

EE 202

I, Introduction

- A, Intent & Scope of course
 - 1, Introductory in nature
 - 2, Mainly biological
 - 3, Vocabulary toughest aspect
- B, My name and phone number
- C, Define
 - 1, Bioengineering
 - 2, Medical Electronics
- D, Political problems associated with Bioengineering
 - 1, In general
 - 2, At Stanford
 - a, History
 - b, Other courses

II, Nature of a cell membrane

III, Body Fluid

- A, Blood & plasma 5% of body weight
- B, Interstitial fluid 15% " "
- C, Intrastitial fluid 40% " "
- D, Main ions
 - 1, Extracellular Na, Cl
 - 2, Intracellular K, PO₄

IV, Donnan Equilibrium

V, Na/K Pump

VI, Membrane Potential

- A, Resting potential controlled primarily to intracellular [K⁺]

$$1, E_K = RT/FZ^k (\ln[K^+_{out}]/[K^+_{in}]) = 61.5 \ln[K_o]/[K_i] \approx -99V$$

- B, Action potential controlled primarily by extracellular [Na⁺]

VII, Nerve Cell

- A, Anatomic Elements
 - 1, Soma, dendrites, nucleus, axon hillock, axon, terminal buttons
 - 2, Schwann Cells
 - 3, Myelinated
 - a, nodes of Ranvier
- B, Physiologic Elements
 - 1, Resting potential
 - 2, Stimulation
 - 3, Local response, firing level

- 4, Latent period, action potential, all or none, refractory period
- 5, Normal & saltatory conduction
- 6, Bi & monophasic action potentials
- 7, Na & K conductances
- 8, Injury potential

VIII, Organization of the nervous system

A, Somatic

- 1, Afferent (sensory)
- 2, Efferent (motor)

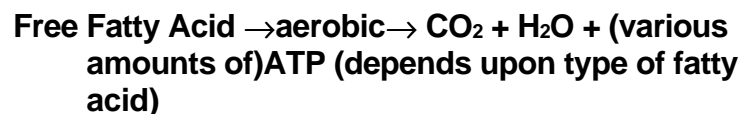
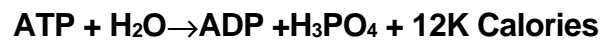
B, Autonomic (Visceral)

- 1, Afferent
 - a, adrenergic (sympathetic)
 - b, cholenergetic (parasympathetic)
- 2, Efferent

IX, Muscle

A, Striated

- 1, Anatomy
 - a, Fiber, fibril, sarcomere
 - b, Other anatomic elements
 - (1), T system, sarcoplasmic reticulum, motor end plate
- 2, Physiology
 - a, Muscle twitch
 - b, isometric-isotonic contraction
 - c, tetanus
 - d, Length-tension curve
 - e, Chronaxie & Rheobase
- 3, Biochemistry
 - a, Energy sources & Metabolism in muscle



B, Cardiac Muscle

- 1, Differences from striated muscle

a, T system located at the Z line in cardiac muscle and at the A band I band junction in striated muscle

b, Cardiac muscle has intercalated discs (gap junctions)

c, Cardiac muscle has a long absolute refractory period and followed by a period of relative refractoriness

d, Pacemaker Tissue

(1), a \downarrow in K^+ permeability \rightarrow a rise (less -) in the resting potential until the firing potential is reached. After this total depolarization occurs. After this there is a \downarrow in K^+ permeability \rightarrow \uparrow in $[K^+]$ on the inside of the membrane. The Na-K pump goes on throughout this process. The changes in the K^+ permeability control the $[K^+]$ and hence the level of polarization.

2, Length-tension (Starling's) relationship

C, Smooth Muscle

X, General electronic considerations

A, Overview of medical electronic signals

1, See table 1.1 on page 10 in Webster

B, General noise considerations.

