**KARPAGAM ACADEMY OF HIGHER EDUCATION**

**(Deemed to be University Established Under Section 3 of UGC Act 1956)**

**Pollachi Main Road, Eachanari Post,**

**Coimbatore – 641 021**

**FACULTY OF ENGINEERING**

**DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING**

## LECTURE PLAN

**NAME OF THE STAFF : Dr.A.MOHANARATHINAM**

**DESIGNATION : ASSISTANT PROFESSOR**

**CLASS : B.E-IV YEAR ECE**

**SUBJECT : MEDICAL ELECTRONICS**

**SUBJECT CODE : 16BEEC801A**

| S.No | TOPICS TO BE COVERED | TIME DURATION | SUPPORTING MATERIALS | TEACHING AIDS |
|---|---|---|---|---|
| **UNIT- I ELECTRO-PHYSIOLOGY AND BIO-POTENTIAL RECORDING** | | | | |
| 1 | The origin of biopotentials, biopotential electrodes | 01 | T1- Page.no : 49-53, 66-76 | BB |
| 2 | Biological amplifiers | 01 | T1 Page.no : 109-111 | BB |
| 3 | ECG | 01 | T1- Page.no : 117-121 | BB |
| 4 | EEG | 01 | T1 Page.no. 296-300 | BB |
| 5 | EMG | 01 | T1 page.no. 300-303 | BB |
| 6 | PCG | 01 | T1 page.no. 169-172 | BB |
| 7 | EOG | 01 | www.medicine.mcgill.ca | BB |
| 8 | Lead systems and recording methods | 01 | T1 page.no.111-126 | BB |
| 9 | Typical waveforms and signal characteristics | 01 | T1 page.no.55-62 | BB |
| **Total Lecture Hours** | | **09** | | |
| **Total Hours** | | **09** | | |

| | | | | |
|---|---|---|---|---|
| **UNIT-II BIO-CHEMICAL AND NON ELECTRICAL PARAMETERS MEASUREMENT** | | | | |
| 10 | PH,$PO_2$,$PCO_2$,$PHCO_3$ measurements | 01 | T1 Page.no: 78-83,233-237 | PPT , BB |
| 11 | Electrophoresis | 01 | | PPT , BB |
| 12 | Colorimeter, photometer | 01 | T1 Page.no: 351-355 | PPT , BB |
| 13 | Auto analyzer | 01 | T1 Page.no: 359-362 | PPT , BB |
| 14 | Blood flow meter | 01 | T1 Page.no :150-158 | PPT , BB |
| 15 | Cardiac output, respiratory measurement | 01 | T1 Page.no: 158-162, 221-227 | PPT , BB |
| 16 | Blood pressure measurement | 01 | T1 Page.no: 126-150 | PPT , BB |
| 17 | Temperature, pulse measurement | 01 | T1 Page.no: 244-255 | PPT , BB |

| | | | | |
|---|---|---|---|---|
| 18 | Blood cell counter | 01 | T1 Page.no: 347-349 | PPT , BB |
| **Total Lecture Hours** | | **09** | | |
| **Total Hours** | | **09** | | |

| **UNIT-III ASSIST DEVICES AND BIO-TELEMETRY** | | | | |
|---|---|---|---|---|
| 19 | Cardiac pacemakers | 01 | T1 Page.no:195-205 | BB, PPT |
| 20 | DC defibrillator | 02 | T1 Page.no: 206-212 | BB, PPT |
| 21 | Telemetry principles | 01 | T1 Page.no: 317-320 | BB, PPT |
| 22 | Frequency selection | 01 | T2 Page.no: 8.6-8.7 | BB |
| 23 | Bio-telemetry | 02 | T1 Page.no:321-342 | BB,PPT |
| 24 | Radio- pill | 01 | T1 Page.no: | BB |
| 25 | Tele-stimulation | 01 | T1 Page.no: | |
| **Total Lecture Hours** | | **09** | | |
| **Total Hours** | | **09** | | |

| **UNIT-IV RADIOLOGICAL EQUIPMENTS** | | | | |
|---|---|---|---|---|
| 26 | Introduction to radiology | 01 | T1 Page.no:363-369 | BB |
| 27 | Diagnostic x-ray equipment | 02 | T1 Page.no:369-373 | BB,PPT |
| 28 | Use of radio isotope in diagnosis | 02 | T1 Page.no:376-382 | BB,PPT |
| 29 | Ionizing radiation | 02 | T1 Page.no:365-368 | BB,PPT |
| 30 | Radiation therapy | 02 | T1 Page.no:383 | BB |
| **Total Lecture Hours** | | **09** | | |
| **Total Hours** | | **09** | | |

| **UNIT-V RECENT TRENDS IN MEDICAL INSTRUMENTATION** | | | | |
|---|---|---|---|---|
| 31 | Thermograph | 02 | T1 Page.no: 252-255 | BB,PPT |
| 32 | Endoscopy unit | 02 | T3 Page.no:10.12-10.15 | BB,PPT |
| 33 | Laser in medicine | 01 | T3 Page.no:10.1-10.11 | BB |
| 34 | Diathermy units | 02 | T3 Page.no:6.1-6.5 | BB,PPT |
| 35 | Electrical safety in medical equipment | 02 | T1 Page.no:430-448 | BB |
| **Total Lecture Hours** | | **09** | | |
| **Total Hours** | | **09** | | |

Total No of Lecture Hours Planned: 45 Hrs

**Total No of Hours Planned : 45 Hours**

**TEXT BOOKS:**

| S.NO. | Author(s) Name | Title of the book | Publisher | Year of Publication |
|---|---|---|---|---|
| 1. | Leislie Cromwell | Biomedical instrumentation and measurement | Prentice Hall of India Pvt. Ltd., New Delhi | 2002 |
| **2.** | Khandpur R.S | Handbook of biomedical | Tata McGraw-Hill, New Delhi | 1997 |
| **3.** | Dr.M.Arumugam | Biomedical instrumentation | Anuradha Publications | 2016 |

**REFERENCES:**

| S.No | Author(s) Name | Title of the book | Publisher | Year of Publication |
|---|---|---|---|---|
| 1. | Joseph.J.Carrand John M.Brown | Introduction to biomedical Equipment technology | John Wiley and sons, NewYork | 1997 |

**STAFF IN-CHARGE** **HOD/ECE**

| 16BEEC801A | MEDICAL ELECTRONICS | L T P C<br>3 0 0 3 |
|---|---|---|

**OBJECTIVES**

- To study the method s of recording various bio potentials
- To study how to measure biochemical and various physiological information
- To understand the working of units whichwill help to restore normal functioning
- To understand the use of radiation for diagnostic and therapy
- To understand the need and technique of electrical safety in Hospitals

**INTENDEDOUTCOMES:**

- Gainknowledgeaboutthemethodsofrecording variousBio potential
- Gainknowledgeabouthowto measurebiochemicalandvariousphysiological information
- Gainknowledgeabouttheworking ofunitswhichwillhelptorestorenormal functioning
- Gainknowledgeabouttheuseofradiationfordiagnosticandtherapy
- Gainknowledgeabouttheneedandtechniqueofelectrical safety inHospitals

**UNIT-I ELECTRO-PHYSIOLOGY AND BIO-POTENTIAL RECORDING**

Theorigin of Bio-potentials; Biopotential electrodes, biological amplifiers, ECG,EEG,EMG, PCG, EOG, leadsystems and recording methods, typical waveforms and signal characteristics.

**UNIT-II BIO-CHEMICAL AND NON ELECTRICAL PARAMETER MEASUREMENT**

PH, PO2, PCO2, PHCO3, Electrophoresis, colorimeter, photometer, Auto analyzer, Blood flow meter, cardiac output, respiratory measurement, Blood pressure, temperature, pulse, Blood cell counters.

**UNIT-III ASSIST DEVICES AND BIO-TELEMETRY**

Cardiac pacemakers, DC Defibrillator, Telemetry principles, frequency selection, Bio-telemetry radio- pill and tele-stimulation.

**UNIT-IV RADIOLOGICAL EQUIPMENTS**

Ionizing radiation, Diagnostic x-ray equipments, use of Radio Isotope in diagnosis, Radiation Therapy.

**UNIT-V RECENT TRENDS IN MEDICAL INSTRUMENTATION**

Thermograph, endoscopy unit, Laserin medicine, Diathermy units, Electrical safetyin medical equipment.

**TEXTBOOK:**

| S.NO. | Author(s)Name | Titleof thebook | Publisher | Yearof Publication |
|---|---|---|---|---|
| 1. | LeislieCromwell | Biomedical instrumentation and measurement | PrenticeHallof India,NewDelhi. | 2002 |
| 2. | Khandpur,R.S. | Handbook of Biomedical | TataMcGraw-Hill, NewDelhi. | 1997 |

**REFERENCES:**

| S.NO. | Author(s)Name | Titleof thebook | Publisher | Yearof Publication |
|---|---|---|---|---|
| 1. | JosephJ.Carrand JohnM.Brown | Introductionto Biomedicalequipment Technology | JohnWileyand Sons,NewYork | 1997 |

**16BEEC801B DIGITAL IMAGE PROCESSING L T P C**
**3 0 0 3**

**OBJECTIVES**

- To understand the Fundamentals of image processing.
- To learn Various transforms used in image processing.
- To learn the Image processing techniques like image enhancement, reconstruction, compression and segmentation.

**INTENDED OUTCOMES:**

- Understand the Fundamentals of image processing.
- Knowledge about various transforms used in image processing.
- Knowledge about the Image processing techniques like image enhancement, reconstruct ion, compression and segmentation.

**UNIT I-DIGITAL IMA GE FUNDAMENTALS**

Introduction -Elements of Digital Image Processing system- elements of visual perception – image sensing and acquisition – Image sampling and quantization - image representation -Some basic relationship between pixels.

**UNIT II-IMAGE TRANSFORMS**

Introduction -2D Discrete Fourier Transform – Properties- Importance of Phase -Walsh –Hadamard – Discrete Cosine Transform, Haar –K L transforms –Singular Value Decomposition.

**UNIT III-IMAGE ENHANCEMENT**

Enhancement through point operation- Histogram manipulation – Gray level transformation- Neighborhood operation – Median filter - Image Sharpening- Bit plane slicing - Homomorphism Filtering – Zooming operation.

**UNIT IV-IMAGE RESTORATION**

Model of Image Degradation/restoration process –Inverse filtering -Least mean square (Wiener)filtering – Constrained least mean square restoration – Singular value decomposition-Recursive filtering.

Questions

In diastole, blood flows in the back ward direction from aorta to left ventricles when valves are damaged, then this sound is

Murmur is produced when blood is passed from left atrium to left ventricular is called as

Transmittance in calorimeter is given by ……..where $I_0$ is the incident light and $I_1$ is the light leaving the cuvette.

Absorbance is ……to transmittance

Absorbance ……. if the number of cuvettes are decreased, provided the concentration of the sample remains the same and the length of the cuvette is also same

The concentration of Sodium, Potassium and Calcium iron In blood

Fluoroscopic observation of cardiac catheterization is made by

Lithium salt when ignited will produce

Sodium ions when ignited will produce

Potassium ions when ignited will produce

Spectrophotometer consists of

Peristaltic movement of air and sample is followed in

The movement achieved by mixing sample with air following one behind the other in some defined ratio

Among the following things which have the highest attenuation of

Two low a blood pressure is known as

The normal PH of the blood is

Blood flow can be measured using the electromagnetic principle because blood has a high

To avoid electrode polarization and biopotential artifacts, electromagnetic Blood flow meters are using

In addition to measuring mean flow speed of the blood, the pulsed Doppler Ultrasonic blood flow meter also displays

The average of values of systolic and diastolic pressure of normal

Blood plasma is obtain by -_____ blood that has been prevented

By listening over the heart with a stethoscope and palpating the arterial pulse In the wrist of an adult the time delay between systole and the pulse wave in the wrist is almost

Electromagnetic blood flow meter are based on the principle of

Ultrasonic blood flow meter is based on the principle of

Ultrasonic blood flow meter uses an ultrasound singal of frequencies

$\theta=0^{0}$ , V=100mm/s , C =1500m/s, a 2MHz ultrasonic beam is shifted

…….Utilise contrast agent into arteries to make visible on

The invasion method of blood flow measurement is

Cardiac output is obtained by

Heart beat of normal adult ranges from

During each beats the amount of blood pumped from the heart

Area under the curve in dye dilution method is obtained by

In Ficks method, the cardiac output is given by _____Where $C_A$ and $C_V$ are the oxygen concentrations in the artery and venous blood ,I is the amount of dye injected

Cardiac output of a normal adult ranges from ……litres /min

Non invasive method of measuring cardiac output is

TLC refers to

Inspiratory reserve volume is the extra amount of gas

End Expiratory volume is the extra amount of gas

Inspiratory capacity is

Vital capacity is maximum volume of gas that

Plethysmograph for measuring total lung capacity is based on

Red blood cells are used in

White blood cells are used in

Platelets are used in

Hemoglobin in the blood decreases ,…….is produced

Hemoglobin in the blood increases ,…… is produced

Pressure transducer for measuring pressure is from

The blood pressure cuff used in plethysmography is inflated to a pressure greater than the …… pressure but less than the

A plethysmograph measures …….changes in the limb

Sphygmomanometer is ……. Method of pressure

The …….pressure is indicated by the onset of korotkoff sound

The …….. pressure is indicated when the korotkoff sound

Cardiac output is measured in ……..

Cardiac output measured using invasive method is

Hemoglobin is a pigment present in

Blood has a Ph value of

The Non- invasive method of Blood flow measurement

The palpation method measures only the …… values of arterial

Auscultation determines …….. values of arterial blood

The most common indirect method for blood pressure

opt1
mitral regurgitation murmur

aortic regurgitation murmur

$I_1 / I_0$

Directly proportional
Remains the same

Flame Photometry
Echocardiography
Red Flame
Red Flame
Red Flame
Halogen lamp, mirror, prism or diffraction Grating and diode.
Autoanalyser
Endostatic

Blood
Hypertension
14
magnetic induction

Circular magnets

Size of the blood vessel

80 mm Hg and 120 mm Hg

Coagulating
1 second

Electromagnetic induction
Transmission
10 MHz
frequencies by about
EEG
Angiogram
Stroke volume/ heart beat rate per minute

100-170 beats/min
190  to 210ml
Averaging
$Q= I / (C_A - C_V )$

3-Feb
Calorimeter
Twin lungs capacity
Inspired with maximal effort after reaching the normal end of inspiratory level
Inspired with maximal effort after reaching the normal end of inspiratory level
Inspired with maximal effort after reaching the normal end of inspiratory level
Can be expelled from the lungs after a maximal inspiration

Electromagnetic conduction

$O_2$ and $CO_2$ transportation
O2 and Co2 transportation
O2 and Co2 transportation
Anemia
Anemia
Strain gauge transducer
Diastolic and systolic

Frequency
Non-invasive
Systolic
Systolic
Mm /min
Ficks method
WBC
7.36
Angiogram
Diastolic
Diastolic
Auscultator

opt2
mitral sterosis murmur

mitral sterosis murmur

$I_0 / I_1$

Square
Differs

PH meter
Fibers  Endoscope
Yellow Flame
Yellow Flame
Yellow Flame
Halogen lamp, filter and diode
Calorimeter
Peristaltic

Bone
Hypothalamus
7.4
Electrical resistivity

D.c.magnetic fields.

