II [9hours]		
2.1	Lateral-flow immunoassay (LFIA) devices: Structure, Advantages, Antibody, Labels, Membranes, Applications	2
2.2	Overview of Polymeric-Based In Vitro Diagnostic Devices, Selection of Polymer Materials: Polydimethylsiloxane; Cyclic Olefin Copolymer,	2
2.3	Fabrication of Polymer Devices : Structure Formation; Device Sealing; World-to-Chip Interface, Fluidic Control Components: Valve; Pump; Mixer,	2
2.4	Applications Detection of Metabolites and Small Molecules; DNA- and RNA-Based Diagnosis; Protein-Based Diagnosis; Cell Analysis	3
MODULE III [9 hours]		
3.1	Overview of Low-cost In Vitro Diagnostic Technologies	1
3.2	Paper-Based Microfluidic Devices: Benefits of Paper; Fabrication Techniques; Detection Methods; New Functions and Design; Diagnostic Applications,	2
3.3	Thread-/Cotton-Based Microfluidics	2
3.4	Basics of optical (Colorimetric) and electrochemical (Voltametric and Amperometric)biosensors	3
3.5	Commercialization of Low-cost Devices for Clinical Diagnostics	1
MODULE IV [9 hours]		
4.1	Glucose Sensor and Its Potential Directions; Disposable Screen printed electrodes: design and principles of detection,	3
4.2	Design and Fabrication of the Contact Lens-Based Glucose Sensor: Glucose Sensor Design and Fabrication; LED (Red Light) Fabrication; Antenna Design; Wireless Readout Chip Architecture; Fabrication for the Integration of Radio and Sensor with Contact Lens	2
4.3	Other wearable sensors for bimolecular analysis	2
4.4	Potential Directions	2

CO Assessment Questions	
CO-1	1. Discuss the classification of In Vitro Diagnostic (IVD) devices and their significance in healthcare. **(Understand)** 2. Explain the WHO Model List of Essential In Vitro Diagnostics and the methodologies used to establish it. **(Understand)**
CO-2	1. Describe the structure and working principle of Lateral-Flow Immunoassay devices with examples. **(Understand)** 2. Compare different polymeric materials used in diagnostic devices and their impact on device performance. **(Analyze)**
CO-3	1. Assess the benefits and challenges of paper-based and thread-based microfluidic technologies in low-cost diagnostics. **(Evaluate)** 2. Evaluate the efficacy of detection methods used in affordable diagnostic devices and their clinical impact. **(Evaluate)**
CO-4	1. Explain the design principles of screen-printed electrodes for glucose monitoring. **(Understand)** 2. Propose innovative sensor-based approaches for non-invasive glucose monitoring in future healthcare. **(Create)**

Prepared by
Dr. Jeethu Raveendran, Assistant Professor
Dept of Biomedical Engineering

24BMM416	QUANTITATIVE PHYSIOLOGY	L	T	P	R	C	Year of Introduction
		3	1	2	0	5	2024

Preamble: This course introduces the quantitative analysis and modeling of key human physiological systems, integrating biomedical concepts with computational tools. It emphasizes cardiovascular, respiratory, neural, renal, and metabolic functions, enabling students to simulate, analyze, and interpret physiological processes for biomedical applications.

Prerequisite: Human Physiology, Engineering Mathematics, Signals and Systems, Programming and Simulation

Course Outcomes: After the completion of the course, the student will be able to

CO 1	Understand the physiological principles of cardiovascular and respiratory systems, including ECG interpretation and hemodynamics.**[Understand]**
CO 2	Analyze electrophysiological phenomena such as action potentials, synaptic transmission, and muscle contraction using modeling approaches. [**Analyze**]
CO 3	Apply knowledge of renal physiology, endocrine control, and glucose-insulin dynamics in quantitative modeling contexts. [**Apply**]
CO 4	Evaluate the body's response to thermal stress, metabolism, and exercise, integrating hormonal regulation and physiological adaptation mechanisms. [**Evaluate**]

CO - PO MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	3	2	2	2	3	2	1	1	3	3	1
CO2	3	3	2	2	2	2	-	-	3	2	1
CO3	3	3	2	2	2	1	1	-	2	3	2
CO4	2	2	2	2	1	2	1	1	3	2	2

Assessment Pattern

Bloom's Category	Continuous Assessment Tools			End Semester Examination
	Test1	Test 2	Other tools	
Remember				
Understand	√	√	√	√
Apply	√	√	√	√
Analyze	√	√	√	√
Evaluate	√	√	√	
Create				

