GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Diploma Engineering

Level: Diploma

Branch: Biomedical Engineering

Subject Code: DI04003021

Subject Name: Therapeutic Medical Instrumentation

w. e. f. Academic Year:	2025-26
Semester:	4th
Category of the Course:	PCC

Prerequisite:	Basic Human Anatomy & Physiology, Fundamentals of Electrical & Electronic Engineering, Fundamental of Biomedical Instrumentation, Basic Physics and Mathematics
Rationale:	Therapeutic Medical Instrumentation emphasizes medical devices used primarily for treatment, life-support, and rehabilitation rather than diagnosis. Modern hospitals depend extensively on therapeutic systems such as dialysis units, infusion pumps, physiotherapy equipments, and laser-based therapy devices. Biomedical engineers must therefore understand the working principles, design considerations, clinical applications, and safety requirements of these instruments. This subject provides students with: 1. Knowledge of therapeutic and physiotherapy equipment such as laser therapy units, Short-Wave Diathermy (SWD), Ultrasonic therapy, and TENS systems used in hospitals and rehabilitation centers. 2. Understanding of haemodialysis machines and automated drug delivery devices including infusion pumps and syringe pumps, which are essential in critical care treatment and emergency therapy. 3. Skills in the operation, troubleshooting, and preventive maintenance of surgical and therapeutic systems including diathermy units and neonatal care incubators used in OT and NICU. 4. Awareness of patient-safety protocols and medical equipment standards such as leakage current testing, grounding, and plate contact monitoring, alarms, isolation, and HF safety. 5. Exposure to modern concepts of Environmental Physiotherapy (EPT) including therapeutic environment design, nature-based rehabilitation, and safe movement systems used in rehabilitation centers and physiotherapy labs.

Course Outcome:

After Completion of the Course, Student will be able to:

No	Course Outcomes	RBT Level
1	Explain the use of lasers in therapeutic instruments and describe their applications in surgery, dermatology, ophthalmology, and physiotherapy.	Understand
2	Identify and understand various Physiotherapy and Electrotherapy equipment, including ultrasound therapy units, TENS, muscle stimulators, short-wave diathermy, and heat/cold therapy devices.	Remember/ Understand
3	Perform basic maintenance and troubleshooting of Haemodialysis machines and Infusion pumps, ensuring safe and effective operation in clinical settings.	Apply
4	Identify and describe the working principles of Electrosurgical Units (ESU) and Infant Incubators, along with their safety features and clinical applications.	Understand
5	Understand Electro-Physical Therapies (EPT) and explain their role, benefits, and overall impact on healthcare and patient rehabilitation.	Understand/ Analyze

**Revised Bloom's Taxonomy (RBT)*

Teaching and Examination Scheme:

Teaching Scheme (in Hours)			Total Credits L+T+ (PR/2)	Assessment Pattern and Marks				Total Marks
				Theory		Tutorial / Practical		
L	T	PR	C	ESE(E)	PA(M)	PA(I)	ESE(V)	
3	0	2	3	70	30	20	30	150

Course Content:

Unit No.	Content	No. of Hours	% of Weightage
1	**Laser Therapy**	08	
	1.1 Introduction to Therapeutic Instrumentation Definition		15%

	1. Definition and scope 2. Difference between diagnostic and therapeutic instrumentation 3. Role of therapeutic devices in hospitals and rehabilitation 4. Classification of therapeutic equipment 1.2 LASER (Light Amplification by Stimulated Emission of Radiation) 1.2.1 Basic Principle 1. Stimulated emission 2. Population inversion 3. Optical pumping 4. Coherence, monochromaticity and collimation features 1.2.2 Main Elements of LASER 1. Active medium (solid, liquid, gas, semiconductor) 2. Energy source (optical pump, electrical pump) 3. Optical cavity (mirrors, resonator) 4. Output coupling 5. Beam delivery system 1.2.3 Therapeutic Applications 1. Dermatology: wound healing, scar removal 2. Ophthalmology: photocoagulation 3. Surgery: cutting, coagulation 4. Physiotherapy: low-level laser therapy (LLLT)		
2	**Physiotherapy and Electrotherapy Equipment**	10	
	2.1 High Frequency Heat Therapy Positive Feedback 2.1.1 Short Wave Diathermy (SWD) 1. Principle of deep heating using electromagnetic waves 2. Types: Inductive & Capacitive SWD 3. Circuit diagram and block diagram 4. Components: RF oscillator, tuning circuit, applicator 5. Application techniques: Contraindications, Treatment positions, Continuous vs Pulsed mode 2.1.2 Ultrasonic Therapy Unit 1. Principle of piezoelectric effect 2. Frequency range (0.7–3 MHz) 3. Circuit and block diagram 4. Transducer structure		25%