Number of red cell per unit

120 mm Hg and 80 mm Hg

Centrifuging
1 minute

Beers law
Conductivity
2 MHz
500hz
cardio pulse
Electro magnetic blood flow meter
Stroke volume*heart beat per minute

170-180 beats/min
100  to 150ml
Interpolation
$Q= C_A / C_V$

6-Apr
Dye dilution
Total lung capacity
Inspired with maximal effort after reaching the normal end of expiratory  level
Inspired with maximal effort after reaching the normal end of expiratory  level
Inspired with maximal effort after reaching the normal end of expiratory  level
Can be inhaled with full effort

Faraday's law of induced emf

Defence mechanism of the body
Defence mechanism of the body
Defence mechanism of the body
Polycythemia
Polycythemia
Strain gauge or capacitive transducer
Systolic and atmospheric

Volume
Invasive
Diastolic
Diastolic
Liters/ hour
Calorimeter
Chromosome
9
Coulter counter
Systolic
Systolic
Pneumotachometer

opt3
mitral regurgitation murmur

mitral regurgitation murmur

$I_0 * I_1$

Inversely proportional
Doubles

Blood gas analyzer
Electrocardiogram
Violet Flame
Violet Flame
Violet Flame
Flame, filters and Galvanometer
Blood cell counter
Gush movement

Fat
Hypotension
6.6
Electrical conductivity

D.c.current

Electrical conductivity of the blood

70 mm Hg and 140 mm Hg

Heating
0.2 second

boyle’s law
Induction
3 MHz
267 hz
myogram
Coulter counter
Number of heart beat in one hour*stroke volume

80-120 beats/min
70 to100ml
Extrapolation
$Q= I * C_A / C_V$

9-Aug
Ficks method
Tri length carrier
Expired with maximal effort after reaching the normal end of expiratory level
Expired with maximal effort after reaching the normal end of expiratory level
Expired with maximal effort after reaching the normal end of expiratory level
Can be inhaled after a maximum expiration

Boyle’s law

Blood clotting

Blood clotting

Blood clotting

Hemotocrit

Hemotocrit

Resistive transducer

Atmospheric and Systolic

Pressure

Direct

Mean

Mean

Mg /min

Impedance

Platelets

11

Electromagnetic blood flow meter

Mean

Mean

Coulter counter

opt4
aortic regurgitation murmur

aortic sterosis murmur

$I_1 I_0$ / 2

Half
Reduces by 2

Ultrasonic Doppler Velocity meter.
X-ray imaging
Colorless Flame.
Colorless Flame.
Colorless Flame.
Halogen lamp, filter and potentio meter.
Chromatography
Sterile movement.

Muscle.
Vasodilatation.
8. 8
Impedance

A.c.magnetic fields

Velocity profile

140 mm Hg and 60 mm Hg

Mixing water with
0.01 seconds

Conductivity
Transit time
5 MHz
300hz
Angiograms
Ultrasound Doppler shift method
Blood delivered by heart to pulmonary veins per minutes

72-75 beats/min
30 to 50ml
Squaring
$Q= I – C_V / C_A$

14-15
Impedance method
Total laser capacity
Volume of gas remaining in the lungs at the end of maximal expiration
Volume of gas remaining in the lungs at the end of maximal expiration
Volume of gas remaining in the lungs at the end of maximal expiration
Can be inhaled to the lungs after a normal inspiration

Flemings right hand rule

Blood purification

Blood purification

Blood purification

Packed cell volume

Packed cell volume

Fiber optic sensor

Systolic and diastolic

Time

indirect

Atmospheric

Atmospheric

Liters / min

Photometer

RBC

5

Pneumotachograph

Systolic / diastolic

Systolic / diastolic

Ficks method

opt5

opt6

c

Answer
aortic regurgitation murmur

mitral sterosis murmur

$I_1 / I_0$

Inversely proportional
Remains the same

Flame Photometry
X-ray imaging
Red Flame
Yellow Flame
Violet Flame
Halogen lamp, mirror, prism or diffraction Grating and diode.
Autoanalyser
Peristaltic

Bone
Hypotension
7.4
Electrical conductivity

A.c.magnetic fields

Velocity profile

120 mm Hg and 80 mm Hg

Coagulating
0.2 second

Electromagnetic induction
Transit time
10 MHz
500hz
Angiograms
Angiogram
Stroke volume*heart beat per minute

72-75 beats/min
70 to100ml
Extrapolation
$Q= I / (C_A - C_V )$

6-Apr
Impedance method
Total lung capacity
Inspired with maximal effort after reaching the normal end of inspiratory level
Expired with maximal effort after reaching the normal end of expiratory level
Inspired with maximal effort after reaching the normal end of expiratory level
Can be expelled from the lungs after a maximal inspiration

Boyle's law

$O_2$ and $CO_2$ transportation
Defence mechanism of the body
Blood clotting
Anemia
Polycythemia
Strain gauge or capacitive transducer
Systolic and diastolic

Volume
Non-invasive
Systolic
Diastolic
Liters / min
Ficks method
RBC
7.36
Electromagnetic blood flow meter
Systolic
Systolic / diastolic
Auscultator

Questions

_____ process gives rise to a balance of ions between inside and outside of the cell.

The nerves and muscle cells readily permit the entry of

The nerves and muscle cells doesn't permit

Under equilibrium condition the potential difference across the membrane is

The membrane potential caused by different concentration of ions such as negative ions inside and positive ions outside is called as

The human cell is in resting stage is said to be

The resting potential VR is

The resting potential is maintained as a constant until some _____

When the cell membrane is excited by some external energy, then the cell allow

The cell has a slightly positive potential on inside and negative potential at the outside is called as

The positive potential of the cell membrane during excitation is called as

The range of action potential

The range of resting potential is

As long as the action potential exists, the cell is said to be

The passage of sodium ions is stopped, the cell membrane reserved back to the equilibrium condition is called as

Potential are generated at a cellular level is called as

The discharge and recharging of the cell is termed as
Which of the following bio-potential present in our body
The contraction of the heart muscle is termed as

The relaxation of the heart muscle is termed as
The process of breathing inside is called as
The process of breathing outside is called as
_____are generally used to pick up the electric signals of the body
The bio potential available from the skin is measured using
The bio potential available near (or) within a single cell are measured using
The bio-potential available from specific group of muscles are measured using
The voltage developed at an electrode- electrolyte interface is termed as

The half cell potential is measured with reference to
The half cell potential is measured is expressed by
Ehc =

Micro electrodes are broadly classified into
The micro-electrode is located within the cell, where as the reference electrode is placed
The electrical activity of neuron of superficial layer of the brain is measured using
_____ are used to record the peripheral nerve action potential
_____ are used to measure the pH content and pO2 of blood

The hydrogen electrode can be used to measure the _____ of the body fluid

pH is defined as

pH is less than 7 means

The problems exists at the time of recording bio-potentials are

The chopper amplifier is used to sample

To prevent accidental internal cardiac shock _____ are used

using isolation amplifier the relation between the patient and a.c power line is

The lead system using ECG is

The defibrillator protection circuit consists of

The elevation occur in ST period during ECG measurement which causes

EEG is the study of electrical activity of

The temporal and central points are kept in scalp at _____distance from the pre auricular point

Alpha waves are measured at

beta waves are measured at

Delta waves are measured at _____of the brain

Epilepsy is the symptom of

Conduction velocity is given as V=

Electro myo graph is used for recording the electrical activity of _____

EOG is the recording of the bio-potentials generated by movement of

ERG is the method of recording and interpreting the electrical activity of

The process of recording the change in potential when light falls on the eye is known as

The graphical record of heart sound is known as

_____are generally caused by improper opening the values

Murmur is produced when the blood flows in backward direction through the mitral valve during systole is called as

If the transmitter substance is inhibitory, then the membrane potential of the receptor neuron increases in a negative direction. This induced potential change is called as

The electrical stimuli are detected by sense organs that cause some change in the electrical activity of the brain. This induced potential change is called as

| opt1 | opt2 | opt3 |
| --- | --- | --- |
| ionization | electrolyte | diffusion and drift |
| Calcium | potassium and chloride | sodium ions |
| sodium ions | potassium and chloride | magnesium |
| positive potential inside and negative potential outside | negative potential inside and positive potential outside | positive potential inside and positive potential outside |
| action potential | deep potential | Resting potential |
| repolarised state | depolarised state | unpolarised state |
| –(KT/q)ln{[cl+]i/[cl-]o} | –(KT/q)ln{[K+]i/[K-]o} | –(KT/q)ln{[Na+]i/[Na-]o} |
| disturbances | temperature | noise |
| K | cl- | Na |
| action potential | deep potential | Resting potential |
| action potential | deep potential | Resting potential |
| 20mV | 60mV | 40mV |
| -60mV to -100mV | -60mV to -80mV | -40mV to -50mV |
| repolarised state | depolarised state | unpolarised state |
| repolarised state | depolarised state | unpolarised state |
| electric potential | bio-electric potential | polarised state |

| | | |
|---|---|---|
| polarised state and repolarised | depolarised state and repolarised state | polarised state and depolarised state |
| electric potential diastole | non electric potential isotonic contraction | ECG and EEG systole |
| systole inspiration inspiration | isotonic contraction expiration expiration | isometric contraction isotonic contraction isotonic contraction |
| templates | plates | rods |
| chemical electrode | depth electrode | surface electrode |
| chemical electrode | depth electrode and needle | surface electrode |
| chemical electrode | depth electrode and needle electrode | surface electrode |
| bio-potential | electric potential | half cell potential |
| nitrogen electrode –(RT/nF) ln[ (C1/C2)*(F1/F2)] | oxygen electrode –(RT/nF) ln[ (C2/C1)*(F1/F2)] | co2 electrode –(RT/nF) ln[ (C1/C2)*(F2/F1)] |
| linear and non linear | metallic and non metallic | non linear and non metallic |
| outside cell | inside cell | near cell |
| surface electrode | micro electrode | depth electrode |
| needle electrode | micro electrode | depth electrode |
| needle electrode | chemical electrode | micro electrode |

| | | |
|---|---|---|
| pCO2 | pH | pO2 |
| –log10[H+] | –log10[cl+] | –log10[H-] |
| basic | neutral | acidic |
| amplitude variation | voltage drift | Noise and dc drift |
| analog signal | dc signal | ramp signal |
| differential amplifier | isolation amplifier | instrumentation amplifier |
| 1012Ω | 2012Ω | 1015Ω |
| 10%-20% electrode | Auxiliary lead system | bipolar and unipolar lead system |
| lead selection unit and over voltage protection | power amplifier | buffer amplifier and over voltage protection |
| widening of QRS complex | myocardial infarction | negative T wave |
| lungs | heart | eye |
| 20% to 30% | 30% to 40% | 10% to 20% |
| parietal region | frontal region | occipital region |
| occipital region | central region | parietal and frontal region |
| medulla oblongata | spinal cord | cortex |
| brain damage | head injury | brain tumor |
| ( l1-l2)/(t2-t1) | ( l1-l2)/(t1-t2) | ( t1-tl2)/(l1-l2) |
| nerve | brain | muscles |

| | | |
|---|---|---|
| nerve | muscles | eye |
| nerve | muscles | neurons |
| ERG | EOG | ECG |
| ERG | phono cardio gram | EEG |
| asculation | epilepcy | murmurs |
| aortic regurgitation murmur | mitral sterosis murmur | mitral regurgitation murmur |
| excitatory post synaptic potential | event related potential | inhibitory post synaptic potential |
| excitatory post synaptic potential | inhibitory post synaptic potential | lead potential |

opt4 opt5 opt6

MITCHONDRIA process

bicarbonate

bicarbonate
negative potential
inside and negative
potential outside

rising potential
polarised state

–ln{[K+]i/[K-]o}

during sleeping

Mg

rising potential

rising potential
50mV
-60mV to -90mV

polarised state

polarised state

unpolarised state

unpolarised state

lead potential
isometric contraction

diastole
isometric contraction
isometric contraction

electrodes

micro electrode

micro electrode

micro electrode

non electric potential

hydrogen electrode

ln[ (C1/C2)*(F1/F2)]

micro and macro

adjacent cells

chemical electrode

chemical electrode

depth electrode

pNa
–log10[K+]
ideal

current drift
pulsating signal

chopper amplifier

2015Ω

central lead system

auxiliary amplifier

ventricular fibrillation
brain

15% to 20%
central region

inion region

cerebellum
myo cardinal infraction
( l2-l1)/(t1-t2)

neurons

neurons

eye

EEG
EOG

brain tumor

aortic sterosis murmur

inhibitory synaptic
potential

event related potential

Answer

diffusion and drift

potassium and chloride

sodium ions

negative potential inside and positive potential outside

Resting potential
polarised state

–(KT/q)ln{[K+]i/[K-]o}

disturbances

Na

action potential

action potential
20mV
-60mV to -100mV

depolarised state

repolarised state

bio-electric potential

depolarised state and repolarised state

ECG and EEG
systole

diastole
inspiration
expiration

electrodes

surface electrode

micro electrode

depth electrode and needle electrode

half cell potential

hydrogen electrode

–(RT/nF) ln[ (C1/C2)*(F1/F2)]

metallic and non metallic

outside cell

depth electrode

needle electrode

chemical electrode

pH
–log10[H+]
acidic

Noise and dc drift
analog signal

isolation amplifier

1012Ω

bipolar and unipolar lead system

buffer amplifier and over voltage protection

myocardial infarction
brain

10% to 20%
occipital region

parietal and frontal region

cortex
brain damage
( l1-l2)/(t1-t2)

muscles

eye

eye

ERG
phono cardio gram

murmurs

mitral regurgitation murmur

inhibitory post synaptic potential

event related potential

| Questions | opt1 |
| --- | --- |
| Boyle’s law states that the volume is …… to pressure ata given temp | Square |
| Blood contains | 60% cells ,40% plasma |
| The heart’s natural pacemaker is the | AV node |
| The ……. Of heart acts analogously to an electronic delay time | Mitral valve |
| The minimum energy required to excite the heart muscle is | 100 µJ |
| Pacemaker pulses ranges from …….. pulses/min | 25-155 |
| Weight of a pacemaker approximate | 1000 gm |
| Size of a pacemaker approximates …….cm | 200 |
| When two electrodes are used,one for stimulating heart and other for return path of current to the Pacemaker it is called as | Bipolar |
| when a single electrode used for stimulating heart it is called as | Bipolar |
| The electrodes applied for the external pacemaker are called | Myocardiac |
| The electrodes applied for internal pacemaker can be | semi polar |