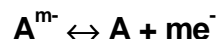
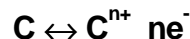
1, Line noise

2, muscle noise

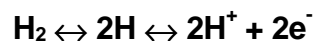
3, electrode noise

XI, Electrodes

A, Oxidation/Reduction



B, Hydrogen electrode



C, Polarization

1, If current flows \rightarrow Polarization

a, (observed potential) - (zero current 1/2 cell potential) = overpotential

2, overpotentials

a, ohmic overpotential

b, concentration overpotential

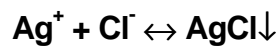
$$(1), E = -(RT/nF)\ln(a_1/a_2)$$

c, activation overpotential

$$(1), E = E^{\circ} + (RT/nF)\ln(a_{\text{cn}+})$$

(a), The redox reaction is not entirely reversible. For metal to be oxidized to ions an energy barrier must be overcome. This energy is the activation overpotential.

D, Polarizable & Nonpolarizable Electrodes 1, Silver/silver chloride Electrodes



a, Under equilibrium conditions:

$$a_{\text{Ag}^+} * a_{\text{Cl}^-} = K_s$$

where K_s = Solubility Product

b, In biological fluids $[\text{Cl}^-]$ is relatively high. Therefore, the Cl^- activity is $<$ but close to 1. K_s for $\text{AgCl} \approx 10^{-10}$. Therefore, $a_{\text{Ag}^+} \approx 10^{-10}$
It follows then:

$$E = E_{0/\text{Ag}} + (RT/nF)\ln(a_{\text{Ag}^+}) \quad \text{Where: } E_0 = 1/2 \text{ cell potential}$$

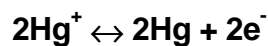
$$E = E_{0/\text{Ag}} + (RT/nF)\ln(K_s/a_{\text{Cl}^-})$$

$$E = E_{0/\text{Ag}} + (RT/nF)\ln K_s - (RT/nF)\ln(a_{\text{Cl}^-})$$

The first two terms are constants and the third ≈ 0 .

c, Beyond their stability, Ag/AgCl electrodes are relatively noise free.

2, Calomel Electrodes (also nearly nonpolarizable)



- E, Electrode behavior & circuit models
- F, Electrode Skin Interface & Motion Artifact
 - 1, Skin Anatomy
 - a, Stratum Corneum
 - b, Epidermis

c, Dermis

2, Equivalent Circuit of Electrode/Skin Interface

G, Motion Artifact

- 1, Motion alters concentrations, air bubbles at the electrode/electrolyte interface and concentrations in the epidermal zone etc.**

H, Body Surface Electrodes

1, Metal plates

- a, Discuss effect of sanding and electrode paste on skin resistance.**

2, Suction

3, Floating

4, Flexible

- a, Mylar backed AgCl over Ag films)**

5, Dry

- a, Essentially Capacity coupling with amplifiers built in that have input impedances of $\approx 1G\Omega$**

J, Internal electrodes

1, Needle

2, suction and corkscrew for fetal EKG's

3, Microelectrodes

a, Metal

b, Micropipettes

c, Micropipettes based upon solid state techniques

e, Electrical properties of microelectrodes

XII, Bioamplifiers in General

A, Balanced

- 1, problems with high and variable source impedances, and electrode popping.**

B, Driven shields and grounds

C, D.C. Amplifiers

D, Safety isolation

XIII, Electromyogram (0.1-5 mv. dc-10000 Hz)

A, Clinical

B, Needle Electrodes

C, Amplifier Specs

D, Output devices

- 1, Scope, speaker, mag. tape, more modern**

XIV, Nerve Conduction (Electroneurogram=ENG in Webster)

A, Clinical

B, Motor nerve (same as EMG)

- 1, Stimulate high on nerve; record in muscle down stream.**

C, Sensory nerve (0.01-3 mV dc-10,000 Hz)

- 1, Stimulate low and measure high, ground ring between stimulation electrodes and recording electrodes, a short (100-300 μ s) 100V square pulse, this avoids motor stimulation and stimulates the more sensitive large, rapid sensory fibers

D, H Reflex

- 1, Stimulate a sensory nerve as in B,1 above and note EMG response in the associated muscle, this is analogous to an ankle jerk etc..