Mark Distribution of CIA

Course Structure [L-T-P-R]	Lecture [L]				
	Attendance	Assignment	Test-1	Test-2	Total Marks
3-1-2-0	5	10	12.5	12.5	40

Total Mark distribution			
Total Marks	**CIA (Marks)**	**ESE (Marks)**	**ESE Duration**
100	40	60	2.5 hours

End Semester Examination [ESE]: Pattern			
PATTERN	**PART A**	**PART B**	**ESE Marks**
PATTERN 1	8 Questions (2 Questions from each module), each question carries 3 marks Marks: (3x8 =24 marks)	2 questions will be given from each module, out of which 1 should be answered. Each question can have a maximum of two sub-divisions. Each question carries 9 marks. Marks: (9x4 = 36 marks)	60

SYLLABUS

MODULE 1: Cardiovascular and Respiratory Systems (9 Hours)

Hemodynamics: Cardiac output, Stroke volume influencers, Blood pressure regulation, Flow dynamics (Laminar vs. turbulent flow), Reynolds number. **ECG interpretation:** Normal sinus rhythm vs. arrhythmias. **Respiratory mechanics and gas exchange**: Lung volumes and capacities, Compliance and elasticity, Airway resistance and flow, Ventilation-perfusion (V/Q) ratio. **Cardiovascular and pulmonary modeling:** MATLAB/Simulink for physiology-based modeling.

Tutorial(3hrs)

1. Understand the physiological basis of cardiac output and factors influencing stroke volume (preload, afterload, contractility).
2. Discuss flow dynamics with worked examples on Reynolds number and implications of turbulent vs. laminar flow.
3. Interpret different types of ECG waveforms including normal sinus rhythm and common arrhythmias using case discussions.

Practical(6hrs)

1. **Respiratory Simulation**: Model changes in lung compliance and airway resistance. Simulate obstructive vs. restrictive lung diseases and V/Q mismatch.
2. **Cardiac Modeling with MATLAB/Simulink**: Build and simulate a lumped-parameter model of the cardiovascular system. Modify preload/afterload values and observe effects on pressure-volume loops and cardiac output.

Self Study(18hrs)

5. Analyze open-access ECG datasets and prepare short diagnostic reports.

6. Draw and interpret lung volume graphs and explain the impact of pathophysiological changes.
7. Complete video-based learning modules (NPTEL/SWAYAM) on pulmonary and cardiovascular mechanics.Submit the Assignment based on that.

MODULE II: Neural and Muscular Systems (9 Hours)

Action potential: Basic Concept, Phases of Action Potential, **Hodgkin-Huxley model:** Core Features, Application. **Synaptic transmission** : Chemical Synapse Electrical Synapse. **Muscle contraction dynamics:** Excitation-Contraction Coupling, Sliding Filament Theory, Types of Contractions, Force-Velocity Relationship. **Neural and EMG modeling:** Concept and Applications .

Tutorial (3 hrs)

4. Explain the Hodgkin-Huxley model structure and simulate its use in modeling neural excitability.
5. Compare chemical vs. electrical synapses through diagrams and functional examples.
6. Discuss types of muscle contractions and the force-velocity relationship.

Practical (6 hrs)

3. Simulate the Hodgkin-Huxley Model: Use MATLAB to visualize action potential generation and propagation by modifying ion conductances.
4. Muscle Force Simulation: Model a basic muscle twitch, simulate isometric and isotonic contractions, and analyze the force-velocity curve.
5. EMG Data Acquisition and Analysis: Record (or use open datasets) and process EMG signals. Identify amplitude and frequency components during different muscle activities.

Self-Study (18 hrs)

4. Explore interactive tools or visualizations of action potential generation and Hodgkin-Huxley equations.
5. Read research articles or textbooks on differences between chemical and electrical synapses and their physiological significance.
6. Analyze and compare EMG signal patterns under voluntary movement and fatigue conditions using open datasets.
7. Submit a mini-project/report: "Modeling Action Potential and Muscle Force Output Using MATLAB/Simulink or Python." Include simulation plots and physiological interpretations.