| | |
|---|---|
| Internal pacemaker is preferred over external pacemaker for patients having | Temporary heart irregularities |
| External pacemaker are preferred for patients having | Temporary heart irregularities |
| Competitive pacemaker has | Synchronous pacing |
| The internal pacemaker that sets the biological rhythm | is located in the brain |
| Heart rate can be matched according to the patient need in | Ventricular asynchronous pacemaker |
| Ventricular synchronous pacemaker generates its pulses only when | R wave is present |
| Ventricular inhibited pacemaker generates its pulses only | R wave due to natural pacing is present with 1.6mv |
| Relative refractory period is the period in which | The cell does not respond to any stimuli |
| Absolute refractory period is the period in which | The cell does not respond to any stimuli |
| _____is a serious cardiac emergency resulting from asynchronous contraction of heart muscles. | Arrhythmia |

| | |
|---|---|
| The magnitude of shock voltage to stimulate the heart in internal defibrillator is | 50V to 1000V |
| The magnitude of shock voltage to stimulate the heart in external defibrillator is | 50V to 1000V |
| The energy required for excitation of heart muscle in internal defibrillator is | 15 to 50 joules |
| During myocardial infarction one can use | Nerve stimulator |
| In the case of defibrillator, double square pulse is used to | Restart the heart rhythm after the open heart surgery |
| In direct current defibrillator, a pulse with duration of about 5ms is generated by means of | A stable multivibrator |
| In ventricular asynchronous PM, the pacing pulses are generated using | Astable multivibrator |
| To produce ventricular contraction with an electric pulse, the minimum energy required is | 10 µJ |
| Suppose the pacemaker pulse has high energy and occurs during the vulnerable part of T- wave then the heart is in | Normal state |
| The commonest source of energy for pacemaker is the | Mercury battery |

| | |
|---|---|
| Because of risk of electromagnetic interference, pacemaker patients should not be given | Cancer treatment |
| In the case of stable total AV block, a pacemaker is chosen | With constant frequency |
| After the chest operation, the patient has feels difficult to breathe, and then the patient is connected to a | Pacemaker |
| Radio capsule is | An encapsulated radio receiver |
| The …….. System of the heart controls synchronization of the hearts pumping by controlling the distribution of pacemaker impulse | Conduction |
| Pacemaker output energy levels of ……..or more may cause ventricular fibrillation | 20 µJ |
| In an ECG, the QRS complex represents the | Depolarization of atria |
| An ECG would be useful for determining patients | Heart murmur |
| During exercise, there is an increase flow of blood to | The brain |
| . ……fibrillation may cause to death | Atrial |

| | |
|---|---|
| Dual peak defibrillator are applied to | Reduce the current passing to heart |
| The increase in heart rate is called | Bradycardia |
| The decrease in heart rate is called | Bradycardia |
| The purpose of electrical shock to correct arrhythmias is to ……. the heart, so that all cells enter their refractory period together. | Stimulate |
| In biotelemetry, the type of modulation employed is | Amplitude modulation |
| In biotelemetry ……..cannot be employed | Amplitude modulation |
| Radio capsules are | Some kind of treatment to reduce brain activity |
| The ……. fibrillation can cause mild effect to the patient | Atrial |
| Atrial fibrillation cannot be corrected using | AC defibrillator |
| The application of an electrical shock to resynchronize the heart is called | Fibrilator |
| Hearts vulnerable period is | QRS segment |
| In an ECG, the ST segment corresponds to | Depolarization of Atria |
| an ECG, The P segment corresponds to | Depolarization of Atria |

| | |
|---|---|
| In an ECG, The U wave corresponds to | Depolarization of Atria |
| Ventricular Inhibited pacemaker is otherwise called as | Demand pacemaker |
| Av delay is approximately | 0 .0012 sec |
| The contact impedance for external defibrillator is | 100 Ω |
| If the counter shock falls in the T wave ……. Is possible | Atrial fibrillation |

| opt2 | opt3 |
| --- | --- |
| Directly proportional | Inversely proportional |
| 50%plasma , 10% cells, 40%proteins | 60% plasma , 40 % cells |
| Mitral valve | SA node |
| SA node | Tricuspid valve |
| 10 µJ | >400 µJ |
| 10-250 | 72 |
| 2 kg | 100 gm |
| 80 | 2000 |
| Unipolar | Augmented |
| Unipolar | Augmented |
| Unicardiac | Endocardiac |
| Unicardiac | 10-20 lead |

| | |
|---|---|
| Permanent heart irregularities | Minor steno sis |
| Permanent heart irregularities | Minor steno sis |
| Asynchronous pacing | R-wave inhibited |
| is located in SA node of heart | Does not function in the absence of light or other environmental cues |
| Ventricular synchronous pacemaker | Ventricular inhibited pacemaker |
| R wave is absent | P wave is present |
| R wave due to natural pacing is absent | R wave due to natural pacing is of low amp |
| The cell responds to any stimuli | The cell responds to the stimuli with very high energy |
| The cell responds to any stimuli | The cell responds to the stimuli with very high energy |
| Steno sis | Fibrillation |

| | |
|---|---|
| 5V to 500V | 3V to 600V |
| 1000V to 6000V | 3V to 600V |
| 50 to 400 joules | 1000 to 15000 joules |
| Heart lung machine | pacemaker |
| Arrest ventricular fibrillation | Arrest leakage of blood from heart |
| Monstable multivibrator | IC 555 |
| Monstable multivibrator | IC 555 |
| 1 µJ | 10 mv |
| Atrial fibrillation | Ventricular fibrillation |
| The ordinary dry cell | Nuclear battery |

| | |
|---|---|
| Diathermy treatment | Saline water |
| that is atrial synchronous | that is ventricular synchronous |
| Defibrillator | Ventilator |
| A system emitting radio active radiation | An encapsulated biosignal transmitter |
| Excretory | Respiratory |
| 400 µJ | 1000 µJ |
| Depolarization of ventricles | Polarization of atria |
| Stroke volume | Cardiac output |
| The kidneys | The skin |
| Ventricular | AV node |

| | |
|---|---|
| Increase the current passing to heart | Increase the voltage passing to heart |
| Tachycardia | Hypotension |
| Tachycardia | Hypotension |
| Sense | Steno sis |
| Frequency modulation | Pulse modulation |
| Frequency modulation | Pulse modulation |
| Drugs to reduce ventricular fibrillation | Biotelemetry transmitter |
| Ventricular | SA node |
| DC defibrillator | Square wave circuit |
| Steno sis | Counter shock |
| P segment | In the middle of T segment |
| Depolarization of ventricles | Polarization of atria |
| Depolarization of ventricles | Polarization of atria |

| | |
|---|---|
| Depolarization of ventricles | Polarization of atria |
| Standby pacemaker | Asynchronous pacemaker |
| 1.2sec | 0.12 sec |
| 1000 Ω | 10k Ω |
| Ventricular fibrillation | Steno sis |

| opt4 | opt5 |
| --- | --- |
| Half | |
| 10%plasma,20%proteins , 70% cells | |
| Tricuspid valve | |
| AV node | |
| <100 µJ | |
| 1000 | |
| 5 gm | |
| 5 | |
| 10-20 lead system | |
| 10-20 lead system | |
| Semi cardiac | |
| Myocardiac or endocardiac | |

Heart arrhythmias

Heart arrhythmias

None of the above

is located in the lungs

Standby pacemaker

ST segment is present

ST segment is present

The cell responds to low amp stimulus

The cell respond to low amp stimulus

Defibrillation

500V to 10000V

5V to 100V

2000 to 3000 joules

kidney machine

Arrest the reverse flow of
blood from ventricle to atrium

Capacitor discharge

Capacitor discharge

1W

Low pressure

Solar cell

The room with fans

With variable frequency and synchronization with ventricular action

Heart lung machine

A medicine for treatment of cancer

Digestive

50 µJ

Repolarisation of ventricles

Blockage of conduction of electrical signals between the atria and ventricles

Liver

SA node

Reduce the energy delivered to the heart

Hypertension

Hypertension

Fibrillate

Phase modulation

Phase modulation

Used for animals to cure tumors

AV node

Biphasic defibrillator

Arrhythmia

PQ segment

Repolarization of ventricles

Repolarization of ventricles

Repolarization of ventricular fibers

Fixed rate pacemaker

0.12msec

50 Ω

Arrhythmia

opt6

Answer

Inversely proportional

60% plasma , 40 % cells

SA node

AV node

10 μJ

72

100 gm

80

Bipolar

Unipolar

Endocardiac

Myocardiac or endocardiac

Permanent heart irregularities

Temporary heart irregularities

Asynchronous pacing

is located in the lungs

Ventricular inhibited pacemaker

R wave is present

R wave due to natural pacing is absent

The cell responds to the stimuli with very high energy

The cell does not respond to any stimuli

Fibrillation

50V to 1000V

1000V to 6000V

15 to 50 joules

pacemaker

Restart the heart rhythm after the open heart surgery

Capacitor discharge

Monstable multivibrator

10 µJ

Ventricular fibrillation

Mercury battery

Diathermy treatment

With constant frequency

Ventilator

An encapsulated biosignal transmitter

Conduction

400 μJ

Depolarization of ventricles

Blockage of conduction of electrical signals between the atria and ventricles

The skin

Ventricular

Reduce the current passing to heart

Tachycardia
Bradycardia

Stimulate

Frequency modulation

Amplitude modulation

Biotelemetry transmitter

Atrial

AC defibrillator

Counter shock

In the middle of T segment

Repolarization of ventricles

Depolarization of Atria

Repolarization of ventricular fibers

Demand pacemaker

0.12 sec

100 Ω

Ventricular fibrillation

| Questions | opt1 |
| --- | --- |
| Dual peak D.C. defibrillator is used to …… supplied to the patient | Maintain the current |
| Where does the refractory period lies in the ECG waveform | T wave |
| During Myocardial Infraction, one can use | Pacemaker |
| Justify the following statement. “Heart Lung Machine” can be used for a longer time for a patient. | Yes |
| Inflammation of the kidney is called | otitis |
| In the case of defibrillator, a double square pulse type is used to | Restart the heart rhythm after the open heart surgery |
| In direct current defibrillator, a pulse with a duration of about 5ms is generated by means of a | Astable multivibrator |
| To produce ventricular contraction with an electric pulse, the minimum energy required is | 10µJ |

| | |
|---|---|
| Suppose the Pacemaker pulse has high energy and occurs during the vulnerable part of the T wave then the heart is in | Normal state |
| The commonest source of energy for pacemaker is the | Mercury battery |
| Because of the risk of electromagnetic interference, pacemaker patients should not be given | Cancer treatment |
| In the case of stable total AV block, a pacemaker is choosen | With constant frequency |
| After the chest operation, the patient feels difficult to breath. Then the patient is connected to a | Pacemaker |
| The apparatus used for extra corporeal circulation of blood is called | Heart lung machine |
| During open heart surgery, the operation time can be increased by | Giving more anesthesia |
| Most blood pumps use the principle of | Peristaltic compression |

| | |
|---|---|
| To reduce hemolysis, the blood pump design should provide a flow that minimises | Oxygen tension |
| Radio capsule is | an encapsulated radio receiver |
| In Biotelemetry, FDM refers to | Frequency Division Modulation |
| The radio capsules are | Some kind of treatment to reduce brain activity |
| The obstruction of blood flow is known as | Cyanosis |
| Too low blood pressure is known as | Hypertension |
| The mass defect for an isotope was found to be 0.410 amu/atom. Calculate the binding energy in kJ/mol of atoms. (1 J = 1 kg m2/s2) | 3.69 x 1010 kJ/mol |

| | |
|---|---|
| Calculate the binding energy per nucleon (in units of MeV) for 9Be, for which the atomic mass is 9.01219 amu. Particle masses in amu are: proton = 1.007277; neutron = 1.008665; electron = 0.0005486. Conversion factor for E = mc2 is 931 MeV/amu | 6.46 MeV |
| Which isotope below has the highest nuclear binding energy per gram? No calculation is necessary. | 4He |
| Which of the following statements is incorrect? | Mass defect is the amount of matter that would be converted into energy if a nucleus were formed from initially separated protons and neutrons. |
| A positron has a mass number of _____, a charge of _____, and a mass equal to that of a(an) _____. | 0, 1+, proton |

| | |
|---|---|
| Emission of which one of the following leaves both atomic number and mass number unchanged? | positron |
| Which type of radiation is the least penetrating? | alpha |
| A radioisotope of argon, 35Ar, lies below the "band of stability: (n/p ratio too low). One would predict that it decays via _____. | neutron emission |
| A Geiger-Muller tube is a _____ | gas ionization detector |
| The half life of 231Pa is 3.25 x 104 years. How much of an initial 10.40 microgram sample remains after 3.25 x 105 years? | 0.0102 micrograms |
| Consider the case of a radioactive element X which decays by electron (beta) emission with a half-life of 4 days to a stable nuclide of element Z. Which of the following statements is CORRECT? | After 8 days the sample will consist of one-fourth element Z and three-fourths element X. |

| | |
|---|---|
| How old is a bottle of wine if the tritium (3H) content (called activity) is 25% that of a new wine? The half-life of tritium is 12.5 years. | 1/4 yr |
| A Geiger counter registered 1000 counts/second from a sample that contained a radioactive isotope of polonium. After 5.0 minutes, the counter registered 281 counts/second. What is the half-life of this isotope in seconds? | 87 |
| The 14C activity of some ancient Peruvian corn was found to be 10 disintegrations per minute per gram of C. If present-day plant life shows 15 dpm/g, how old is the Peruvian corn? The half-life of 14C is 5730 years. | 1455 years |
| Which of the following describes what occurs in the fission process? | A heavy nucleus is fragmented into lighter ones. |

| | |
|---|---|
| Which of the following statements about nuclear fission is always correct? | Very little energy is released in fission processes. |
| Which one of the following would be most likely to undergo thermonuclear fusion? | 2H |
| Which one of the following statements about nuclear reactions is false? | Particles within the nucleus are involved |
| Complete ha particle 239Pu + alp22._____ + neutron and balance the following equation. The missing term is _____ . | 2 115Ag |
| When 59Cu undergoes positron emission, what is the immediate nuclear product? | 59Ni |
| As a result of the process of electron capture ("K-capture") by 211At, the new isotope formed is: | 210At |
| When 235U is bombarded with one neutron, fission occurs and the products are three neutrons, 94Kr, and _____ | 139Ba |

| | |
|---|---|
| In general, the body cells most susceptible to damage by radiation are those found in: | rigid or semi rigid tissues |
| In a picocurie of any radioactive substance, the disintegration rate is: | 2.22 dpm |
| Which of the following radionuclides cannot be detected by gamma spectrometry pulse height analysis? | Hydrogen-3 |
| The elemental symbols for Boron, Beryllium, Cadmium, and Calcium are: | Bo, B, Ca, C |
| Which of the following radionuclides is most suited to in-vivo measurements? | Hydrogen-3 |
| How long must a sample with a count rate of 300 cpm be counted to give a total count rate standard deviation of 1%? | 3.5 min |
| At what radius would you post a radiation area around an 8 curie Cesium 137 (662 Kev photon energy and a photon yield of 0.85 photons/disintegration) point source? | 10 feet |

| | |
|---|---|
| An air filter with a collection efficiency of 99.97% is being used in a decontamination effort. Calculate the decontamination factor for this filter. | 9997 |
| During an emergency in a DOE regulated facility, with known or potential high radiation fields, exposure to personnel must be voluntary if it is anticipated that such exposure may exceed a whole body exposure of: | 5 rem |