XV, Galvanic Skin Response (1-500 k Ω 0.01-1 Hz)**A, Physiological****B, Clinical**

- 1, Lie detector
- 2, Air Force

C, Electromechanical aspects**XVI, Eighth Cranial Nerve****A, Ear****1, Anatomy****a, External Ear**

- (1), Ear drum

b, Middle Ear

- (1), Ossicles
 - (a), Malleus
 - (b), Incus
 - (c), Stapes

- (2), Oval window

- (3), Round window

c, Inner Ear

- (1), Bony Labyrinth

- (2), Membranous labyrinth

(a), Cochlea**i, Reissner's Membrane****ii, Basilar Membrane****iii, Organ of Corti**

- (i), Inner (sensory: sound transduction) and outer Hair Cells (motor: control tension on Basilar Membrane)

(ii), Tectorial Membrane**(iii), Rods of Corti****(b), Semicircular Canals****i, Sacculus****(i), Hair Cells****(ii), Otolithic membrane****ii, Ampullae****(i), Hair Cells**

2, Instrumentation**a, Hearing**

- (1), Audiometry
- (2), Hearing Aids

b, Balance

- (1), Electro-oculogram (EOG also called
electronystagmogram ENG!!!) (50-3500 μ V 0-50 Hz)
 - (a), Clinical
 - (b), Incus
 - (c), Stapes
- (2), Oval window
- (3), Round window

c, Inner Ear

- (1), Bony Labyrinth
- (2), Membranous labyrinth
 - (a), Cochlea
 - i, Reissner's Membrane
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 - ii, Ampullae
 - (i), Hair Cells

2, Instrumentation**a, Hearing**

- (1), Audiometry
- (2), Hearing Aids

b, Balance

- (1), Electro-oculogram (EOG also called
Electronystagmogram ENG!!!) (50-3500 μ V 0-50 Hz)
 - (a), Clinical
 - (b), Electronic

XVII, Electroencephalogram (EEG) (5-300 μ V 0-150 Hz)**A, Anatomy**

- 1, Cerebrum
- 2, Cerebellum
- 3, Brain Stem

- a, diencephalon
- b, midbrain
- c, pons
- d, medulla oblongata
- e, reticular formation

(1), throughout brain stem

(a), It is generally excitatory though there is a small area of inhibitory neurons. It is generally inhibited by incoming neurons. It has outputs to the motor system.

(b), The facilitory portion of the reticular system provides inputs to the reticular activating system (RAS). Stimulation of the RAS causes an animal to wake up from a sound sleep. Many areas of the sensory system have inputs into the RAS.

4, Cortex

a, Histology of cortex

(1), Discuss mainly the dendritic nature of the cortex.

(2), Motor and sensory areas are located on the opposite of the brain from the dominant side. The motor area is in front of the central fissure. The sensory area is behind the central fissure.

B, Physiology

1, Biopotentials in the Brain

a, probably arise in the dendritic arrays of the cortical pyramidal cells, especially their long, parallel, ascending, major dendrites

2, Resting Rhythms

a, amplitude of waves about 100 μ V

b, Alpha

(1), 8-13 Hz

(2), lost with sleep and attentive state (especially visual)

(3), Recorded in occipital region

c, Beta

(1), 14-30 Hz

(2), parietal and frontal

(3), Beta I

(a), abolished by mental activity

(4), Beta II

(a), seen at best with intense mental activity

d, Theta

(1), 4-7 Hz

(2), parietal and temporal

(3), seen best in children but also in adults experiencing frustration

e, Delta

(1), < 3.5 Hz

(2), seen in deep sleep, infancy, and with serious organic brain disease

C, Clinical EEG

1, Generalized Epilepsy

a, Petit mal

(1), myoclonic

(a), EEG similar to grand mal but doesn't last very long, patient jerks but doesn't lose consciousness, resumes activity, may progress with time to grand mal

(2), absence

(a), 5-20 sec. unconsciousness, resumes activity, spike and dome pattern

b, Grand mal

(1), tonic→clonic

2, Partial Epilepsy

a, Jacksonian March

b, Psychomotor

(1), may cause:

(a), short period of amnesia

(b), abnormal rage

(c), sudden anxiety

(d), incoherent speech

(e), some motor act

3, Sleep patterns

a, excited--low voltage, random, high freq. waves

b, relaxed--alpha

c, drowsy--moderate amplitude, lower freq., random

d, asleep--very low freq., with bursts of alpha (sleep spindles)

e, deep sleep--random low freq. variable amplitude waves

f, paradoxical sleep--during REM sleep, low freq. waves with bursts like waves seen in alert state

D, Electronics (5-300 μ V dc-150 Hz)

1, Electrode systems

2, Input switching

3, General electronic considerations

4, Write out devices

a, Pens

b, Hot wires

c, types on paper

XVIII, Electrocardiography (0.5-4 mV 0.01-250 Hz ??)

A, Anatomy

B, Electrophysiology

1, one and two sphere analogies

C, Pathology

- 1, cardiac axis
 - 2, conduction defects
 - a, L & RBBB
 - b, 1st degree block
 - c, 2nd degree block
 - (1), 2:1, 3:1, etc.
 - (2), Wenckebach phenomenon
 - d, 3rd degree (complete block)
 - e, Aberrant conduction
 - f, Stokes Adams
 - 3, arrhythmias
 - a, sinus arrhythmia
 - b, APC's
 - c, atrial tachycardia
 - d, atrial flutter
 - e, atrial fibrillation
 - f, PVC's
 - g, ventricular tachycardia
 - h, " fibrillation
 - f, stand-still
 - 4, hypoxia & anoxia
 - a, ↓ blood supply →
 - (1), rapid reopening of K^+ channels → more rapid polarization in infarcted area → $ST\uparrow$
 - (2), delayed depolarization
 - (3), injury current
- D, EKG systems**
- 1, general
 - a, isolation
 - b, high voltage protection
 - c, input networks
 - (1), driven ground
 - d, ground loops
 - e, E & H field pickup
 - 2, resting
 - 3, stress
 - 4, vector
 - 5, hi fi
 - 6, esophageal
 - 7, computer analysis
 - 8, recorded
 - a, Holter
 - 9, fetal EKGs
 - 10, Telemetry
 - 11, averaging cardiometer

A, Physiology**1, Define:**

- a, systole & diastole
 - (1), how blood pressure is measured
- b, arterial pulse
- c, peripheral resistance
- d, review Starling's curve
 - (1), preload & postload
 - (2), contractility
- e, cardiac output
 - (1), volume & velocity flow
 - (a), flow profile
 - (2), factors effecting

2, Heart sounds

- a, normal
 - (1), 1st & 2nd sounds
 - (2), 3rd sound
 - (a), occurs after about first 1/3 of diastole in normals, due to rapid LV filling
 - (3), 4th sound
 - (a), occurs just before 1st sound with \uparrow Bp or \downarrow LV compliance

b, abnormal

- (1), murmurs

3, Peripheral vascular anatomy**a, Veins**

- (1), venous valves
- (2), venous pressure
- (3), muscle pumping

b, Capillaries

- (1), fluid exchange
- (2), lymphatics

4, Sphygmomanometer**B, Pathology****1, Heart Failure**

- a, normal & high output

2, Shock**a, Hypovolemic**

- (1), neurogenic

b, Toxic**c, Cardiogenic****C, Measurements involving the cardiovascular system****1, Arterial Pressure (10-400 mmHg dc-50 Hz)****a, sphygmomanometry****b, catheter-transducer systems**

- (1), catheter's effect on frequency response

- (a), clots & air bubbles
- (2), transducers
 - (a), effect of dynamic volume on frequency response
 - (b), types
 - i, strain gauge
 - (i), wire
 - (ii), solid state
 - ii, variable transformer
 - iii, fiber optic
 - c, catheter tip transducers
 - d, cardiac catheterization
- 2, Cardiac output
 - a, Fick
 - (1), AV difference
 - (2), Dye dilution
 - (3), heat dilution

$$\text{Vol. Flow} = (\text{amt. injected}) / \left(\text{The integral of concentration from } t = 0 \text{ to } t, dt \right)$$