	5. Modes: continuous/pulsed 6. Applications and precautions 2.2 Electrotherapy 1. Definition and purpose 2. Types of currents used: Galvanic current, Faradic current, Surging current, Exponentially progressive current, Biphasic stimulation 3. Waveforms used for stimulation (diagrams required) 4. Muscle re-education and nerve stimulation 2.3 Pain Relief through Electrical Stimulation 1. Principle of gate control theory 2. Types: Conventional TENS, Acupuncture TENS, Burst TENS, cervical Traction machine 3. Electrode placement techniques 4. Applications in chronic and acute pain		
3	**Haemodialysis Machine and Automated Drug Delivery System**	10	
	1.1 Artificial Kidney – Principle 1. Diffusion, ultra filtration, osmosis 2. Removal of toxins and excess fluid 3. Dialysate composition 1.2 Haemodialysis Machine 1.2.1 Hollow Fiber Hemodialyzer 1. Structure of hollow fiber bundle 2. Membrane material and pore size 3. Blood and dialysate flow paths 1.2.2 Block Diagram of HD Machine 1. Blood pump system 2. Heparin pump 3. Pressure monitors 4. Conductivity and temperature control 5. Ultra filtration controller 6. Leak detection and alarms 1.3 Infusion Pumps 1. Principle of controlled drug delivery 2. Types: Volumetric, PCA pumps		25%

	1.3.1 Syringe Pumps 1. Basic principle 2. Motor control and plunger mechanism 3. Block diagram and working 4. Applications in ICU and neonatal care		
4	**Surgical Diathermy and Neonatal Therapy**	09	
	4.1 Surgical Diathermy 4.1.1 Principle 1. High-frequency current for cutting and coagulation 2. Monopolar and bipolar modes 4.1.2 Electrodes 1. Cutting electrodes (needle, blade) 2. Coagulation electrodes (ball, loop) 3. Return plate (patient plate) 4.1.3 Safety Aspects 1. Leakage current 2. Plate contact monitoring 3. Burns prevention 4. HF isolation 5. Earthing and insulation standards 4.2 Neonatal Therapy 4.2.1 Temperature-Controlled Incubator 1. Principle of thermal regulation 2. Components: heater, humidity control, fan, sensors 3. Airflow system 4. Servo control mechanism 5. Alarms and safety features 6. Application in preterm infants		20%
5	**Environmental Physiotherapy (EPT)**	8	
	5.1 Environmental Physiotherapy (EPT) 1. Definition 2. Relationship between environment and therapeutic outcomes 3. Nature-based rehabilitation 5.2 Steps Towards EPT 1. Green physical therapy 2. Outdoor therapy approach		15%

	3. Safe movement spaces 4. Designing patient-friendly environments 5.3 EPT in Patient Care 5.3.1 Nature-Based Interventions 1. Active transport (walking, cycling) 2. Physical exercise 3. Mental health benefits 4. Reduction in sedentary lifestyle disorders 5. Role in chronic disease rehabilitation		
	Total	**45 Hrs.**	**100 %**

Suggested Specification Table with Marks (Theory):

Distribution of Theory Marks (in %)					
R Level	**U Level**	**A Level**	**N Level**	**E Level**	**C Level**
30 %	**40 %**	**30 %**	**--**	**--**	**--**

Where R: Remember; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create (as per Revised Bloom's Taxonomy)

References/Suggested Learning Resources:

(a) Books:

1. "Handbook of Biomedical Instrumentation", Dr. R. S. Khandpur, McGraw Hill Education (India) Pvt. Ltd., New Delhi.
2. "Medical Instrumentation: Application and Design", John G. Webster, John Wiley & Sons, New Delhi.
3. "Medical Lasers and Their Safe Use", David H. Sliney & Stephen L. Trokel, Springer Publications.
4. "Introduction to Biomedical Equipment Technology", Joseph J. Carr & John M. Brown, Pearson Education Asia, New Delhi.
5. "Biomedical Instrumentation and Measurements", Leslie Cromwell, Fred J. Weibell & Erich A. Pfeiffer, PHI Learning, New Delhi.