| | |
|---|---|
| A worker is to perform maintenance on a Reactor Coolant pump under the following radiological conditions; Dose rate on contact with the pump - 350 mrem/hr, Dose rate at 30 cm from the pump (working area dose rate) is 85 mrem/hr, and an airborne concentration of .45 DAC. She will spend a maximum of 14 hours in this area during the week. According to 10CFR20, how is this area to be posted? | Danger High Radiation Area,<br>Airborne Radioactivity Area |
| For an exclusive use vehicle that is transporting radioactive materials, radiation levels oncontact with any external surface of the vehicle must not exceed: | 0.01 mSv/hour |
| Two categories of ionization are: | alpha and beta |
| Intrinsic efficiency of a detector expresses the: | probability that a count will be recorded if radiation enters the sensitive volume. |

| | |
|---|---|
| The antiparticle of a positron is a: | proton |
| Forms of the same chemical element that contain different numbers of neutrons are called: | isobars |
| An atom of a radionuclide that has a low neutron to proton ratio, and an atomic rest mass energy that is 1.02 Mev greater than the product atom's rest mass energy may decay by which of the following? | Either positron emission or electron capture |

| opt2 | opt3 |
| --- | --- |
| Double the current | Multiply the current |
| RS segment | QR segment |
| Heart lung Machine | Nerve stimulator |
| No | It depends upon the condition of the patient |
| hepatitis | rephritis |
| Arrest ventricular fibrillation | Arrest leakage of blood from the heart |
| Monostable multivibrator | Clock IC 555 |
| 1J | 10mW |

| | |
|---|---|
| Atrial fibrillation | Ventricular fibrillation |
| The ordinary dry cell | Nuclear battery |
| Diathermy treatment | Saline water |
| That is atrial synchronous | That is ventricular synchronous |
| Defibrillator | Ventilator |
| Ventilator | Dialyser |
| Connecting a pacemaker | Connecting a ventilator |
| Centrifuge | Compression |

| | |
|---|---|
| Turbulence | Body temperature |
| a system emitting radio active radiations | an encapsulated bio signal transmitter |
| Fourier Domain Modulation | Frequency Division Multiplexing |
| Drugs to reduce ventricular fibrillation | Biotelemetry transmitter |
| Edema | Hyperemia |
| Hypothalamus | Hypotension |
| 1.23 x 1020 kJ/mol | 3.69 x 1013 kJ/mol |

| | |
|---|---|
| 6.33 MeV | 6.23 MeV |
| 16O | 32S |
| Nuclear binding energy is the energy released in the formation of an atom from subatomic particles. | Nuclei with highest binding energies are the most stable nuclei |
| 1, 2+, proton | 0, 1+, electron |

| | |
|---|---|
| neutron | alpha particle |
| beta | gamma |
| beta emission | positron emission |
| cloud chamber | fluorescence detector |
| 0.240 micrograms | 2.18 micrograms |
| Element Z will weigh exactly the same as element X when decay is complete (weighed to an infinite number of significant figures). | .0 g of element X is required to produce 1.5 g of element Z after 8 days (to 2 significant figures). |

| | |
|---|---|
| 3.1 yr | 25 yr |
| 110 | 164 |
| 1910 years | 3350 years |
| A neutron is split into a neutron and proton | Two light nuclei are combined into a heavier one |

| | |
|---|---|
| Nuclear fission is an energetically favorable process for heavy atoms. | Due to its instability, 56Fe readily undergoes fission. |
| 4He | 56Fe |
| No new elements can be produced. | Rate of reaction is independent of the presence of a catalyst. |
| 2 106Rh | 235U |
| 58Ni | 58Cu |
| 212At | 211Po |
| 141Ba | 139Ce |

| | |
|---|---|
| muscle tissues | rapidly dividing tissues |
| 2.22 x 10 E 6 dpm | 37,000,000 dpm |
| Iodine-131 | Cerium-144 |
| B, By, Cd, Ca | Bo, Be, Cd, Ca |
| Carbon-14 | Strontium-90 |
| 17 min | 30 min |
| 74 feet | 145 feet |

| | |
|---|---|
| 0.9997 | 3000 |
| 10 rem | 25 rem |

| | |
|---|---|
| Caution Radiation Area, Airborne Radioactivity Area | Caution High Radiation Area, Airborne Radioactivity Area |
| 0.02 mSv/hour | 0.1 mSv/hour |
| direct and indirect | microwave and infrared |
| ability of an instrument to count different energies. | percent of gamma energy producing ion pairs. |

| | |
|---|---|
| neutrino | electron |
| isomers | radionuclides |
| Annihilation | Beta minus emission |

| opt4 | opt5 | opt6 |
| --- | --- | --- |
| Reduce the current | | |
| P wave | | |
| Kidney Machine | | |
| When there is no power failure, the statement is true | | |
| Toxemia | | |
| Arrest the reverse flow of blood from ventricle to atrium | | |
| Capacitor discharge | | |
| 1W | | |

Low pressure

Solar cell

The rooms with fans

With variable frequency and synchronization with ventricular action

Heart lung machine

Pacemaker

Inducing hypothermia

Normal acceleration

Continuous flow

a medicine for
treatment of cancer

Fesimle Distance
Modulation

Used for animals to
cure tumors

Stasis

vasodilation

1.23 x 103
kJ/mol

11.39 MeV

55Mn

Mass number is
the sum of all
protons and
electrons in an atom

1, 2+, electron

gamma radiation

x-ray

alpha emission

spectrophoto
meter

0.0240
micrograms

If element X as an
atomic number
equal to n, then
element X has an
atomic number
equal to n-1.

37.5 yr

264

3820 years

A proton is split into
three quarks

In fission reactions, a neutron is split into a proton and an electron.

141Ba

Rate of reaction is independent of temperature.

242Cm

59Zn

211Rn

139Xe

highly specialized
tissues

3.7 x 10 E 4 dps

Ruthenium-106

B, Be, Cd, Ca

Iodine-131

33 min

53 feet

3333

75 rem

Caution Radiation
Area

2.0 mSv/hour

charged and
uncharged

total detector
counts minus the
background.

meson

isotopes

Isomeric
transition

Answer

Reduce the current

RS segment

Pacemaker

No

rephritis

Restart the heart rhythm after the open heart surgery

Capacitor discharge

10μJ

Ventricular fibrillation

Mercury battery

Diathermy treatment

With constant frequency

Ventilator

Heart lung machine

Inducing hypothermia

Peristaltic compression

Turbulence

an encapsulated bio signal transmitter

Frequency Division Multiplexing

Biotelemetry transmitter

Stasis

Hypotension

3.69 x 1010
kJ/mol

6.46 MeV

55Mn

Mass number is
the sum of all protons and electrons in an atom

0, 1+, electron

gamma
radiation

alpha

positron
emission

gas ionization
detector

0.0102
micrograms

.0 g of element X is required to produce 1.5 g of element Z after 8 days (to 2 significant figures).

25 yr

164

3350 years

A heavy nucleus is fragmented into lighter ones.

Nuclear fission is
an energetically favorable process for heavy atoms.

2H

No new elements
can be produced.

242Cm

59Ni

211Po

139Ba

rapidly dividing tissues

2.22 dpm

Hydrogen-3

B, Be, Cd, Ca

Iodine-131

33 min

74 feet

3333

5 rem

Caution Radiation
Area

2.0 mSv/hour

direct and
indirect

probability that a count will be recorded if
radiation enters the sensitive volume.

electron

isotopes

Either positron
emission or electron capture

Questions

Which radioactive decay series includes Ra-226 as one of its decay products?

An individual who receives an acute, whole body (DDE) radiation exposure of approximately 8Gy will likely suffer symptoms of up to which level of the Acute Radiation Syndrome?

The term “isokinetic sampling” refers to the procedure of using sampling velocity that is exactly equal to the:

In which of the following radioactive decays will the daughter product be an isobar of the parent?

The respiratory protection device of choice for entry into an atmosphere immediately dangerous to life and health is a (an):

The average distance of travel in a medium between interactions, describes a photon’s:

The Bragg-Gray principal is based upon the relationship of:

Given a gamma-energy value of 0.662 Mev,and a photon yield of 0.85 per decay, the exposure rate at 2 yards from an unshielded 10 mCi Cs-137 point source is:

A radionuclide has a decay constant of 0.1314
years, a gamma energy (per disintigration) of 2.50 Mev, and will produce a dose rate of approximately 30 R/hour at one foot from a 2 Curie source. Calculate the radiological half life of this nuclide:

With reference to the interaction of electrons
(cathode) with atoms of the anode, what percentage of typically heat occurs?

Stationary X-ray tubes are utilised mainly in:

The inner envelope of an X-ray tube is usually made from

Which of the following is NOT a requirement for an X-ray tube filament material?

Typical anode angles in general diagnostic X-ray tubes (excluding mammography) tend to be between

The following material is added to the anode disc of a rotating X-ray tube to prevent the crazing effect

Modern anode discs, which contain more than one material in their construction may be referred to as a

The expansion bellows performs the following task

The added filtration of a diagnostic X-ray tube typically consists of

The filtration of an X-ray beam has the effect of

Regarding subject contrast in radiography, which of the following are correct?

concerning radiographic contrast

Which of the following are correct for positive-contrast media?

The relationship between radiation and some biologic response is in:

The ADE method of calculating considers the differences in radiation damage by using a modifying or

The radiation equivalent man is equal to?

X-ray heat is generated by:

A penetrameter is used to indicate:

A graph which expresses the relationship between material thickness, KV, and Time specific to film, machine, FFD, processing conditions, and the resulting photographic density is called:

If a piece of lead 1/2-inch this is placed in the path of a beam of radiation emanating from cobalt-60, it will reduce the dose rate at a given location by:

To produce X rays, electrons are accelerated to a high velocity by an electrical field and then suddenly stopped by a collision with a solid body. This body is called:

The difference between the densities of two areas of a radiograph is called:

The cause for poor image definition could be considered:

Excessive exposure of film to light prior to development of the film will most likely result in:

Three liquids which are essential to process an exposed film properly are:

During manual film processing, the purpose of the stop bath is to:

The three main steps in processing a radiograph are:

The duration of an exposure is usually controlled by:

An advantage of the pocket dosimeter type of ionization chamber used to monitor radiation received by personnel is:

In order to decrease geometric unsharpness:

The density of a radiograph image refers to:

A section with a significant increase in thickness variation is required to be shown on a single radiograph within a desired film density range. This may be accomplished by:

The primary parts of an atom are:

As a check on the adequacy of the radiographic technique, it is customary to place a standard test piece on the source side of the specimen. This standard test piece is called a:

In order to increase the intensity of X-radiation:

What is sometimes used to change the alternating current from the high voltage transformer to direct current for the purpose of increasing the X-ray machine output:

A curie is the equivalent of:

The most widely used unit of measurement for measuring the rate at which the output of a gamma-ray source decays is the:

A thin metallic sheet (brass, copper, aluminum,etc) placed at the source to reduce effects of softer radiation is known as:

By using a___ transformer, the incoming voltage can be adjusted in order to heat the filament of an x-ray tube; is about ____volts

Which of the following are the process by which x-ray are produced?

Which meter registers indicating x-ray exposure?

Which of the following applies to the filament transformer?

The purpose of the circuit breaker is to

The film for and SSD treatment on a linear accelerator is taken at 133 cm. What is the magnification factor?

A patient is simulated to receive a treatment to cover a tumor volume plus 1 cm on each side. The tumor is 3.5 cm wide and the depth of 4 cm. What will be the necessary field width at the skin surface, using a linear accelerator with the isocentric setup?

What is the field size on a film if the collimator setting is 7X19 CM, and the magnification factor is 1.33X?

What types of diagnostic exams expose patients to ionizing radiation?

A chest X-ray and a CT scan of the chest use similar amounts of radiation while obtaining their images.

In the next few decades, what percentage of cancers will be directly linked to the use of CT scans?

Over the past decade, what percent has CT scan usage increased?

| opt1 | opt2 |
| --- | --- |
| Thorium | Uranium |
| Subclinical | Hemopoietic |
| velocity of the gas stream at the point of sampling | velocity at the center of the main gas stream corrected for temperature and pressure |
| alpha decay | gamma decay |
| supplied air hood | air-purifying respirator equipped with a high efficiency filter |
| mass energy absorption coefficient | mean free path |
| secondary charged particle equilibrium requirements and the thickness of the wall material of the chamber. | ionization in an air-filled ionization chamber to the dose in air |

| | |
|---|---|
| 1.10 R/hour | 0.55 R/hour |
| 5.27 years | 229 years |
| 1 percent | 10 percent |
| Fluoroscopy rooms | General X-ray rooms |
| Perspex | Lead |
| High work function | Ductile |
| 4 - 6 degrees | 15 – 17 degrees |

| Molybdenum | Carbon |
| --- | --- |
| bi-anode | double anode |
| Provides additional X-ray production | Permits greater heat capacity of the anode surface |
| aluminium or copper | aluminium or beryllium |
| improving the quality of the transmitted X-ray beam | improving the quantity of the transmitted X-ray beam |
| It depends on the thickness of the structure being imaged | It depends on the linear attenuation coefficients of the structures being imaged It increases with the tube kV |
| Attenuation of the X-ray beam depends upon the degree of Bremsstrahlung in the tissue | Most structures on a chest radiograph exhibit good radiographic contrast |

| | |
|---|---|
| They should ideally have an absorption edge just to the left of the major part of the beam spectrum | Barium has a K-absorption edge of approximately 23 keV |
| Non Linear, non threshold relationship | Linear, threshold relationship |
| QF | AD |
| REM | RAD |
| The current passing through the filament (cathode) | The distance from the cathode to the anode |
| The size of the discontinuities in a part | The density of the film |
| A bar chart | An exposure chart |
| One-third | One-quarter |

| | |
|---|---|
| Cathode | Filament |
| Radiographic contrast | Subject contrast |
| Too short source-to-film distance | Screens and film not in close contact |
| A foggy film | Poor definition |
| Stop batch, acetic acid, and water | Developer, stop bath, and H2O2 |
| Change the exposed silver salts to black metallic silver | Neutralize the developer and stop the developing process |
| Developing, frilling, and fixation | Developing, fixation, and washing. |
| . Controlling the milliamperage | A timer |
| It provides a permanent record of accumulated dosage | It provides an immediate indication of dosage |

| | |
|---|---|
| Radiation should proceed from as small a focal spot as other considerations will allow | Radiation should proceed from as large a focal spot as other considerations will allow. |
| The thickness of the film | The thickness of the specimen |
| Increasing kilo voltage | Using a coarse grain film |
| . Proton, neutrino, electron | Proton, electron, gamma ray |
| Reference plate | Lead screen |
| The tube current should be increased | The tube current should be decreased |
| Rectifier | Cathode X-ray tubes |
| 0.001 milli curies | 1.000 milli curies |

| | |
|---|---|
| Curie | Roentgen |
| An intensifying screen | A filter |
| Step up, 1000 to 3000 volts | Step up, 500 to 1000 volts |
| Brims | Photoelectric |
| Voltmeter | Line Voltage compensator |
| A step up transformer is needed | A step down transformer is needed |
| Prevent electrical shock to the patient | Decrease exposure to the patient |
| 1.33 cm | 1.53 cm |