where t = time required for concentrations extrapolated value to reach zero

- b, thermal convection cooling of thermistor
- c, Ballistocardiogram
- 3, Blood flow (1-300 mm/s dc-20 Hz)
 - a, plethysmography
 - (1), fluid systems
 - (2), impedance
 - (3), capacitance
 - (4), light transmission
 - (5), Cuffs
 - b, Electromagnetic flow meters
 - (1), AC
 - (a), transformer leak through a problem that can be reduced by quadrature feedback
 - (2), Square wave
 - (a), flat top eliminates the transformer leak through but rapid rise can saturate the amplifier
 - (3), Trapezoidal wave
 - (a), best compromise
 - c, doppler flow meters
 - (1), implantable

- (2), surface
 - (a), arterial & venous
 - (b), fetal use
- (3), gated
- 4, Heart sounds
 - a, Phonocardiography (threshold \approx 100 μ P 5-2000 Hz)

XX, Laboratory Medicine

A, Spectrophotometry

- 1, use prisms or diffraction grating to obtain monochromatic light and pass through cuvette

B, Flame Photometry

- 1, emission
 - a, but compound in flame and look for color
 - b, works for Na^+ , K^+ , Li^+ , Ca^+
- 2, absorption
 - a, see what colors are absorbed by it vapor while burning
 - b, works for Ca, Pb, Cu, Zn, Fe, Mg

C, Fluorometry

- 1, use Hg arc and I $^\circ$ filter to let UV through, then II $^\circ$ filter to pass fluorescence, very sensitive but Ph dependent

D, Mass Spectroscopy

E, Automated clinical laboratory systems

F, pH electrode

- 1, use ion selective glass membranes, approach of H^+ to outside of membrane \rightarrow the passage of a hole to the ionic solution on the inside, Ph electrode is referenced to a calomel electrode

G, pCO₂ Electrode

- 1, $\Delta \text{pCO}_2 + \text{NaHCO}_3 \rightarrow \Delta \text{pH}$ (read with pH electrode)

H, pO₂ Electrode

- 1, O₂ diffuses through semipermeable glass membrane, [O₂] is electrometrically within cell with temperature compensation

I, Chromatography

J, Electrophoresis

K, Hematology

- 1, Coulter counter

L, Chemical fibrosensors

- 1, oximeters
- 2, miniature of pCO₂ & pO₂ as above

M, ion-selective field-effect transistors

N, noninvasive blood-gas monitoring

- 1, transcutaneous oximetry
- 2, transcutaneous PCO₂
- 3, transcutaneous PO₂
- 4, transcutaneous glucose
 - a, oxidizes glucose with enzyme and measures $\downarrow[\text{O}_2]$

polarographically

XXI, Medical Imaging

A, Standard Xray

- 1, Clinical applications
 - a, strengths & limitations
- 2, Instrumentation
 - a, Xray tube & supporting electronics
 - b, Al filters
 - c, collimators
 - d, Bucky
 - e, double emulsions & screens
 - f, Image intensifiers

B, Thermography

C, Nuclear Medicine

- 1, Isotopes
- 2, Uptakes
- 3, Scanners
 - a, old type mechanical
 - b, transverse scanners
 - c, gamma cameras
 - d, single-photon emission computed tomography (SPECT)
 - (1), uses isotopes that produce a single photon at a specific energy, system collects parallel rays and does a reconstruct like CT
 - e, positron emission tomography (PET)
 - (1), certain isotopes positrons that react with electrons to emit two photons at 511 keV in opposite directions, system takes advantage of this and views patient from opposite sides, used to use two detectors now uses multiple.
 - (2), used mainly to evaluate brain function, different isotopes (^{10}F , ^{11}C , ^{13}N , ^{60}Ga , ^{82}Rb , evaluates brain activity

D, Ultrasound

1, Define

- a, A Mode Scan
 - (1), Echo Amplitude vs. Depth
- b, B Mode Scan
 - (1), X Spatial Axis vs. Y Spatial Axis vs. Echo Amplitude on Z Axis
- c, M Mode Scan
 - (1), Depth vs. Time
- d, Real Time Systems
 - (1), mechanical
 - (2), phased
 - (a), Simple Linear Arrays
 - i, Only of Historic Interest

