SNS COLLEGE OF TECHNOLOGY

(An Autonomous Institution)

Coimbatore - 35

B.E/B.Tech - Internal Assessment - III

Academic Year 2024-2025 (Even Semester)

Fourth Semester - Biomedical Engineering

23BMT204 - Biomedical Instrumentation

Answer Key

PART - A (5 × 2 = 10 Marks)

1.Define Pedobarograph and its clinical application (CO4, REM)

Definition: A pedobarograph is a diagnostic tool that measures and maps pressure distribution under the foot during standing or walking.

Clinical Application: Used to assess foot deformities (e.g., flat feet), diagnose diabetic foot ulcers, and design custom orthotics for pressure relief.

2.Mention two fatigue characteristics observed in EMG signal analysis (CO4, REM, GATE 2023 BM)

- Decrease in mean frequency of the EMG signal.
- Increase in amplitude due to recruitment of additional motor units.

3.Identify the impact of conductive surfaces on patient safety (CO5, UND)

- Conductive surfaces (e.g., metal bed frames) can create unintended electrical pathways, increasing the risk of electric shock or burns. Proper insulation and grounding are essential to prevent current leakage to the patient.

4.Outline the concept of patient's electrical environment (CO5, UND, GATE 2022 BM)

- The patient's electrical environment includes all electrical devices, wiring, and grounding systems in proximity to the patient. It must be designed to minimize electromagnetic interference and ensure safety by preventing leakage currents and maintaining proper isolation.

5.List two basic electrical safety codes applicable to medical instruments (CO5, APP)

IEC 60601-1: General requirements for safety and essential performance of medical electrical equipment.

NFPA 99: Health care facilities code for electrical safety in patient care areas.

PART - B (2 × 13 = 26 Marks)

6.(a) Compare the clinical effectiveness of nerve stimulation based on Gate Control Theory vs Endorphin Theory of pain modulation. Which mechanism is more suitable for chronic pain management? (CO4, APP)

Gate Control Theory: Proposes that non-painful stimuli (e.g., TENS) close the "gate" in the spinal cord, blocking pain signals. Effective for acute pain (e.g., post-surgical) by stimulating large-diameter sensory fibers.

Endorphin Theory: Suggests nerve stimulation (e.g., low-frequency TENS) triggers endorphin release, mimicking natural pain relief. Effective for chronic pain due to sustained opioid-like effects.

Comparison: Gate Control is faster for immediate relief but less effective long-term. Endorphin Theory provides longer-lasting relief through neurochemical changes.

Suitability for Chronic Pain: Endorphin Theory is more suitable for chronic pain management due to its sustained analgesic effect and ability to reduce pain perception over time.

OR

(b) Illustrate the nerve conduction velocity measurement process and discuss its clinical relevance (CO4, APP)

Process:

- Electrodes are placed on the skin over a nerve (stimulating and recording electrodes).
- A low-intensity electrical stimulus is applied to the nerve.
- The time taken for the nerve impulse to travel between electrodes is measured (latency).
- Nerve conduction velocity (NCV) is calculated as distance/latency (m/s).
- Sensory and motor nerves are tested separately.

Clinical Relevance:

- Diagnoses peripheral neuropathies (e.g., diabetic neuropathy, carpal tunnel syndrome).
- Assesses nerve damage severity in conditions like Guillain-Barré syndrome.
- Monitors treatment progress (e.g., nerve regeneration post-injury).
- Helps differentiate between axonal and demyelinating neuropathies.

7.(a) Examine the physiological effects of electricity on the human body with appropriate susceptibility parameters (CO5, ANA)

Physiological Effects:

Muscular Effects: Low currents (1–10 mA) cause tingling or muscle contractions. Higher currents (>50 mA) can lead to tetany or paralysis.

Cardiac Effects: Currents >10 mA can disrupt heart rhythm, causing ventricular fibrillation (especially at 50–60 Hz AC).

Thermal Effects: High currents cause burns due to tissue heating.

Neurological Effects: Currents >100 mA can affect nerve signaling, leading to unconsciousness or respiratory failure.

Susceptibility Parameters:

Current Magnitude: Microshock (10–100 µA) can cause fibrillation in direct heart contact; macroshock (>10 mA) affects skin contact.

Frequency: AC (50–60 Hz) is more dangerous than DC due to repetitive stimulation.

Duration: Longer exposure increases tissue damage risk.

Pathway: Current through the heart or brain is most hazardous.

Skin Resistance: Wet skin lowers resistance, increasing current flow.