| | |
|---|---|
| 5.28 CM | 6.31 CM |
| 8x15 cm | 10x10 cm |
| Computed Tomography | Ultra Sound |
| True | False |
| 10% | 2% |
| 74% | 120% |

| opt3 | opt4 |
| --- | --- |
| Actinium | Neptunium |
| Gastrointestinal | Central Nervous System |
| velocity at the center of the main gas stream | velocity of the gas stream adjacent to the duct wall |
| neutron decay (elastic scatter) | positron decay |
| air-purifying respirator, full face piece, equipped with organic vapor canister | self-contained breathing apparatus equipped with a pressure demand regulator |
| linear attenuation coefficient | Compton cross section |
| ionization of the gas in an ionization chamber to the dose in the wall material | ionization in a gas-filled ionization chamber to the dose in the gas |

| | |
|---|---|
| 5.50 R/hour | 0.94 mR/hour |
| 3.93 years | 30.1 years |
| 0.1 percent | 99 percent |
| Computerised Tomography | Intra-oral X-ray units |
| Borosilicate glass | Aluminium |
| High melting point | High atomic number |
| 20 – 25 degrees | 25 – 28 degrees |

| | |
|---|---|
| Rhenium | Copper |
| Compound anode | Rare earth anode |
| Acts as a safety device within the X-ray tube | Aids in the exposure timing |
| Copper or tin | Tin or lead |
| Reducing the quantity and decreasing quality of the transmitted X-ray beam | Improving the quality and increasing quantity of the transmitted X-ray beam |
| Contrast between low-atomic-number structures (e.g. fat and muscle) is strongly affected by changes in the tube kV | Contrast between air and soft tissue is due to differences in their atomic numbers |
| In principle, contrast media have the same effect on demonstrating contrast between tissues as increasing the peak kV (kVp) | Positive-contrast media should generally have high atomic numbers to maximize the degree of photoelectric absorption |

| | |
|---|---|
| Iodine has a lower atomic number than barium | Iodine most effectively attenuates photons with energies close to 37 keV |
| Linear, non threshold relationship | Non Linear, threshold relationship |
| AF | MA |
| R | C/kg |
| The type of material used in the target | The voltage and waveform applied to-the X-ray tube |
| The amount of the film contrast | The quality of the radiographic technique |
| The characteristic curve | |
| One-half | Three-quarters |

| | |
|---|---|
| Target | Generator |
| Film contrast | Definition |
| Film graininess | All of the above |
| Streaks | Yellow stain |
| Developer,<br>fixer, and water | Acetic acid,<br>fixer, and stop bath |
| Eliminate most<br>water spot and streaks | Note of the<br>above |
| Exposure,<br>developing, and fixation | Developing,<br>reticulating, and fixation |
| Controlling the<br>source-to-film distance | A choke coil in<br>the filament transformer |
| It is the most<br>sensitive detector available | All of the above<br>are advantages |

The film should
be as far as possible from the
object being radiographed

The distance
from the anode to the
material examined should
be as small as is practical.

The weight of
the film

The degree of
film blackening

Both A and B
are correct

Neither A nor
B is correct

Photon, electron,
neutron

Proton, electron,
neutron

Pentameters

Illuminator

The test specimen
should be moved further from
the film.

A lower kilo
voltage should be applied to
the tube

Gas X-ray
tube

Vacuum X-ray
tube

1.000 mega
curies

100 mega
curies

| | |
|---|---|
| Half-life | MeV |
| An electron inducer | A focusing cup |
| Step down, 100 to 200 volts | Step down, 10 to 12 volts |
| Characteristic | A & B are correct |
| Milliamp meter | Dead man switch |
| An auto-transformer is needed | Must have at least four diodes |
| Reduce secondary radiation | Prevent overloading |
| 1.85 cm | 1.75 cm |

4.45 CM

6.67 CM

9x25 cm

11x25 cm

Magnetic Resonace Imaging

All of the above

5%

0%

50%

300%

opt5

opt6

Answer

Uranium

Gastrointestinal

velocity of the gas
stream at the point of sampling

positron decay

self-contained
breathing apparatus equipped with a
pressure demand regulator

mean free path

ionization of the
gas in an ionization chamber to the dose in
the wall material

0.94 mR/hour

5.27 years

99 percent

Intra-oral
X-ray units

Borosilicate
glass

High work
function

15 – 17
degrees

Rhenium

Compound
anode

Acts as a safety
device within the X-ray tube

aluminium or
copper

improving the
quality of the transmitted
X-ray beam

It depends on the thickness of the
structure being imaged

Positive-contrast media should generally
have high atomic numbers
to maximize the degree of photoelectric
absorption

They should
ideally have an absorption edge just to the
left of the major part of the beam spectrum

Non Linear,
non threshold relationship

QF

REM

The current passing
through the filament (cathode)

The quality of the
radiographic technique

An exposure chart

C. One-half

Target

Radiographic
contrast

D. All of the above

A foggy film

Developer,
stop bath, and H2O2

Neutralize the
developer and stop the developing process

Developing,
fixation, and washing.

A timer

It provides an
immediate indication of dosage

Radiation should
proceed from as small a focal spot as other
considerations will allow

The degree of film
blackening

Increasing kilo
voltage

Proton, electron,
neutron

Pentameters

The tube current
should be increased

Rectifier

1.000 milli curies

Curie

A filter

Step down, 10 to
12 volts

A & B are correct

Milliamp meter

A step down
transformer is needed
Prevent
overloading

1.33 cm

A. 5.28 CM

10x10 cm

Computed
Tomography

True

2%

300%

| 16BEEC801A | MEDICAL ELECTRONICS | L T P C<br>3 0 0 3 |
|---|---|---|

**OBJECTIVES**

- To study the method s of recording various bio potentials
- To study how to measure biochemical and various physiological information
- To understand the working of units whichwill help to restore normal functioning
- To understand the use of radiation for diagnostic and therapy
- To understand the need and technique of electrical safety in Hospitals

**INTENDEDOUTCOMES:**

- Gainknowledgeaboutthemethodsofrecording variousBio potential
- Gainknowledgeabouthowto measurebiochemicalandvariousphysiological information
- Gainknowledgeabouttheworking ofunitswhichwillhelptorestorenormal functioning
- Gainknowledgeabouttheuseofradiationfordiagnosticandtherapy
- Gainknowledgeabouttheneedandtechniqueofelectrical safety inHospitals

**UNIT-I ELECTRO-PHYSIOLOGY AND BIO-POTENTIAL RECORDING**

Theorigin of Bio-potentials; Biopotential electrodes, biological amplifiers, ECG,EEG,EMG, PCG, EOG, leadsystems and recording methods, typical waveforms and signal characteristics.

**UNIT-II BIO-CHEMICAL AND NON ELECTRICAL PARAMETER MEASUREMENT**

PH, PO2, PCO2, PHCO3, Electrophoresis, colorimeter, photometer, Auto analyzer, Blood flow meter, cardiac output, respiratory measurement, Blood pressure, temperature, pulse, Blood cell counters.

**UNIT-III ASSIST DEVICES AND BIO-TELEMETRY**

Cardiac pacemakers, DC Defibrillator, Telemetry principles, frequency selection, Bio-telemetry radio- pill and tele-stimulation.

**UNIT-IV RADIOLOGICAL EQUIPMENTS**

Ionizing radiation, Diagnostic x-ray equipments, use of Radio Isotope in diagnosis, Radiation Therapy.

**UNIT-V RECENT TRENDS IN MEDICAL INSTRUMENTATION**

Thermograph, endoscopy unit, Laserin medicine, Diathermy units, Electrical safetyin medical equipment.

**TEXTBOOK:**

| S.NO. | Author(s)Name | Titleof thebook | Publisher | Yearof Publication |
|---|---|---|---|---|
| 1. | LeislieCromwell | Biomedical instrumentation and measurement | PrenticeHallof India,NewDelhi. | 2002 |
| 2. | Khandpur,R.S. | Handbook of Biomedical | TataMcGraw-Hill, NewDelhi. | 1997 |

**REFERENCES:**

| S.NO. | Author(s)Name | Titleof thebook | Publisher | Yearof Publication |
|---|---|---|---|---|
| 1. | JosephJ.Carrand JohnM.Brown | Introductionto Biomedicalequipment Technology | JohnWileyand Sons,NewYork | 1997 |

**16BEEC801B DIGITAL IMAGE PROCESSING L T P C**
**3 0 0 3**

**OBJECTIVES**

- To understand the Fundamentals of image processing.
- To learn Various transforms used in image processing.
- To learn the Image processing techniques like image enhancement, reconstruction, compression and segmentation.

**INTENDED OUTCOMES:**

- Understand the Fundamentals of image processing.
- Knowledge about various transforms used in image processing.
- Knowledge about the Image processing techniques like image enhancement, reconstruct ion, compression and segmentation.

**UNIT I-DIGITAL IMA GE FUNDAMENTALS**

Introduction -Elements of Digital Image Processing system- elements of visual perception – image sensing and acquisition – Image sampling and quantization - image representation -Some basic relationship between pixels.

**UNIT II-IMAGE TRANSFORMS**

Introduction -2D Discrete Fourier Transform – Properties- Importance of Phase -Walsh –Hadamard – Discrete Cosine Transform, Haar –K L transforms –Singular Value Decomposition.

**UNIT III-IMAGE ENHANCEMENT**

Enhancement through point operation- Histogram manipulation – Gray level transformation- Neighborhood operation – Median filter - Image Sharpening- Bit plane slicing - Homomorphism Filtering – Zooming operation.

**UNIT IV-IMAGE RESTORATION**

Model of Image Degradation/restoration process –Inverse filtering -Least mean square (Wiener)filtering – Constrained least mean square restoration – Singular value decomposition-Recursive filtering.

**KARPAGAM ACADEMY OF HIGHER EDUCATION**

**(Deemed to be University Established Under Section 3 of UGC Act 1956)**

**Pollachi Main Road, Eachanari Post,**

**Coimbatore – 641 021**

**FACULTY OF ENGINEERING**

**DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING**

## LECTURE PLAN

**NAME OF THE STAFF : Dr.A.MOHANARATHINAM**

**DESIGNATION : ASSISTANT PROFESSOR**

**CLASS : B.E-IV YEAR ECE**

**SUBJECT : MEDICAL ELECTRONICS**

**SUBJECT CODE : 16BEEC801A**

| S.No | TOPICS TO BE COVERED | TIME DURATION | SUPPORTING MATERIALS | TEACHING AIDS |
|---|---|---|---|---|
| **UNIT- I ELECTRO-PHYSIOLOGY AND BIO-POTENTIAL RECORDING** | | | | |
| 1 | The origin of biopotentials, biopotential electrodes | 01 | T1- Page.no : 49-53, 66-76 | BB |
| 2 | Biological amplifiers | 01 | T1 Page.no : 109-111 | BB |
| 3 | ECG | 01 | T1- Page.no : 117-121 | BB |
| 4 | EEG | 01 | T1 Page.no. 296-300 | BB |
| 5 | EMG | 01 | T1 page.no. 300-303 | BB |
| 6 | PCG | 01 | T1 page.no. 169-172 | BB |
| 7 | EOG | 01 | www.medicine.mcgill.ca | BB |
| 8 | Lead systems and recording methods | 01 | T1 page.no.111-126 | BB |
| 9 | Typical waveforms and signal characteristics | 01 | T1 page.no.55-62 | BB |
| **Total Lecture Hours** | | **09** | | |
| **Total Hours** | | **09** | | |

| | | | | |
|---|---|---|---|---|
| **UNIT-II BIO-CHEMICAL AND NON ELECTRICAL PARAMETERS MEASUREMENT** | | | | |
| 10 | PH,$PO_2$,$PCO_2$,$PHCO_3$ measurements | 01 | T1 Page.no: 78-83,233-237 | PPT , BB |
| 11 | Electrophoresis | 01 | | PPT , BB |
| 12 | Colorimeter, photometer | 01 | T1 Page.no: 351-355 | PPT , BB |
| 13 | Auto analyzer | 01 | T1 Page.no: 359-362 | PPT , BB |
| 14 | Blood flow meter | 01 | T1 Page.no :150-158 | PPT , BB |
| 15 | Cardiac output, respiratory measurement | 01 | T1 Page.no: 158-162, 221-227 | PPT , BB |
| 16 | Blood pressure measurement | 01 | T1 Page.no: 126-150 | PPT , BB |
| 17 | Temperature, pulse measurement | 01 | T1 Page.no: 244-255 | PPT , BB |

| | | | | |
|---|---|---|---|---|
| 18 | Blood cell counter | 01 | T1 Page.no: 347-349 | PPT , BB |
| **Total Lecture Hours** | | **09** | | |
| **Total Hours** | | **09** | | |

| **UNIT-III ASSIST DEVICES AND BIO-TELEMETRY** | | | | |
|---|---|---|---|---|
| 19 | Cardiac pacemakers | 01 | T1 Page.no:195-205 | BB, PPT |
| 20 | DC defibrillator | 02 | T1 Page.no: 206-212 | BB, PPT |
| 21 | Telemetry principles | 01 | T1 Page.no: 317-320 | BB, PPT |
| 22 | Frequency selection | 01 | T2 Page.no: 8.6-8.7 | BB |
| 23 | Bio-telemetry | 02 | T1 Page.no:321-342 | BB,PPT |
| 24 | Radio- pill | 01 | T1 Page.no: | BB |
| 25 | Tele-stimulation | 01 | T1 Page.no: | |
| **Total Lecture Hours** | | **09** | | |
| **Total Hours** | | **09** | | |

| **UNIT-IV RADIOLOGICAL EQUIPMENTS** | | | | |
|---|---|---|---|---|
| 26 | Introduction to radiology | 01 | T1 Page.no:363-369 | BB |
| 27 | Diagnostic x-ray equipment | 02 | T1 Page.no:369-373 | BB,PPT |
| 28 | Use of radio isotope in diagnosis | 02 | T1 Page.no:376-382 | BB,PPT |
| 29 | Ionizing radiation | 02 | T1 Page.no:365-368 | BB,PPT |
| 30 | Radiation therapy | 02 | T1 Page.no:383 | BB |
| **Total Lecture Hours** | | **09** | | |
| **Total Hours** | | **09** | | |

| **UNIT-V RECENT TRENDS IN MEDICAL INSTRUMENTATION** | | | | |
|---|---|---|---|---|
| 31 | Thermograph | 02 | T1 Page.no: 252-255 | BB,PPT |
| 32 | Endoscopy unit | 02 | T3 Page.no:10.12-10.15 | BB,PPT |
| 33 | Laser in medicine | 01 | T3 Page.no:10.1-10.11 | BB |
| 34 | Diathermy units | 02 | T3 Page.no:6.1-6.5 | BB,PPT |
| 35 | Electrical safety in medical equipment | 02 | T1 Page.no:430-448 | BB |
| **Total Lecture Hours** | | **09** | | |
| **Total Hours** | | **09** | | |

Total No of Lecture Hours Planned: 45 Hrs

**Total No of Hours Planned : 45 Hours**

**TEXT BOOKS:**

| S.NO. | Author(s) Name | Title of the book | Publisher | Year of Publication |
|---|---|---|---|---|
| 1. | Leislie Cromwell | Biomedical instrumentation and measurement | Prentice Hall of India Pvt. Ltd., New Delhi | 2002 |
| **2.** | Khandpur R.S | Handbook of biomedical | Tata McGraw-Hill, New Delhi | 1997 |
| **3.** | Dr.M.Arumugam | Biomedical instrumentation | Anuradha Publications | 2016 |

**REFERENCES:**

| S.No | Author(s) Name | Title of the book | Publisher | Year of Publication |
|---|---|---|---|---|
| 1. | Joseph.J.Carrand John M.Brown | Introduction to biomedical Equipment technology | John Wiley and sons, NewYork | 1997 |

**STAFF IN-CHARGE** **HOD/ECE**

Questions

In diastole, blood flows in the back ward direction from aorta to left ventricles when valves are damaged, then this sound is

Murmur is produced when blood is passed from left atrium to left ventricular is called as

Transmittance in calorimeter is given by ……..where $I_0$ is the incident light and $I_1$ is the light leaving the cuvette.

