Basic Principles of Electricity
Chapter 4

Modalities and Electricity

- Certain modalities can take electrical energy and convert it to produce a physiological response in human tissue.
- Which modalities require electrical energy?

Electrical Currents

- All matter is composed of charged particles or ions.
- Ions
  - Anion
    - Gains electron
    - Negative charge
  - Cathion
    - Loses electron
    - Positive Charge

Electrical Currents (Con't)

- Electricity is:
  - Flow of charged particles.
- Electrical current:
  - Net movement of electrons
  - Flow from neg. to pos.
  - Flow from higher to lower concentration
- Current:
  - Flow from one point to another.

Ampere

- Unit of measure that indicates the rate in which electrons move past a given point.
- 1 ampere = 1 coulomb/sec
- In modalities: measured in milliamps (1/1000 amp) or microamps (1/1,000,000 amp).

Coulomb’s

- The number of electrons moving
- 1 coulomb = 6.25 x 10^{18} electrons per second.
- Opposites attract, likes repel
Electromotive Force

- Imbalance in electrons
- Potential difference between two points = Voltage
  - When a proper conductor connects the two points the electrons will move from higher to lower concentrations.
- Unit of Measure: Volt

Conductance

- The ease in which a current flows along a conducting medium
- Conductor: Materials that permit the free movement of electrons
  - Metals: copper, gold, silver, aluminum
  - Electrolyte solutions

Insulators

- Materials that resist current flow
- Contain few free electrons
- Offer great resistance to electron flow
- Examples: wood, glass, and air.

Electrical Impedance

- Opposition to the flow of electrons in a conducting material
- Unit of Measure: Ohm

Ohm’s Law

- The current in an electrical circuit is directly proportional to the voltage and inversely proportional to the resistance.
- Current Flow = Voltage/Resistance
  - Voltage = force needed to cause flow
  - Resistance = depends on medium being used.

Electrical Power

- Product of the voltage and amount of current flowing.
- Unit of Measure: Watts
- Watts = Volts x Amperes
- Indicates the rate that electrical power is being used.
Electrical Circuits

- Series Circuit
  - Has 1 path for charges to move along
  - Move in a series going from 1 resistor to the next
  - If one item is broken that no charge occurs. (ex. Holiday lights)

- Parallel Circuits
  - Has multiple paths to move along
  - If one item is broken no charge will move through that path, but others will continue to have flow. (ex.)

Electrotherapeutic Currents

- Three types
  - Direct Current (DC)
  - Alternating Current (AC)
  - Pulsitile Current

Direct Current

- AKA: galvanic current
- Has uninterrupted unidirectional flow electrons toward the positive pole
- On most newer machines polarity can be either positive or negative.
- Monophasic current

Alternating Current

- Continuous Automatic reversal of polarity between positive and negative poles
- Electrons will always move from negative to positive pole.
- Biphasic current
- Can be symmetrical or asymmetrical

Pulsitile Current

- Contain three or more pulses grouped together called bursts, packets, or envelopes.
- Pulses will be interrupted for a short interval and then repeated again.
- Polyphasic current
- Examples: Russian and Interferential Stim.
Generators of Therapeutic Current

- Transcutaneous electrical stimulators = ALL therapeutic generators.
- Transcutaneous Electrical Nerve Stimulators (TENS): stimulate peripheral nerves.
- Neuromuscular electrical stimulator: specifically stimulates muscular tissue directly.
  - Needed when peripheral nerves are not functioning.
  - Most common example: MENS

WAVEFORMS

- Graphic representation of electrical current
- Displayed on an oscilloscope
- Will show the shape, direction, amplitude, duration, and pulse frequency.

Anatomy of a Waveform

- Pulse: individual waveform that can contain one or two phases.
- Phase: portion of a pulse that rises above or below the baseline for a period of time.
- Amplitude: intensity of the current.
- Intraperiod interval: short period of time when current is not flowing
- Intrapulse interval: interruption of a single pulse
- Rate of Rise: how quickly a pulse reaches maximum amplitude
- Rate of Decay: how quickly a pulse goes from maximum amplitude to 0.
- Pulse Duration: length of time a current is flowing in one cycle.