MODULE III : Renal and Endocrine Systems (9 Hours)

Glomerular filtration: Filtration Mechanism, Mathematical Calculation(GFR),**Tubular Transport:** Reabsorption and Secretion, Transport Mechanisms. **Clearance:** Renal Clearance, Important Markers. **Hormonal control Systems and Endocrine Feedback:** Renin-Angiotensin-Aldosterone System (RAAS),ADH (Vasopressin),Parathyroid Hormone (PTH),Endocrine Feedback Loops, **Glucose-Insulin Dynamics:** Pancreatic Regulation, Glucose Homeostasis, Bergman's Minimal Model.

Tutorial (3 hrs)

4. Understand the mechanism of glomerular filtration and derive the mathematical basis of GFR using Starling forces.
5. Explore hormonal regulation of fluid balance via RAAS, ADH, and PTH. Use flowcharts to explain feedback mechanisms.
6. Introduce glucose-insulin regulation and Bergman's Minimal Model for glucose dynamics.

Practical (6 hrs)

3. GFR and Clearance Calculation Lab: Use sample clinical data to calculate GFR and renal clearance using standard formulas.
4. Simulate Tubular Transport Mechanisms: Model sodium and glucose transport using compartment models in MATLAB or Excel.
5. Glucose-Insulin Modeling: Implement Bergman's Minimal Model in MATLAB/Simulink to simulate glucose-insulin feedback and assess diabetic vs. normal states.

Self-Study (18 hrs)

- Review textbook chapters and research articles on renal physiology, including glomerular filtration and tubular function.
- Practice numerical problems on GFR, clearance, and solute transport.
- Watch NPTEL/SWAYAM modules on endocrine feedback mechanisms and hormonal regulation of homeostasis.
- Analyze publicly available glucose-insulin datasets or simulated data; interpret dynamic responses.

MODULE IV: Thermoregulation and Metabolism (9 Hours)

Thermoregulation and Homeostasis: Definition, Negative Feedback Loop. **Metabolic rate and Hormonal Regulation :** Basal Metabolic Rate (BMR), Hormonal Regulation of Metabolism. **Stress and Exercise Physiology:** Stress Response(Acute stress, Chronic stress), Exercise Physiology(Cardiovascular adaptations, Respiratory response, Muscle metabolism), Types of Exercise(Aerobic, Anaerobic).

Tutorial (3 hrs)

- Discuss the principles of thermoregulation and homeostasis, including core temperature control mechanisms and negative feedback loops (hypothalamic role).
- Understand how metabolic rate is measured and the hormonal influences on BMR (e.g., thyroid hormones).
- Explore the physiological response to acute and chronic stress, and compare cardiovascular, respiratory, and metabolic changes in aerobic vs. anaerobic exercise.

Practical (6 hrs)

- Thermoregulatory Simulation: Model core body temperature regulation using feedback control models. Simulate fever and heat stress responses.

- Metabolic Rate Estimation: Use indirect calorimetry data or predictive equations to calculate BMR and assess hormonal influences.
- Exercise Physiology Lab: Analyze pre-recorded or real-time physiological data (heart rate, respiratory rate, oxygen consumption) from aerobic and anaerobic exercise conditions. Use MATLAB or Excel to plot and interpret response curves.

Self-Study (18 hrs)

- Read scientific literature on thermoregulation and endocrine control of metabolism.
- Watch NPTEL/SWAYAM video modules on energy metabolism, exercise physiology, and stress responses.
- Analyze datasets on cardiovascular and respiratory adaptations during different types of exercise.
- Complete case-based scenarios on hypothyroidism, adrenal stress, or thermoregulatory disorders.
- Prepare a report: "Physiological Modeling of Thermoregulation and Metabolic Response During Exercise," including visual outputs and explanation of adaptive mechanisms under different stressors (e.g., heat, cold, physical activity)

Text Books

1.**Textbook of Medical Physiology** by A.K. Jain, Avichal Publishing Company, 2022.
2.**Essentials of Medical Physiology** by K. Sembulingam & Prema Sembulingam, Jaypee Brothers Medical Publishers, 2021.
3.**Guyton and Hall Textbook of Medical Physiology** by John E. Hall, Elsevier, 2020.

Reference books

- **Biomedical Signal Processing and Signal Modeling** by Eugene N. Bruce, Wiley-Interscience, 2001.
- **Physiological Control Systems: Analysis, Simulation, and Estimation** by Michael C.K. Khoo, Wiley-IEEE Press, 2018.