Absorbance is ……to transmittance

Absorbance ……. if the number of cuvettes are decreased, provided the concentration of the sample remains the same and the length of the cuvette is also same

The concentration of Sodium, Potassium and Calcium iron In blood

Fluoroscopic observation of cardiac catheterization is made by

Lithium salt when ignited will produce

Sodium ions when ignited will produce

Potassium ions when ignited will produce

Spectrophotometer consists of

Peristaltic movement of air and sample is followed in

The movement achieved by mixing sample with air following one behind the other in some defined ratio

Among the following things which have the highest attenuation of

Two low a blood pressure is known as

The normal PH of the blood is

Blood flow can be measured using the electromagnetic principle because blood has a high

To avoid electrode polarization and biopotential artifacts, electromagnetic Blood flow meters are using

In addition to measuring mean flow speed of the blood, the pulsed Doppler Ultrasonic blood flow meter also displays

The average of values of systolic and diastolic pressure of normal

Blood plasma is obtain by -_____ blood that has been prevented

By listening over the heart with a stethoscope and palpating the arterial pulse In the wrist of an adult the time delay between systole and the pulse wave in the wrist is almost

Electromagnetic blood flow meter are based on the principle of

Ultrasonic blood flow meter is based on the principle of

Ultrasonic blood flow meter uses an ultrasound singal of frequencies

$\theta=0^{0}$ , V=100mm/s , C =1500m/s, a 2MHz ultrasonic beam is shifted

…….Utilise contrast agent into arteries to make visible on

The invasion method of blood flow measurement is

Cardiac output is obtained by

Heart beat of normal adult ranges from

During each beats the amount of blood pumped from the heart

Area under the curve in dye dilution method is obtained by

In Ficks method, the cardiac output is given by _____Where $C_A$ and $C_V$ are the oxygen concentrations in the artery and venous blood ,I is the amount of dye injected

Cardiac output of a normal adult ranges from ……litres /min

Non invasive method of measuring cardiac output is

TLC refers to

Inspiratory reserve volume is the extra amount of gas

End Expiratory volume is the extra amount of gas

Inspiratory capacity is

Vital capacity is maximum volume of gas that

Plethysmograph for measuring total lung capacity is based on

Red blood cells are used in

White blood cells are used in

Platelets are used in

Hemoglobin in the blood decreases ,…….is produced

Hemoglobin in the blood increases ,…… is produced

Pressure transducer for measuring pressure is from

The blood pressure cuff used in plethysmography is inflated to a pressure greater than the …… pressure but less than the

A plethysmograph measures …….changes in the limb

Sphygmomanometer is ……. Method of pressure

The …….pressure is indicated by the onset of korotkoff sound

The …….. pressure is indicated when the korotkoff sound

Cardiac output is measured in ……..

Cardiac output measured using invasive method is

Hemoglobin is a pigment present in

Blood has a Ph value of

The Non- invasive method of Blood flow measurement

The palpation method measures only the …… values of arterial

Auscultation determines …….. values of arterial blood

The most common indirect method for blood pressure

opt1
mitral regurgitation murmur

aortic regurgitation murmur

$I_1 / I_0$

Directly proportional
Remains the same

Flame Photometry
Echocardiography
Red Flame
Red Flame
Red Flame
Halogen lamp, mirror, prism or diffraction Grating and diode.
Autoanalyser
Endostatic

Blood
Hypertension
14
magnetic induction

Circular magnets

Size of the blood vessel

80 mm Hg and 120 mm Hg

Coagulating
1 second

Electromagnetic induction
Transmission
10 MHz
frequencies by about
EEG
Angiogram
Stroke volume/ heart beat rate per minute

100-170 beats/min
190  to 210ml
Averaging
$Q= I / (C_A - C_V )$

3-Feb
Calorimeter
Twin lungs capacity
Inspired with maximal effort after reaching the normal end of inspiratory level
Inspired with maximal effort after reaching the normal end of inspiratory level
Inspired with maximal effort after reaching the normal end of inspiratory level
Can be expelled from the lungs after a maximal inspiration

Electromagnetic conduction

$O_2$ and $CO_2$ transportation
O2 and Co2 transportation
O2 and Co2 transportation
Anemia
Anemia
Strain gauge transducer
Diastolic and systolic

Frequency
Non-invasive
Systolic
Systolic
Mm /min
Ficks method
WBC
7.36
Angiogram
Diastolic
Diastolic
Auscultator

opt2
mitral sterosis murmur

mitral sterosis murmur

$I_0 / I_1$

Square
Differs

PH meter
Fibers  Endoscope
Yellow Flame
Yellow Flame
Yellow Flame
Halogen lamp, filter and diode
Calorimeter
Peristaltic

Bone
Hypothalamus
7.4
Electrical resistivity

D.c.magnetic fields.

Number of red cell per unit

120 mm Hg and 80 mm Hg

Centrifuging
1 minute

Beers law
Conductivity
2 MHz
500hz
cardio pulse
Electro magnetic blood flow meter
Stroke volume*heart beat per minute

170-180 beats/min
100  to 150ml
Interpolation
$Q= C_A / C_V$

6-Apr
Dye dilution
Total lung capacity
Inspired with maximal effort after reaching the normal end of expiratory  level
Inspired with maximal effort after reaching the normal end of expiratory  level
Inspired with maximal effort after reaching the normal end of expiratory  level
Can be inhaled with full effort

Faraday's law of induced emf

Defence mechanism of the body
Defence mechanism of the body
Defence mechanism of the body
Polycythemia
Polycythemia
Strain gauge or capacitive transducer
Systolic and atmospheric

Volume
Invasive
Diastolic
Diastolic
Liters/ hour
Calorimeter
Chromosome
9
Coulter counter
Systolic
Systolic
Pneumotachometer

opt3
mitral regurgitation murmur

mitral regurgitation murmur

$I_0 * I_1$

Inversely proportional
Doubles

Blood gas analyzer
Electrocardiogram
Violet Flame
Violet Flame
Violet Flame
Flame, filters and Galvanometer
Blood cell counter
Gush movement

Fat
Hypotension
6.6
Electrical conductivity

D.c.current

Electrical conductivity of the blood

70 mm Hg and 140 mm Hg

Heating
0.2 second

boyle’s law
Induction
3 MHz
267 hz
myogram
Coulter counter
Number of heart beat in one hour*stroke volume

80-120 beats/min
70 to100ml
Extrapolation
$Q= I * C_A / C_V$

9-Aug
Ficks method
Tri length carrier
Expired with maximal effort after reaching the normal end of expiratory level
Expired with maximal effort after reaching the normal end of expiratory level
Expired with maximal effort after reaching the normal end of expiratory level
Can be inhaled after a maximum expiration

Boyle’s law

Blood clotting

Blood clotting

Blood clotting

Hemotocrit

Hemotocrit

Resistive transducer

Atmospheric and Systolic

Pressure

Direct

Mean

Mean

Mg /min

Impedance

Platelets

11

Electromagnetic blood flow meter

Mean

Mean

Coulter counter

opt4
aortic regurgitation murmur

aortic sterosis murmur

$I_1 I_0$ / 2

Half
Reduces by 2

Ultrasonic Doppler Velocity meter.
X-ray imaging
Colorless Flame.
Colorless Flame.
Colorless Flame.
Halogen lamp, filter and potentio meter.
Chromatography
Sterile movement.

Muscle.
Vasodilatation.
8. 8
Impedance

A.c.magnetic fields

Velocity profile

140 mm Hg and 60 mm Hg

Mixing water with
0.01 seconds

Conductivity
Transit time
5 MHz
300hz
Angiograms
Ultrasound Doppler shift method
Blood delivered by heart to pulmonary veins per minutes

72-75 beats/min
30 to 50ml
Squaring
$Q= I – C_V / C_A$

14-15
Impedance method
Total laser capacity
Volume of gas remaining in the lungs at the end of maximal expiration
Volume of gas remaining in the lungs at the end of maximal expiration
Volume of gas remaining in the lungs at the end of maximal expiration
Can be inhaled to the lungs after a normal inspiration

Flemings right hand rule

Blood purification

Blood purification

Blood purification

Packed cell volume

Packed cell volume

Fiber optic sensor

Systolic and diastolic

Time

indirect

Atmospheric

Atmospheric

Liters / min

Photometer

RBC

5

Pneumotachograph

Systolic / diastolic

Systolic / diastolic

Ficks method

opt5

opt6

c

Answer
aortic regurgitation murmur

mitral sterosis murmur

$I_1 / I_0$

Inversely proportional
Remains the same

Flame Photometry
X-ray imaging
Red Flame
Yellow Flame
Violet Flame
Halogen lamp, mirror, prism or diffraction Grating and diode.
Autoanalyser
Peristaltic

Bone
Hypotension
7.4
Electrical conductivity

A.c.magnetic fields

Velocity profile

120 mm Hg and 80 mm Hg

Coagulating
0.2 second

Electromagnetic induction
Transit time
10 MHz
500hz
Angiograms
Angiogram
Stroke volume*heart beat per minute

72-75 beats/min
70 to100ml
Extrapolation
$Q= I / (C_A - C_V )$

6-Apr
Impedance method
Total lung capacity
Inspired with maximal effort after reaching the normal end of inspiratory level
Expired with maximal effort after reaching the normal end of expiratory level
Inspired with maximal effort after reaching the normal end of expiratory level
Can be expelled from the lungs after a maximal inspiration

Boyle's law

$O_2$ and $CO_2$ transportation
Defence mechanism of the body
Blood clotting
Anemia
Polycythemia
Strain gauge or capacitive transducer
Systolic and diastolic

Volume
Non-invasive
Systolic
Diastolic
Liters / min
Ficks method
RBC
7.36
Electromagnetic blood flow meter
Systolic
Systolic / diastolic
Auscultator

Questions

_____ process gives rise to a balance of ions between inside and outside of the cell.

The nerves and muscle cells readily permit the entry of

The nerves and muscle cells doesn't permit

Under equilibrium condition the potential difference across the membrane is

The membrane potential caused by different concentration of ions such as negative ions inside and positive ions outside is called as

The human cell is in resting stage is said to be

The resting potential VR is

The resting potential is maintained as a constant until some _____

When the cell membrane is excited by some external energy, then the cell allow

The cell has a slightly positive potential on inside and negative potential at the outside is called as

The positive potential of the cell membrane during excitation is called as

The range of action potential

The range of resting potential is

As long as the action potential exists, the cell is said to be

The passage of sodium ions is stopped, the cell membrane reserved back to the equilibrium condition is called as

Potential are generated at a cellular level is called as

The discharge and recharging of the cell is termed as
Which of the following bio-potential present in our body
The contraction of the heart muscle is termed as

The relaxation of the heart muscle is termed as
The process of breathing inside is called as
The process of breathing outside is called as
_____are generally used to pick up the electric signals of the body
The bio potential available from the skin is measured using
The bio potential available near (or) within a single cell are measured using
The bio-potential available from specific group of muscles are measured using
The voltage developed at an electrode- electrolyte interface is termed as

The half cell potential is measured with reference to
The half cell potential is measured is expressed by
Ehc =

Micro electrodes are broadly classified into
The micro-electrode is located within the cell, where as the reference electrode is placed
The electrical activity of neuron of superficial layer of the brain is measured using
_____ are used to record the peripheral nerve action potential
_____ are used to measure the pH content and pO2 of blood

The hydrogen electrode can be used to measure the _____ of the body fluid

pH is defined as

pH is less than 7 means

The problems exists at the time of recording bio-potentials are

The chopper amplifier is used to sample

To prevent accidental internal cardiac shock _____ are used

using isolation amplifier the relation between the patient and a.c power line is

The lead system using ECG is

The defibrillator protection circuit consists of

The elevation occur in ST period during ECG measurement which causes

EEG is the study of electrical activity of

The temporal and central points are kept in scalp at _____distance from the pre auricular point

Alpha waves are measured at

beta waves are measured at

Delta waves are measured at _____of the brain

Epilepsy is the symptom of

Conduction velocity is given as V=

Electro myo graph is used for recording the electrical activity of _____

EOG is the recording of the bio-potentials generated by movement of

ERG is the method of recording and interpreting the electrical activity of

The process of recording the change in potential when light falls on the eye is known as

The graphical record of heart sound is known as

_____are generally caused by improper opening the values

Murmur is produced when the blood flows in backward direction through the mitral valve during systole is called as

If the transmitter substance is inhibitory, then the membrane potential of the receptor neuron increases in a negative direction. This induced potential change is called as