OR

(b) Compare the approaches for handling micro shock versus macro shock risks in ICU settings using protective systems (CO5, ANA)

Microshock:

Definition: Low currents (10–100 µA) entering directly into the heart (e.g., via catheters).

Protective Systems:

- Use of isolated power systems to minimize leakage currents.
- Low-leakage medical equipment (IEC 60601-1 compliant).
- Equipotential grounding to equalize potential differences.
- Regular testing of catheters and invasive devices for insulation integrity.

Macroshock:

Definition: Higher currents (>1 mA) through skin contact, affecting larger body areas.

Protective Systems:

- Ground Fault Circuit Interrupters (GFCI) to detect and interrupt leakage currents.
- Double insulation in medical devices to prevent contact with live parts.
- Proper grounding of all equipment in the ICU.
- Staff training on safe equipment handling.

Comparison: Microshock requires stricter controls due to direct heart access and lower current thresholds. Macroshock focuses on preventing external contact with high currents. Both use grounding and insulation, but microshock demands higher precision in invasive device design.

PART - C (1 × 14 = 14 Marks)

8.(a) (i) Propose a muscle stimulator design for physiotherapy applications with adjustable pulse width and frequency. Justify its relevance for different muscle groups (CO4, ANA)

Design:

Pulse Generator: Produces biphasic square waves (safe for tissue).

Adjustable Parameters: Pulse width (50–500 μs), frequency (1–100 Hz).

Electrodes: Surface electrodes placed on target muscle groups.

Control Unit: Microcontroller-based interface for setting pulse width, frequency, and intensity.

Safety Features: Current limiter (<50 mA), auto-shutoff, and skin impedance monitoring.

Power Supply: Rechargeable battery for portability.

Relevance for Muscle Groups:

Large Muscles (e.g., quadriceps): Low frequency (10–20 Hz), wider pulse width (300–500 μs) for strong contractions and endurance training.

Small Muscles (e.g., hand muscles): Higher frequency (50–80 Hz), shorter pulse width (50–150 μs) for precise stimulation and reduced fatigue.

Justification: Adjustable parameters allow tailored stimulation for rehabilitation (e.g., post-stroke recovery) or strengthening specific muscle groups, improving therapy outcomes.

(ii) Break down the root causes of electrical shock incidents in hospital dialysis units and propose technical safety upgrades (CO5, ANA)

Root Causes:

- Leakage currents from dialysis machines due to poor insulation.
- Improper grounding of equipment or patient bed.
- Wet environments increasing conductivity.
- Faulty maintenance or outdated equipment.
- Human error (e.g., incorrect connections).

Technical Safety Upgrades:

- Install isolated power systems to reduce leakage currents.
- Use GFCI devices to interrupt fault currents.
- Regular calibration and testing of dialysis machines per IEC 60601-1.
- Implement non-conductive flooring and dry environment protocols.
- Train staff on electrical safety and emergency procedures.

OR

(b) (i) Analyze the use of EMG signals in identifying abnormalities during the stance and swing phases of the gait cycle (CO4, ANA)

EMG in Gait Analysis:

Stance Phase: EMG records activity in muscles like tibialis anterior (foot stabilization) and gastrocnemius (propulsion). Abnormalities include reduced activity (e.g., drop foot) or asynchronous firing (e.g., spasticity in stroke patients).

Swing Phase: EMG monitors muscles like iliopsoas and hamstrings for leg advancement. Abnormalities include weak signals (muscle weakness) or prolonged activity (neurological disorders).

Analysis:

- EMG amplitude indicates muscle strength; timing reflects coordination.
- Abnormal patterns (e.g., co-contraction in cerebral palsy) are identified by comparing with normative data.
- Used in diagnosing conditions like Parkinson's or peripheral neuropathy.

Applications: Guides rehabilitation strategies, orthotic design, or surgical planning.

(ii) Evaluate the role of electrical safety analyzers in pre-surgical checks. How can test results prevent equipment-related hazards? (CO5, ANA)

Role of Electrical Safety Analyzers:

- Measure leakage currents, ground resistance, and insulation integrity of surgical equipment.
- Verify compliance with standards (e.g., IEC 60601-1).
- Test diathermy machines, monitors, and other devices for electrical faults.

Preventing Hazards:

- Detects excessive leakage currents that could cause microshock or burns.
- Identifies grounding faults to prevent macroshock.
- Ensures proper insulation to avoid unintended current paths.
- Test results prompt equipment repair or replacement, reducing risks during surgery.

Example: A high leakage current reading ($>100\ \mu A$) in an electrosurgical unit can lead to its isolation, preventing patient burns.