2, Areas of clinical application

3, Artifacts

a, Reverberations

b, Shadowing

(1), Due to Air

(2), Due to Bone

(3), Due to Interface Edges

(a), Due to refraction along rounded surfaces

c, Enhancement

(1), Due to TGC effect

d, Displacement

(1), Misregistration

(a), Mainly a problem of static B scanners; thus now mainly only of historic interest

(2), Multipaths

(a), Due to reflections (eg. liver seen "in" the lung)

(3), Beam-width Distortion

(a), Due to edge of beam picking up something out side of the beam center (eg. "sludge in GB)

e, Distortion

(1), Variations in beam width can produce geometric distortion

(2), Inadequate gray scale dynamics can produce contouring that can simulate structural margins

4, Physics

a, Ultrasound beam

(1), Nature of Beam

(a), Longitudinal Waves

i, Approximate speed in tissue = 540 M/sec

ii, Frequency range of interest in medicine = 1 to 20 MHz

[1], Usual range = 2.5 to 10 MHz

iii, Pulse Repetition Rate \approx 1 KHz

(c), Emanating from a Simple Disk ransducer

i, Near Field = Fresnel Zone = d^2/λ = length

[1], Examples:

[a], At 2.5 MHz with a 1 cm. transducer the length of the near field = 4.2 cm.

[b], At 2.5 MHz with a 1.5 cm. transducer the length of the near field = 9.4 cm.

ii, Far Field = Fraunhofer Zone

$\theta = \sin^{-1}\{1.22*\lambda/d$ Where θ = the angle of divergence

iii, Natural Focus at Transition Zone

iv, Energy is non-uniform in the Near Zone

and Side Lobes

- v, Energy is uniform in the Far Field but divergent
- vi, One usually tries to operate in the Near Field, but as one can see by the relationships above, this cannot always be done
- vii, In practice, due to the loss of energy in the tissues the beam is tear drop shape.
- viii, Lenses can be used to shape beam.

b, Tissue effects

(1), Attenuation

(a), Absorption (about 1db. per MHz. per cm.)

i, Viscosity

[1], Cohesion (molecular attraction)

[2], Adhesion (attraction between the surfaces of bodies)

ii, Relaxation Time

[1], Time required for perturbed Molecules to return to resting state

iii, \uparrow frequency \rightarrow \uparrow absorption

iv, NOTE: In practice to reach 10 centimeters, one must penetrate to 10 cm AND return another 10 cm for the pulse to be detected

(b), Refraction

i, The bending of a beam when it passes at an angle from one medium into another

(c), Scattering

i, Due to the presence of small reflectors in the medium

(d), Diffraction

i, Beam spreading from source, the smaller the source the greater the spreading

(e), Interference

i, The mutual effect on the meeting of two waves, with resulting neutralization at some points and reinforcement at others

(2), Reflection

(a), Specular if due to smooth surface

(b), Effect of angle of incidence

5, Transducers

a, Piezoelectric Crystal (ceramic, quartz)

b, Damping Material

c, Matching Layer

d, Lens

e, Quality Factor = $Q = f_0/\text{bandwidth}$

(1), From our point of view, High Q may not be high quality

(a), The lower the Q the shorter the pulse, all other things constant

6, Resolution

a, Axial

(1), A function of:

(a), Spatial Pulse Length

i, Axial Resolution(mm) =

$$1/2 * (\text{Spatial Pulse Length}) \text{mm} = R^a$$

ii, Axial Resolution(mm) \approx

$$\{0.77 * (\text{number of cycles per pulse}) / \text{frequency(MHz)}\} * R^a$$

(b), US Frequency

b, Lateral

(1), Lateral Resolution = Beam Diameter

(a), Beam Diameter is a function of:

i, Transducer Size

[1], \uparrow Transducer Diameter \rightarrow \uparrow Near Field Diameter

[2], \uparrow Transducer Diameter \rightarrow \downarrow Far Field Diameter

[3], \uparrow Transducer Diameter \rightarrow \uparrow Depth of Field

7, Types of transducer systems

a, Mechanical Sector Scanners

b, Phased Linear Arrays

(1), Can Steer, Focus(parallel to transducer axis), or Steer and Focus Beam

(2), Subsets of a Phased Linear Array

(a), Phased Sector Arrays

(b), Phased Curvilinear Arrays

(3), Pulse Repetition Rate(Hz) = (Frame Rate) * (Number of Elements in Array)