The electrical stimuli are detected by sense organs that cause some change in the electrical activity of the brain. This induced potential change is called as

| opt1 | opt2 | opt3 |
| --- | --- | --- |
| ionization | electrolyte | diffusion and drift |
| Calcium | potassium and chloride | sodium ions |
| sodium ions | potassium and chloride | magnesium |
| positive potential inside and negative potential outside | negative potential inside and positive potential outside | positive potential inside and positive potential outside |
| action potential | deep potential | Resting potential |
| repolarised state | depolarised state | unpolarised state |
| –(KT/q)ln{[cl+]i/[cl-]o} | –(KT/q)ln{[K+]i/[K-]o} | –(KT/q)ln{[Na+]i/[Na-]o} |
| disturbances | temperature | noise |
| K | cl- | Na |
| action potential | deep potential | Resting potential |
| action potential | deep potential | Resting potential |
| 20mV | 60mV | 40mV |
| -60mV to -100mV | -60mV to -80mV | -40mV to -50mV |
| repolarised state | depolarised state | unpolarised state |
| repolarised state | depolarised state | unpolarised state |
| electric potential | bio-electric potential | polarised state |

| | | |
|---|---|---|
| polarised state and repolarised | depolarised state and repolarised state | polarised state and depolarised state |
| electric potential diastole | non electric potential isotonic contraction | ECG and EEG systole |
| systole inspiration inspiration | isotonic contraction expiration expiration | isometric contraction isotonic contraction isotonic contraction |
| templates | plates | rods |
| chemical electrode | depth electrode | surface electrode |
| chemical electrode | depth electrode and needle | surface electrode |
| chemical electrode | depth electrode and needle electrode | surface electrode |
| bio-potential | electric potential | half cell potential |
| nitrogen electrode –(RT/nF) ln[ (C1/C2)*(F1/F2)] | oxygen electrode –(RT/nF) ln[ (C2/C1)*(F1/F2)] | co2 electrode –(RT/nF) ln[ (C1/C2)*(F2/F1)] |
| linear and non linear | metallic and non metallic | non linear and non metallic |
| outside cell | inside cell | near cell |
| surface electrode | micro electrode | depth electrode |
| needle electrode | micro electrode | depth electrode |
| needle electrode | chemical electrode | micro electrode |

| | | |
|---|---|---|
| pCO2 | pH | pO2 |
| –log10[H+] | –log10[cl+] | –log10[H-] |
| basic | neutral | acidic |
| amplitude variation | voltage drift | Noise and dc drift |
| analog signal | dc signal | ramp signal |
| differential amplifier | isolation amplifier | instrumentation amplifier |
| 1012Ω | 2012Ω | 1015Ω |
| 10%-20% electrode | Auxiliary lead system | bipolar and unipolar lead system |
| lead selection unit and over voltage protection | power amplifier | buffer amplifier and over voltage protection |
| widening of QRS complex | myocardial infarction | negative T wave |
| lungs | heart | eye |
| 20% to 30% | 30% to 40% | 10% to 20% |
| parietal region | frontal region | occipital region |
| occipital region | central region | parietal and frontal region |
| medulla oblongata | spinal cord | cortex |
| brain damage | head injury | brain tumor |
| ( l1-l2)/(t2-t1) | ( l1-l2)/(t1-t2) | ( t1-tl2)/(l1-l2) |
| nerve | brain | muscles |

| | | |
|---|---|---|
| nerve | muscles | eye |
| nerve | muscles | neurons |
| ERG | EOG | ECG |
| ERG | phono cardio gram | EEG |
| asculation | epilepcy | murmurs |
| aortic regurgitation murmur | mitral sterosis murmur | mitral regurgitation murmur |
| excitatory post synaptic potential | event related potential | inhibitory post synaptic potential |
| excitatory post synaptic potential | inhibitory post synaptic potential | lead potential |

opt4 opt5 opt6

MITCHONDRIA process

bicarbonate

bicarbonate
negative potential
inside and negative
potential outside

rising potential
polarised state

–ln{[K+]i/[K-]o}

during sleeping

Mg

rising potential

rising potential
50mV
-60mV to -90mV

polarised state

polarised state

unpolarised state

unpolarised state

lead potential
isometric contraction

diastole
isometric contraction
isometric contraction

electrodes

micro electrode

micro electrode

micro electrode

non electric potential

hydrogen electrode

ln[ (C1/C2)*(F1/F2)]

micro and macro

adjacent cells

chemical electrode

chemical electrode

depth electrode

pNa
–log10[K+]
ideal

current drift
pulsating signal

chopper amplifier

2015Ω

central lead system

auxiliary amplifier

ventricular fibrillation
brain

15% to 20%
central region

inion region

cerebellum
myo cardinal infraction
( l2-l1)/(t1-t2)

neurons

neurons

eye

EEG
EOG

brain tumor

aortic sterosis murmur

inhibitory synaptic
potential

event related potential

Answer

diffusion and drift

potassium and chloride

sodium ions

negative potential inside and positive potential outside

Resting potential
polarised state

–(KT/q)ln{[K+]i/[K-]o}

disturbances

Na

action potential

action potential
20mV
-60mV to -100mV

depolarised state

repolarised state

bio-electric potential

depolarised state and repolarised state

ECG and EEG
systole

diastole
inspiration
expiration

electrodes

surface electrode

micro electrode

depth electrode and needle electrode

half cell potential

hydrogen electrode

–(RT/nF) ln[ (C1/C2)*(F1/F2)]

metallic and non metallic

outside cell

depth electrode

needle electrode

chemical electrode

pH
–log10[H+]
acidic

Noise and dc drift
analog signal

isolation amplifier

1012Ω

bipolar and unipolar lead system

buffer amplifier and over voltage protection

myocardial infarction
brain

10% to 20%
occipital region

parietal and frontal region

cortex
brain damage
( l1-l2)/(t1-t2)

muscles

eye

eye

ERG
phono cardio gram

murmurs

mitral regurgitation murmur

inhibitory post synaptic potential

event related potential

| Questions | opt1 |
| --- | --- |
| Boyle’s law states that the volume is …… to pressure ata given temp | Square |
| Blood contains | 60% cells ,40% plasma |
| The heart’s natural pacemaker is the | AV node |
| The ……. Of heart acts analogously to an electronic delay time | Mitral valve |
| The minimum energy required to excite the heart muscle is | 100 µJ |
| Pacemaker pulses ranges from …….. pulses/min | 25-155 |
| Weight of a pacemaker approximate | 1000 gm |
| Size of a pacemaker approximates …….cm | 200 |
| When two electrodes are used,one for stimulating heart and other for return path of current to the Pacemaker it is called as | Bipolar |
| when a single electrode used for stimulating heart it is called as | Bipolar |
| The electrodes applied for the external pacemaker are called | Myocardiac |
| The electrodes applied for internal pacemaker can be | semi polar |

| | |
|---|---|
| Internal pacemaker is preferred over external pacemaker for patients having | Temporary heart irregularities |
| External pacemaker are preferred for patients having | Temporary heart irregularities |
| Competitive pacemaker has | Synchronous pacing |
| The internal pacemaker that sets the biological rhythm | is located in the brain |
| Heart rate can be matched according to the patient need in | Ventricular asynchronous pacemaker |
| Ventricular synchronous pacemaker generates its pulses only when | R wave is present |
| Ventricular inhibited pacemaker generates its pulses only | R wave due to natural pacing is present with 1.6mv |
| Relative refractory period is the period in which | The cell does not respond to any stimuli |
| Absolute refractory period is the period in which | The cell does not respond to any stimuli |
| _____is a serious cardiac emergency resulting from asynchronous contraction of heart muscles. | Arrhythmia |

| | |
|---|---|
| The magnitude of shock voltage to stimulate the heart in internal defibrillator is | 50V to 1000V |
| The magnitude of shock voltage to stimulate the heart in external defibrillator is | 50V to 1000V |
| The energy required for excitation of heart muscle in internal defibrillator is | 15 to 50 joules |
| During myocardial infarction one can use | Nerve stimulator |
| In the case of defibrillator, double square pulse is used to | Restart the heart rhythm after the open heart surgery |
| In direct current defibrillator, a pulse with duration of about 5ms is generated by means of | A stable multivibrator |
| In ventricular asynchronous PM, the pacing pulses are generated using | Astable multivibrator |
| To produce ventricular contraction with an electric pulse, the minimum energy required is | 10 µJ |
| Suppose the pacemaker pulse has high energy and occurs during the vulnerable part of T- wave then the heart is in | Normal state |
| The commonest source of energy for pacemaker is the | Mercury battery |

| | |
|---|---|
| Because of risk of electromagnetic interference, pacemaker patients should not be given | Cancer treatment |
| In the case of stable total AV block, a pacemaker is chosen | With constant frequency |
| After the chest operation, the patient has feels difficult to breathe, and then the patient is connected to a | Pacemaker |
| Radio capsule is | An encapsulated radio receiver |
| The …….. System of the heart controls synchronization of the hearts pumping by controlling the distribution of pacemaker impulse | Conduction |
| Pacemaker output energy levels of ……..or more may cause ventricular fibrillation | 20 µJ |
| In an ECG, the QRS complex represents the | Depolarization of atria |
| An ECG would be useful for determining patients | Heart murmur |
| During exercise, there is an increase flow of blood to | The brain |
| . ……fibrillation may cause to death | Atrial |

| | |
|---|---|
| Dual peak defibrillator are applied to | Reduce the current passing to heart |
| The increase in heart rate is called | Bradycardia |
| The decrease in heart rate is called | Bradycardia |
| The purpose of electrical shock to correct arrhythmias is to ……. the heart, so that all cells enter their refractory period together. | Stimulate |
| In biotelemetry, the type of modulation employed is | Amplitude modulation |
| In biotelemetry ……..cannot be employed | Amplitude modulation |
| Radio capsules are | Some kind of treatment to reduce brain activity |
| The ……. fibrillation can cause mild effect to the patient | Atrial |
| Atrial fibrillation cannot be corrected using | AC defibrillator |
| The application of an electrical shock to resynchronize the heart is called | Fibrilator |
| Hearts vulnerable period is | QRS segment |
| In an ECG, the ST segment corresponds to | Depolarization of Atria |
| an ECG, The P segment corresponds to | Depolarization of Atria |

| | |
|---|---|
| In an ECG, The U wave corresponds to | Depolarization of Atria |
| Ventricular Inhibited pacemaker is otherwise called as | Demand pacemaker |
| Av delay is approximately | 0 .0012 sec |
| The contact impedance for external defibrillator is | 100 Ω |
| If the counter shock falls in the T wave ……. Is possible | Atrial fibrillation |

| opt2 | opt3 |
| --- | --- |
| Directly proportional | Inversely proportional |
| 50%plasma , 10% cells, 40%proteins | 60% plasma , 40 % cells |
| Mitral valve | SA node |
| SA node | Tricuspid valve |
| 10 µJ | >400 µJ |
| 10-250 | 72 |
| 2 kg | 100 gm |
| 80 | 2000 |
| Unipolar | Augmented |
| Unipolar | Augmented |
| Unicardiac | Endocardiac |
| Unicardiac | 10-20 lead |

| | |
|---|---|
| Permanent heart irregularities | Minor steno sis |
| Permanent heart irregularities | Minor steno sis |
| Asynchronous pacing | R-wave inhibited |
| is located in SA node of heart | Does not function in the absence of light or other environmental cues |
| Ventricular synchronous pacemaker | Ventricular inhibited pacemaker |
| R wave is absent | P wave is present |
| R wave due to natural pacing is absent | R wave due to natural pacing is of low amp |
| The cell responds to any stimuli | The cell responds to the stimuli with very high energy |
| The cell responds to any stimuli | The cell responds to the stimuli with very high energy |
| Steno sis | Fibrillation |

| | |
|---|---|
| 5V to 500V | 3V to 600V |
| 1000V to 6000V | 3V to 600V |
| 50 to 400 joules | 1000 to 15000 joules |
| Heart lung machine | pacemaker |
| Arrest ventricular fibrillation | Arrest leakage of blood from heart |
| Monstable multivibrator | IC 555 |
| Monstable multivibrator | IC 555 |
| 1 µJ | 10 mv |
| Atrial fibrillation | Ventricular fibrillation |
| The ordinary dry cell | Nuclear battery |

| | |
|---|---|
| Diathermy treatment | Saline water |
| that is atrial synchronous | that is ventricular synchronous |
| Defibrillator | Ventilator |
| A system emitting radio active radiation | An encapsulated biosignal transmitter |
| Excretory | Respiratory |
| 400 µJ | 1000 µJ |
| Depolarization of ventricles | Polarization of atria |
| Stroke volume | Cardiac output |
| The kidneys | The skin |
| Ventricular | AV node |

| | |
|---|---|
| Increase the current passing to heart | Increase the voltage passing to heart |
| Tachycardia | Hypotension |
| Tachycardia | Hypotension |
| Sense | Steno sis |
| Frequency modulation | Pulse modulation |
| Frequency modulation | Pulse modulation |
| Drugs to reduce ventricular fibrillation | Biotelemetry transmitter |
| Ventricular | SA node |
| DC defibrillator | Square wave circuit |
| Steno sis | Counter shock |
| P segment | In the middle of T segment |
| Depolarization of ventricles | Polarization of atria |
| Depolarization of ventricles | Polarization of atria |

| | |
|---|---|
| Depolarization of ventricles | Polarization of atria |
| Standby pacemaker | Asynchronous pacemaker |
| 1.2sec | 0.12 sec |
| 1000 Ω | 10k Ω |
| Ventricular fibrillation | Steno sis |

| opt4 | opt5 |
| --- | --- |
| Half | |
| 10%plasma,20%proteins , 70% cells | |
| Tricuspid valve | |
| AV node | |
| <100 µJ | |
| 1000 | |
| 5 gm | |
| 5 | |
| 10-20 lead system | |
| 10-20 lead system | |
| Semi cardiac | |
| Myocardiac or endocardiac | |

Heart arrhythmias

Heart arrhythmias

None of the above

is located in the lungs

Standby pacemaker

ST segment is present

ST segment is present

The cell responds to low amp stimulus

The cell respond to low amp stimulus

Defibrillation

500V to 10000V

5V to 100V

2000 to 3000 joules

kidney machine

Arrest the reverse flow of
blood from ventricle to atrium

Capacitor discharge

Capacitor discharge

1W

Low pressure

Solar cell

The room with fans

With variable frequency and synchronization with ventricular action

Heart lung machine

A medicine for treatment of cancer

Digestive

50 µJ

Repolarisation of ventricles

Blockage of conduction of electrical signals between the atria and ventricles

Liver

SA node

Reduce the energy delivered to the heart

Hypertension

Hypertension

Fibrillate

Phase modulation

Phase modulation

Used for animals to cure tumors

AV node

Biphasic defibrillator

Arrhythmia

PQ segment

Repolarization of ventricles

Repolarization of ventricles

Repolarization of ventricular fibers

Fixed rate pacemaker

0.12msec

50 Ω

Arrhythmia

opt6

Answer

Inversely proportional

60% plasma , 40 % cells

SA node

AV node

10 μJ

72

100 gm

80

Bipolar

Unipolar

Endocardiac

Myocardiac or endocardiac

Permanent heart irregularities

Temporary heart irregularities

Asynchronous pacing

is located in the lungs

Ventricular inhibited pacemaker

R wave is present

R wave due to natural pacing is absent

The cell responds to the stimuli with very high energy

The cell does not respond to any stimuli

Fibrillation

50V to 1000V

1000V to 6000V

15 to 50 joules

pacemaker

Restart the heart rhythm after the open heart surgery

Capacitor discharge

Monstable multivibrator

10 µJ

Ventricular fibrillation

Mercury battery

Diathermy treatment

With constant frequency

Ventilator

An encapsulated biosignal transmitter

Conduction

400 μJ

Depolarization of ventricles

Blockage of conduction of electrical signals between the atria and ventricles

The skin

Ventricular

Reduce the current passing to heart

Tachycardia
Bradycardia

Stimulate

Frequency modulation

Amplitude modulation

Biotelemetry transmitter

Atrial

AC defibrillator

Counter shock

In the middle of T segment

Repolarization of ventricles

Depolarization of Atria

Repolarization of ventricular fibers

Demand pacemaker

0.12 sec

100 Ω

Ventricular fibrillation

| Questions | opt1 |
| --- | --- |
| Dual peak D.C. defibrillator is used to …… supplied to the patient | Maintain the current |
| Where does the refractory period lies in the ECG waveform | T wave |
| During Myocardial Infraction, one can use | Pacemaker |
| Justify the following statement. “Heart Lung Machine” can be used for a longer time for a patient. | Yes |
| Inflammation of the kidney is called | otitis |
| In the case of defibrillator, a double square pulse type is used to | Restart the heart rhythm after the open heart surgery |
| In direct current defibrillator, a pulse with a duration of about 5ms is generated by means of a | Astable multivibrator |
| To produce ventricular contraction with an electric pulse, the minimum energy required is | 10µJ |