(b) Open-source software and website:

1. https://www.physio-pedia.com/An_Introduction_to_Environmental_Physiotherapy

2. https://www.fusfoundation.org/posts/therapeutic-ultrasound-course-mooc-now-available-online/
3. www.coursera.org
4. www.edx.org
5. www.nptel.ac.in
6. www.swayam.gov.in

Suggested Course Practical List: If any

Sr. No.	Practical Outcomes (PrOs)	Unit No.	Approx. hours required.
1	Investigate the use of lasers as a means of transmitting information and determine the wavelength.	I	4
2	Demonstrate the working of Laser Therapy Unit.	I	4
3	Operate and test short wave diathermy in condenser/ inductive fields and operation of its control panel.	II	4
4	Test 1MHz frequency ultrasound therapy using an electronic circuit.	II	4
5	Observe the performance and effect of electrotherapy equipment on human body and operation of its control panel.	II	4
6	Demonstrate the working of nerve stimulation using TENS.	III	4
7	Identify various applications of infusion pumps in hospitals and observe their operation.	III	4
8	Demonstrate the working of hemodialysis machine.	III	4
9	Identify various setting parameters and it's significant during hemodialysis procedure.	III	4
10	Demonstrate the delivering of drugs by infusion pump in dummy patients.	III	2
11	Demonstrate the working of volumetric Infusion pump.	IV	2
12	Operate and test Electrosurgical Unit in different mode using various electrodes.	IV	4
13	Perform cut, coagulation and desiccation operation using shop.	IV	4
14	Demonstrate working of neonatal incubators.	IV	4
15	Analyze the importance of active transport as environmental physiotherapy intervention.	V	2
16	Observe the relevance of nutrition on physiotherapy.	V	2

List of Laboratory/Learning Resources Required:

A. Instruments & Equipment

1. Laser Therapy Unit
2. Ultrasound therapy unit
3. Short wave diathermy unit
4. TENS machine
5. IFT (Interferential Therapy Unit)
6. Muscle stimulator
7. Hemodilaysis machine
8. Infusion pumps, syringe pumps
9. Electrosurgical Unit
10. Neonatal incubator
11. Cross cycling unit
12. Traction unit
13. Outdoor Therapy Walking Simulator
14. Treadmill with Gait Analysis
15. Balance Board / Stability Trainer
16. Cycle Ergo meter
17. Rehabilitation Ladder
18. Therapeutic Exercise Mat
19. Smart wearable activity tracker

B. Sensors & Accessories

1. Temperature sensor
2. Pressure sensor
3. Flow sensor
4. Air bubble detector
5. Conductivity sensor
6. Pulse oximeter (SpO_2) sensor
7. Humidity sensor
8. Piezoelectric sensor
9. Photodiode sensor (Laser)
10. Current & voltage sensors
11. Return electrode contact sensor
12. Optical fiber sensor
13. Droplet / drip sensor
14. Leakage current sensor
15. Gait / motion sensor (IMU)

C. Software & Simulation Tools

1. LabVIEW – medical instrumentation & signal processing
2. MATLAB / Simulink – biomedical simulation & analysis
3. COMSOL Multiphysics – laser, heat therapy, tissue interaction modeling
4. Proteus / Multisim – circuit design for therapeutic devices
5. ImageJ – image-based analysis (laser/dermatology applications)
6. Dialysis / ICU Simulator (open-source patient monitor) – clinical training simulation

D. Safety Tools & Accessories

1. Leakage current tester
2. Isolation transformer / ELCB
3. Laser safety goggles
4. Patient return electrode (diathermy)
5. Air bubble detector (dialysis/infusion safety)
6. PPE kit (gloves, mask, apron)

E. General Laboratory Setup

1. Work benches & instrument tables
2. Power supply & electrical outlets (with earthing)
3. UPS / Stabilizer for medical equipment
4. Basic measurement instruments– Multimeter, oscilloscope, signal generator
5. Computer system + software installation area
6. Storage cabinet for devices & consumables
7. Cleaning & sterilization corner (sanitizer, waste bins)

Suggested Project List:

The projects help students apply theoretical concepts of therapeutic devices used in hospitals. They integrate Course Outcomes (COs) with practical engineering skills.