(4), Lenses to reduce beams transverse dimension

(5), Apodization

(a), The process of reducing the sensitivity of the peripheral elements in an array to reduce side lobes and thus their effect

c, Annular Arrays

(1), Fixed Focus

(a), Fixed Phasing

(2), Dynamic Focus

(a), Variable Phasing

8, Electronics

a, Pulser

b, Amplification

(1), RF

- (a), TGC (Time Gain Control or Apodization)
 - c, Demodulation
 - d, Amplification
 - (1), Video
 - e, A/D Converter (if digital scan converter)
 - (1), Preprocessing
 - (a), The process of weighting the RF pulses before they are sent to the scan converter
 - f, Scan Converter
 - (1), Analog
 - (2), Digital
 - g, Post Processing (if digital scan converter & associated with the D/A conversion process)
 - (1), Assigning a specific brightness to the numbers as they come off of the scan converter
 - h, Display
 - (1), Raster Scanning with Interweave-about two sweeps per 1/30th of a second
- 9, DOPPLER
 - a, Doppler Shift Frequency =

$$(\text{Transducer Frequency})\{2 \cdot \text{Velocity of Interface} / (\text{Velocity of Sound in Medium})\} \cdot \cos\Theta$$
 - b, Two Transducer CW (of little interest in Radiology)
 - c, Pulsed
 - (1), Aliasing
- 10, Safety
 - a, Static US systems operate with:
 - (1), SPTP 280-2800 Watts cm^{-1}
 - (2), SPTP 20-2000 " "
 - (3), SATA 10-400 mWatts "
 - b, Heating effect
 - c, Cavitation
 - (1), Felt not to be a problem with the short pulses used in diagnostic US
- E, CT scans
 - 1, Clinical aspects
 - 2, tomographic nature
 - 3, Electronics
 - a, video gain to enhance contrast
 - b, source & target
 - c, reconstruction
- F, MRI
 - 1, Clinical aspects
 - 2, Physics
 - a, dipoles
 - b, bias magnet
 - c, varying field magnet

- 3, Electronics
 - a, RF pulser
 - b, receiver
 - c, reconstruction

XXII, Therapeutic Electronics

A, Pacemakers

- 1, Clinical
- 2, Output
 - a, Voltage pacers (5.0-5.5V 0.5-0.6ms)
 - b, Current pacers (8-10mA 1.0-1.2 ms)
- 3, Lead systems
- 4, Batteries
 - a, lithium iodide now used as it is safest and has good shelf life
- 5, Types
 - a, asynchronous
 - b, demand
 - c, synchronous
 - d, Rate-responsive
 - (1), still experimental
 - (2), responsive to various physiological parameters (eg. body motion, respiration rate, blood pressure, etc.)

B, Defibrillators

- 1, Clinical aspects
- 2, AC
 - a, 160-600V 250 ms.
 - b, variable transformer & timing circuit
- 3, DC
 - a, 2000V 10 ms.
 - b, capacitive-discharge
 - (1), simple capacitor no inductance
 - c, Delay-line
 - (1), Inductance in the line to square off pulse
- 4, Electrodes & safety

C, Cardioverters

D, Implantable defibrillators

E, Electrosurgery

F, Diathermy

XXIII, Electrical Safety

- A, Effect of various current levels (current density is active element.)
 - 1, 1-10 Ma threshold
 - 2, 10-100 Ma let go
 - 3, 30-4000 Ma Ventricular fibrillation
 - 4, 1 A.+ burns
- B, 10-200 Hz worst

XXIV, Shielded Rooms