Anatomy of a Waveform (con’t)

- Pulse period: combined time of pulse duration and interpulse interval.
- Frequency: Number of pulses per second.
  - Less than 50pps: twitch reaction
  - More than 50pps: tetany occurs
- Ramping: current amplitude gradually increases to a preset maximum.
- Waveform shapes:
  - Sinusoidal
  - Rectangular
  - Spiked

Accommodation

- When a fiber has been subjected to a constant level of depolarization
- Becomes inexcitable
- Need to change rate of rise and decay to help decrease this phenomenon.

Asymmetric Waveforms

- Faradic Current
  - Seldom used in modern equipment
  - Did not have very good physiological effects because amplitude of the wave in the negative component could not produce a physiological response
  - Can be used in a monophasic form when the amplitude rises gradually and falls abruptly to stimulate denervated muscle.
    - Allows for accommodation of normal muscle.
Current Modulation

- Modulation: alteration in the magnitude or any variation of pulses.
- Continuous
- Interrupted
- Burst
- Ramped

Current Modulation (con't)

- Continuous Modulation:
  - Flow stays the same for several seconds or minutes.
  - Usually direct current
  - Creates alkaline or acidic environment called medical galvanism.
  - Ex. Iontophoresis

- Interrupted Modulation:
  - Current flows for a period and is off for a period.
  - Can be monophasic or biphasic
  - On time: between 1 and 60 sec.
  - Off time: between 1 and 120 sec

Current Modulation (Con't)

- Burst Modulation
  - Pulsed current flows for a short duration and then is off for a short period.
  - May be used with monophasic or biphasic current.
  - Ex. Interferential

- Ramping Modulation
  - Amplitudes will gradually rise to a preset max and ramp down in intensity.
  - Up time is usually 1/3 of on time.
  - Down time is not on all machines
  - On and off times: between 1 and 10 sec.

Current Flow through tissues

- Current chooses the path of least resistance.
- Need to have good conducting medium
- Tissues with highest water content are the best conductors

Skin
- Various water content
- Considered an insulator
- Need to prepare skin before applying stimulation
- How?

Current Flow through tissues

- Blood
  - Composed largely of water and ions
  - Best conductor of biological tissue
- Muscle
  - 75% water
  - Depends on movement of ions for contraction.
  - Longitudinal is best
- Muscle Tendon
  - Contain little water
  - Poor conductors
- Fat
  - 14% water
  - Poor conductor
- Peripheral Nerves
  - Conductivity is six times that of muscle
  - But, surrounded by sheaths that are poor conductors
- Bone
  - 5% water
  - Poorest conductor of biological tissues.

Physiological Response to Electrical Current

- Thermal
  - Rise in body temperatures in conducting tissues
  - Higher resistance causes higher rise in temperature
  - Those currents used to stimulate nerve and muscular tissue have little thermal effects due to low average current flow
  - Diathermies have a high-frequency and produce increase in tissue temp.

- Physiological
  - Muscle contractions or modification of pain through effects on nervous tissues.
  - At positive pole: acidic reaction causes coagulation of proteins and hardening of tissues
  - At negative pole: alkaline reaction causes liquifying of proteins and softening or tissues
Safety

- Large concern for professionals
- Power coming out of wall is 220 or 120 Volts with 60 Hz
- Can cause significant physiological damage.
- Microshock: shock from an electrical current that cannot be felt (less than 1 mA)
- Macroshock: shock from an electrical current that is greater than 1 mA

Safety (Con’t)

- Ground Fault Interrupters
  - Required by National electrical code
  - Mainly for whirlpools and tubs.
  - If there is a leakage in current flow the circuit breaker will automatically interrupt the flow in as little as 1/40th of a second.

Be sure to have electrical outlets evaluated by an electrician
- Have modalities calibrated yearly