- **Project Types:**
  - Industry-based (hospital biomedical dept., dialysis centers, physiotherapy clinics)
  - Laboratory-based (college electronics/biomedical lab)
  - Workshop or field-based
  - Simulation-based (using Proteus, Multisim, MATLAB)
- **CO Integration:**
  - Each project should link at least two COs, especially:
  - CO1 (Laser)

- CO2 (Physiotherapy/Electrotherapy)
- CO3 (Dialysis & Infusion pumps)
- CO4 (ESU & Incubators)
- CO5 (EPT & lifestyle factors)

- **Project Duration:**
  - Students are encouraged to maintain a dated work diary to document their individual contributions and sufficient engagement time for each project should be allocated by faculty during the course.
- **Project Demonstration:**
  - Before submission, students must give a project demonstration on their project.
  - The presentation should highlight the project's objectives, methodology, results, and relevance to industry-oriented COs.
- **Seminar Presentation:**
  - Before submission, students must give a seminar presentation on their project.
  - The presentation should highlight the project's objectives, methodology, results, and relevance to industry-oriented COs.

Following are suggestive projects, and additional ones can be tailored to specific course objectives. Encourage students to explore innovative solutions and apply their engineering skills effectively.

1. **Design of Low-Power Laser Therapy Demonstration Unit (LILT)**
   Show how low-level lasers are used for pain relief and tissue healing.
3. **Laser Wavelength Measurement Setup Using Diffraction Method**
   Demonstrate how therapeutic lasers are characterized.

3.Safety Module for Laser Therapy Units
Design interlock, goggles detection, and overexposure cut-off circuit.

4. **Ultrasound Therapy Demonstration Circuit (1 MHz Generator)**
   Build and test a basic 1 MHz oscillator used in physiotherapy.
5. **Short-Wave Diathermy (SWD) Heating Simulation**
   Inductive and capacitive field heating demonstration with sensors.
6. **TENS Unit Prototype (Transcutaneous Electrical Nerve Stimulation)**
   Create a basic muscle stimulation circuit with adjustable pulse width.
7. **IF (Interferential Therapy) Signal Generator**
   Make two medium-frequency circuits that interfere to produce low-frequency therapy.
8. **Muscle Stimulator Using Pulse Generator**
   Demonstrate how physiotherapists treat muscle spasms.
9. **Model of Hemodialysis Hydraulic Circuit**

Water flow, dialyzer model, blood pump simulation, pressure alarms.

10. **Dialysate Conductivity Measurement System**
    Demonstrate how dialysis machines check Na+ and K+ levels.
11. **Ultrafiltration Control Simulation for Dialysis**
    Show fluid removal principles using sensors and pumps.
12. **Volumetric Infusion Pump Prototype**
    Demonstrate peristaltic movement using DC motors and flow sensors.
13. **Syringe Pump Model for Accurate Drug Delivery**
    Stepper motor–based syringe driving with selectable infusion rate.
14. **Electrosurgical Unit (ESU) – Cut & Coagulation Waveform Generator**
    Demonstrate high-frequency electrocautery signal generation.
15. **ESU Patient Plate Contact Safety Alarm**
    Design a continuity alarm system for patient safety.
16. **Neonatal Incubator Temperature Control System**
    Closed-loop temperature control with heater and thermistor.
17. **Baby Incubator Humidity Control System**
    Demonstrate humidity monitoring and control using sensors.
18. **Effect of Active Transport on Heart Rate – Experimental Study**
    Measure heart rate before and after walking/cycling.
19. **Nutrition Monitoring System for Physiotherapy Patients**
    Track calories, hydration, and nutritional intake with sensors.
20. **Posture Correction Alarm System**
    Wearable system that warns when back posture deviates.
21. **Biomedical Device Safety Alarm System (Laser + ESU + Dialysis)**
22. **Hospital Physiotherapy Equipment Fault Detection Kit**
23. **Model Making (Dialyzer, SWD, TENS, ESU, Incubator)**
24. **Wearable Posture Correction Belt**
    Small vibration alert if wrong posture detected.
25. **Chart Preparation (Laser types, SWD modes, dialysis cycle, ESU modes)**