NPTEL/SWAYAM Courses for reference:
Human Physiology: Prof. Nishikant Subedar, IIT Madras
Human Physiology - Course

No.	COURSE CONTENTS AND LECTURE SCHEDULE	No. of Hours [36 hours]
	MODULE 1 [9 hours]	
1.1	**Hemodynamics**: Cardiac output, Stroke volume influencers, Blood pressure regulation, Flow dynamics (Laminar vs. turbulent flow), Reynolds number.	3

1.2	**ECG interpretation:** Normal sinus rhythm vs. arrhythmias.	1
1.3	**Respiratory mechanics and gas exchange**: Lung volumes and capacities, Compliance and elasticity, Airway resistance and flow, Ventilation-perfusion (V/Q) ratio.	3
1.4	**Cardiovascular and pulmonary modeling:** MATLAB/Simulink for physiology-based modeling.	2
MODULE II [9 hours]		
2.1	**Action potential:** Basic Concept, Phases of Action Potential,	2
2.2	**Hodgkin-Huxley model:** Core Features, Application.	2
2.3	**Synaptic transmission** : Chemical Synapse Electrical Synapse.	1
2.4	**Muscle contraction dynamics:** Excitation-Contraction Coupling, Sliding Filament Theory, Types of Contractions, Force-Velocity Relationship.	3
2.5	**Neural and EMG modeling:** Concept and Applications	1
MODULE III [9 hours]		
3.1	**Glomerular filtration:** Filtration Mechanism, Mathematical Calculation(GFR),**Tubular Transport:** Reabsorption and Secretion, Transport Mechanisms.	2
3.2	**Clearance:** Renal Clearance, Important Markers.	1
3.3	**Hormonal control Systems and Endocrine Feedback:** Renin-Angiotensin-Aldosterone System (RAAS),ADH (Vasopressin),Parathyroid Hormone (PTH),Endocrine Feedback Loops,	4
3.4	**Glucose-Insulin Dynamics:** Pancreatic Regulation, Glucose Homeostasis, Bergman's Minimal Model.	2
MODULE IV [9 hours]		
4.1	**Thermoregulation and Homeostasis:** Definition, Negative Feedback Loop..	2
4.2	**Metabolic rate and Hormonal Regulation :** Basal Metabolic Rate (BMR), Hormonal Regulation of Metabolism	2
4.3	**Stress and Exercise Physiology:** Stress Response(Acute stress, Chronic stress)	2
4.4	Exercise Physiology(Cardiovascular adaptations, Respiratory response, Muscle metabolism), Types of Exercise(Aerobic, Anaerobic)	3
CO Assessment Questions		
CO-1	1. Define cardiac output and list the primary factors affecting it.(**Understand**) 2. Differentiate between laminar and turbulent flow with examples from circulatory physiology.(**Understand**) 3. Describe the process of pulmonary gas exchange and the clinical relevance of ventilation-perfusion (V/Q) mismatch.(**Apply**)	

	4. Analyze the results of a lumped-parameter cardiovascular model simulated in MATLAB/Simulink and evaluate the physiological significance of the pressure-volume loops in assessing cardiac performance(**Evaluate)**
CO-2	1. State the principle of the sliding filament theory in muscle contraction**.(Understand)** 2. Describe the Hodgkin-Huxley model and its use in simulating action potential dynamics with appropriate equations.**(Apply)** 3. Discuss excitation-contraction coupling and how calcium plays a role in muscle activation**.(Analyze)** 4. Critically evaluate the components of neural or EMG signal modeling and assess their effectiveness and limitations in clinical applications **(Evaluate)**
CO-3	1. Define glomerular filtration rate (GFR) and mention one standard method of estimation**.(Understand)** 2. Explain the mechanisms of reabsorption and secretion in the nephron with relevant transport systems.**(Apply)** 3. Describe the RAAS pathway and its role in long-term blood pressure regulation**.(Analyze)** 4. Illustrate Bergman's Minimal Model for glucose-insulin dynamics and explain its importance in diabetic modeling**.(Evaluate)**
CO-4	1. Distinguish between acute and chronic stress responses. **(Understand)** 2. Discuss the body's thermoregulatory mechanism using the negative feedback loop. **(Understand)** 3. Explain hormonal regulation of metabolism focusing on thyroid and adrenal hormones. **(Apply)** 4. Analyze cardiovascular and respiratory adaptations to prolonged aerobic exercise and their physiological significance. **(Analyze)**

Prepared by
Ms. Rani Varghese, Assistant Professor
Dept of Biomedical Engineering