Suggested Activities for Students: If any

- To enhance learning beyond classroom lectures and laboratory experiments, the following co-curricular activities are suggested. These activities are designed to strengthen students' understanding of biomedical devices used in hospitals (therapeutic, diagnostic and safety-related) and develop practical engineering skills. Students may perform these activities individually or in small groups. Breadboard/PCB work is encouraged wherever applicable. Each activity should be documented in a minimum 5-page report with photos, circuit diagrams,

readings and reflections. Evidence collected during the activity (photos, PCB samples, data, videos) must be preserved in the student portfolio for internship and placement purposes.

Hands-on Circuit Design

- Activity: Design and construct:1 MHz ultrasound therapy oscillator, TENS pulse generator (pulse width, frequency adjustable), Laser driver circuit (low-power demonstration), Temperature control circuit for neonatal incubator, Basic ESU waveform generator (low-voltage model), Build standard amplifier circuits used in therapeutic devices, Inverting, non-inverting, differential, and instrumentation amplifier circuits.
- Objective: To understand the core electronic circuits used in therapeutic medical instruments and reinforce signal behavior, gain, and stability concepts.

Simulation-Based Analysis

- Activity: Using LTspice / Proteus / KiCad / Tinkercad / Multisim, simulate:SWD (Short Wave Diathermy) oscillator, Interferential therapy signal mixing, Laser modulation circuit, Dialysis pressure alarm circuit, Incubator temperature PID control loop
- Objective: To visualize therapeutic device signals, analyze circuit behavior, and understand the impact of parameter variations without hardware limitations.

Signal Conditioning Challenge

- Activity: Design a biomedical signal amplifier such as: ECG pre-amplifier, EMG or EEG amplifierPhotodiode amplifier for laser therapy feedback, Implement filtering for noise removal (low-pass, band-pass, notch filters).
- Objective: Apply amplification and filtering techniques used in TENS, ultrasound therapy, electromedical devices, and dialysis sensors.

Troubleshooting Practice

- Activity: Students are provided intentionally faulty circuits of: TENS, SWD, Incubator controller, ESU low-power circuit, Syringe pump speed control. They must diagnose the problem and repair it.
- Objective: Develop circuit analysis, fault finding, and logical reasoning skills.

Mini-Project Group Activity

- Activity: In small teams, build working prototypes such as: Precision rectifier for ESU signal sensing, Active filters for ultrasound therapy, Instrumentation amplifier for dialysis pressure sensor, Syringe pump rate controller using stepper motor, Laser safety interlock module, Dummy model of hemodialysis hydraulic flow
- Objective: Enhance design thinking, teamwork, documentation, and presentation skills.

Data Sheet Interpretation

- Activity: Study datasheets of devices used in therapeutic instruments: Operational amplifiers (LM741, LM358, TL081, OP07, INA122), Sensors (thermistors, IR sensors, pressure sensors), Power MOSFETs (for ESU switching), Diodes/Lasers (IR, red laser, photodiodes).

- Objective: Enable students to understand specifications, ratings, electrical characteristics, and safe operating conditions.

Expert Lecture or Industry Visit

- Activity: Guest lecture from biomedical professionals on: Laser therapy, Physiotherapy equipment, Dialysis machines, Infusion pumps, Neonatal care instruments, Electrosurgical units. Visit to: Hospital Physiotherapy Department, Dialysis Unit, Operation Theatre (ESU demonstration), NICU (incubator demonstration).
- Objective: Relate classroom learning with real hospital practices, safety standards, troubleshooting, and device management.

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