| | |
|---|---|
| Suppose the Pacemaker pulse has high energy and occurs during the vulnerable part of the T wave then the heart is in | Normal state |
| The commonest source of energy for pacemaker is the | Mercury battery |
| Because of the risk of electromagnetic interference, pacemaker patients should not be given | Cancer treatment |
| In the case of stable total AV block, a pacemaker is choosen | With constant frequency |
| After the chest operation, the patient feels difficult to breath. Then the patient is connected to a | Pacemaker |
| The apparatus used for extra corporeal circulation of blood is called | Heart lung machine |
| During open heart surgery, the operation time can be increased by | Giving more anesthesia |
| Most blood pumps use the principle of | Peristaltic compression |

| | |
|---|---|
| To reduce hemolysis, the blood pump design should provide a flow that minimises | Oxygen tension |
| Radio capsule is | an encapsulated radio receiver |
| In Biotelemetry, FDM refers to | Frequency Division Modulation |
| The radio capsules are | Some kind of treatment to reduce brain activity |
| The obstruction of blood flow is known as | Cyanosis |
| Too low blood pressure is known as | Hypertension |
| The mass defect for an isotope was found to be 0.410 amu/atom. Calculate the binding energy in kJ/mol of atoms. (1 J = 1 kg m2/s2) | 3.69 x 1010 kJ/mol |

| | |
|---|---|
| Calculate the binding energy per nucleon (in units of MeV) for 9Be, for which the atomic mass is 9.01219 amu. Particle masses in amu are: proton = 1.007277; neutron = 1.008665; electron = 0.0005486. Conversion factor for E = mc2 is 931 MeV/amu | 6.46 MeV |
| Which isotope below has the highest nuclear binding energy per gram? No calculation is necessary. | 4He |
| Which of the following statements is incorrect? | Mass defect is the amount of matter that would be converted into energy if a nucleus were formed from initially separated protons and neutrons. |
| A positron has a mass number of _____, a charge of _____, and a mass equal to that of a(an) _____. | 0, 1+, proton |

| | |
|---|---|
| Emission of which one of the following leaves both atomic number and mass number unchanged? | positron |
| Which type of radiation is the least penetrating? | alpha |
| A radioisotope of argon, 35Ar, lies below the "band of stability: (n/p ratio too low). One would predict that it decays via _____. | neutron emission |
| A Geiger-Muller tube is a _____ | gas ionization detector |
| The half life of 231Pa is 3.25 x 104 years. How much of an initial 10.40 microgram sample remains after 3.25 x 105 years? | 0.0102 micrograms |
| Consider the case of a radioactive element X which decays by electron (beta) emission with a half-life of 4 days to a stable nuclide of element Z. Which of the following statements is CORRECT? | After 8 days the sample will consist of one-fourth element Z and three-fourths element X. |

| | |
|---|---|
| How old is a bottle of wine if the tritium (3H) content (called activity) is 25% that of a new wine? The half-life of tritium is 12.5 years. | 1/4 yr |
| A Geiger counter registered 1000 counts/second from a sample that contained a radioactive isotope of polonium. After 5.0 minutes, the counter registered 281 counts/second. What is the half-life of this isotope in seconds? | 87 |
| The 14C activity of some ancient Peruvian corn was found to be 10 disintegrations per minute per gram of C. If present-day plant life shows 15 dpm/g, how old is the Peruvian corn? The half-life of 14C is 5730 years. | 1455 years |
| Which of the following describes what occurs in the fission process? | A heavy nucleus is fragmented into lighter ones. |

| | |
|---|---|
| Which of the following statements about nuclear fission is always correct? | Very little energy is released in fission processes. |
| Which one of the following would be most likely to undergo thermonuclear fusion? | 2H |
| Which one of the following statements about nuclear reactions is false? | Particles within the nucleus are involved |
| Complete ha particle 239Pu + alp22._____ + neutron and balance the following equation. The missing term is _____ . | 2 115Ag |
| When 59Cu undergoes positron emission, what is the immediate nuclear product? | 59Ni |
| As a result of the process of electron capture ("K-capture") by 211At, the new isotope formed is: | 210At |
| When 235U is bombarded with one neutron, fission occurs and the products are three neutrons, 94Kr, and _____ | 139Ba |

| | |
|---|---|
| In general, the body cells most susceptible to damage by radiation are those found in: | rigid or semi rigid tissues |
| In a picocurie of any radioactive substance, the disintegration rate is: | 2.22 dpm |
| Which of the following radionuclides cannot be detected by gamma spectrometry pulse height analysis? | Hydrogen-3 |
| The elemental symbols for Boron, Beryllium, Cadmium, and Calcium are: | Bo, B, Ca, C |
| Which of the following radionuclides is most suited to in-vivo measurements? | Hydrogen-3 |
| How long must a sample with a count rate of 300 cpm be counted to give a total count rate standard deviation of 1%? | 3.5 min |
| At what radius would you post a radiation area around an 8 curie Cesium 137 (662 Kev photon energy and a photon yield of 0.85 photons/disintegration) point source? | 10 feet |

| | |
|---|---|
| An air filter with a collection efficiency of 99.97% is being used in a decontamination effort. Calculate the decontamination factor for this filter. | 9997 |
| During an emergency in a DOE regulated facility, with known or potential high radiation fields, exposure to personnel must be voluntary if it is anticipated that such exposure may exceed a whole body exposure of: | 5 rem |

| | |
|---|---|
| A worker is to perform maintenance on a Reactor Coolant pump under the following radiological conditions; Dose rate on contact with the pump - 350 mrem/hr, Dose rate at 30 cm from the pump (working area dose rate) is 85 mrem/hr, and an airborne concentration of .45 DAC. She will spend a maximum of 14 hours in this area during the week. According to 10CFR20, how is this area to be posted? | Danger High Radiation Area,<br>Airborne Radioactivity Area |
| For an exclusive use vehicle that is transporting radioactive materials, radiation levels oncontact with any external surface of the vehicle must not exceed: | 0.01 mSv/hour |
| Two categories of ionization are: | alpha and beta |
| Intrinsic efficiency of a detector expresses the: | probability that a count will be recorded if radiation enters the sensitive volume. |

| | |
|---|---|
| The antiparticle of a positron is a: | proton |
| Forms of the same chemical element that contain different numbers of neutrons are called: | isobars |
| An atom of a radionuclide that has a low neutron to proton ratio, and an atomic rest mass energy that is 1.02 Mev greater than the product atom's rest mass energy may decay by which of the following? | Either positron emission or electron capture |

| opt2 | opt3 |
| --- | --- |
| Double the current | Multiply the current |
| RS segment | QR segment |
| Heart lung Machine | Nerve stimulator |
| No | It depends upon the condition of the patient |
| hepatitis | rephritis |
| Arrest ventricular fibrillation | Arrest leakage of blood from the heart |
| Monostable multivibrator | Clock IC 555 |
| 1J | 10mW |

| | |
|---|---|
| Atrial fibrillation | Ventricular fibrillation |
| The ordinary dry cell | Nuclear battery |
| Diathermy treatment | Saline water |
| That is atrial synchronous | That is ventricular synchronous |
| Defibrillator | Ventilator |
| Ventilator | Dialyser |
| Connecting a pacemaker | Connecting a ventilator |
| Centrifuge | Compression |

| | |
|---|---|
| Turbulence | Body temperature |
| a system emitting radio active radiations | an encapsulated bio signal transmitter |
| Fourier Domain Modulation | Frequency Division Multiplexing |
| Drugs to reduce ventricular fibrillation | Biotelemetry transmitter |
| Edema | Hyperemia |
| Hypothalamus | Hypotension |
| 1.23 x 1020 kJ/mol | 3.69 x 1013 kJ/mol |

| | |
|---|---|
| 6.33 MeV | 6.23 MeV |
| 16O | 32S |
| Nuclear binding energy is the energy released in the formation of an atom from subatomic particles. | Nuclei with highest binding energies are the most stable nuclei |
| 1, 2+, proton | 0, 1+, electron |

| | |
|---|---|
| neutron | alpha particle |
| beta | gamma |
| beta emission | positron emission |
| cloud chamber | fluorescence detector |
| 0.240 micrograms | 2.18 micrograms |
| Element Z will weigh exactly the same as element X when decay is complete (weighed to an infinite number of significant figures). | .0 g of element X is required to produce 1.5 g of element Z after 8 days (to 2 significant figures). |

| | |
|---|---|
| 3.1 yr | 25 yr |
| 110 | 164 |
| 1910 years | 3350 years |
| A neutron is split into a neutron and proton | Two light nuclei are combined into a heavier one |

| | |
|---|---|
| Nuclear fission is an energetically favorable process for heavy atoms. | Due to its instability, 56Fe readily undergoes fission. |
| 4He | 56Fe |
| No new elements can be produced. | Rate of reaction is independent of the presence of a catalyst. |
| 2 106Rh | 235U |
| 58Ni | 58Cu |
| 212At | 211Po |
| 141Ba | 139Ce |

| | |
|---|---|
| muscle tissues | rapidly dividing tissues |
| 2.22 x 10 E 6 dpm | 37,000,000 dpm |
| Iodine-131 | Cerium-144 |
| B, By, Cd, Ca | Bo, Be, Cd, Ca |
| Carbon-14 | Strontium-90 |
| 17 min | 30 min |
| 74 feet | 145 feet |

| | |
|---|---|
| 0.9997 | 3000 |
| 10 rem | 25 rem |

| | |
|---|---|
| Caution Radiation Area, Airborne Radioactivity Area | Caution High Radiation Area, Airborne Radioactivity Area |
| 0.02 mSv/hour | 0.1 mSv/hour |
| direct and indirect | microwave and infrared |
| ability of an instrument to count different energies. | percent of gamma energy producing ion pairs. |

| | |
|---|---|
| neutrino | electron |
| isomers | radionuclides |
| Annihilation | Beta minus emission |

| opt4 | opt5 | opt6 |
| --- | --- | --- |
| Reduce the current | | |
| P wave | | |
| Kidney Machine | | |
| When there is no power failure, the statement is true | | |
| Toxemia | | |
| Arrest the reverse flow of blood from ventricle to atrium | | |
| Capacitor discharge | | |
| 1W | | |

Low pressure

Solar cell

The rooms with fans

With variable frequency and synchronization with ventricular action

Heart lung machine

Pacemaker

Inducing hypothermia

Normal acceleration

Continuous flow

a medicine for
treatment of cancer

Fesimle Distance
Modulation

Used for animals to
cure tumors

Stasis

vasodilation

1.23 x 103
kJ/mol

11.39 MeV

55Mn

Mass number is
the sum of all
protons and
electrons in an atom

1, 2+, electron

gamma radiation

x-ray

alpha emission

spectrophoto
meter

0.0240
micrograms

If element X as an
atomic number
equal to n, then
element X has an
atomic number
equal to n-1.

37.5 yr

264

3820 years

A proton is split into
three quarks

In fission reactions, a neutron is split into a proton and an electron.

141Ba

Rate of reaction is independent of temperature.

242Cm

59Zn

211Rn

139Xe

highly specialized
tissues

3.7 x 10 E 4 dps

Ruthenium-106

B, Be, Cd, Ca

Iodine-131

33 min

53 feet

3333

75 rem

Caution Radiation
Area

2.0 mSv/hour

charged and
uncharged

total detector
counts minus the
background.

meson

isotopes

Isomeric
transition

Answer

Reduce the current

RS segment

Pacemaker

No

rephritis

Restart the heart rhythm after the open heart surgery

Capacitor discharge

10μJ

Ventricular fibrillation

Mercury battery

Diathermy treatment

With constant frequency

Ventilator

Heart lung machine

Inducing hypothermia

Peristaltic compression

Turbulence

an encapsulated bio signal transmitter

Frequency Division Multiplexing

Biotelemetry transmitter

Stasis

Hypotension

3.69 x 1010
kJ/mol

6.46 MeV

55Mn

Mass number is
the sum of all protons and electrons in an atom

0, 1+, electron

gamma
radiation

alpha

positron
emission

gas ionization
detector

0.0102
micrograms

.0 g of element X is required to produce 1.5 g of element Z after 8 days (to 2 significant figures).

25 yr

164

3350 years

A heavy nucleus is fragmented into lighter ones.

Nuclear fission is
an energetically favorable process for heavy atoms.

2H

No new elements
can be produced.

242Cm

59Ni

211Po

139Ba

rapidly dividing tissues

2.22 dpm

Hydrogen-3

B, Be, Cd, Ca

Iodine-131

33 min

74 feet

3333

5 rem

Caution Radiation
Area

2.0 mSv/hour

direct and
indirect

probability that a count will be recorded if
radiation enters the sensitive volume.

electron

isotopes

Either positron
emission or electron capture

Questions

Which radioactive decay series includes Ra-226 as one of its decay products?

An individual who receives an acute, whole body (DDE) radiation exposure of approximately 8Gy will likely suffer symptoms of up to which level of the Acute Radiation Syndrome?

The term “isokinetic sampling” refers to the procedure of using sampling velocity that is exactly equal to the:

In which of the following radioactive decays will the daughter product be an isobar of the parent?

The respiratory protection device of choice for entry into an atmosphere immediately dangerous to life and health is a (an):

The average distance of travel in a medium between interactions, describes a photon’s:

The Bragg-Gray principal is based upon the relationship of:

Given a gamma-energy value of 0.662 Mev,and a photon yield of 0.85 per decay, the exposure rate at 2 yards from an unshielded 10 mCi Cs-137 point source is:

A radionuclide has a decay constant of 0.1314
years, a gamma energy (per disintigration) of 2.50 Mev, and will produce a dose rate of approximately 30 R/hour at one foot from a 2 Curie source. Calculate the radiological half life of this nuclide:

With reference to the interaction of electrons
(cathode) with atoms of the anode, what percentage of typically heat occurs?

Stationary X-ray tubes are utilised mainly in:

The inner envelope of an X-ray tube is usually made from

Which of the following is NOT a requirement for an X-ray tube filament material?

Typical anode angles in general diagnostic X-ray tubes (excluding mammography) tend to be between

The following material is added to the anode disc of a rotating X-ray tube to prevent the crazing effect

Modern anode discs, which contain more than one material in their construction may be referred to as a

The expansion bellows performs the following task

The added filtration of a diagnostic X-ray tube typically consists of

The filtration of an X-ray beam has the effect of

Regarding subject contrast in radiography, which of the following are correct?

concerning radiographic contrast

Which of the following are correct for positive-contrast media?

The relationship between radiation and some biologic response is in:

The ADE method of calculating considers the differences in radiation damage by using a modifying or

The radiation equivalent man is equal to?

X-ray heat is generated by:

A penetrameter is used to indicate:

A graph which expresses the relationship between material thickness, KV, and Time specific to film, machine, FFD, processing conditions, and the resulting photographic density is called:

If a piece of lead 1/2-inch this is placed in the path of a beam of radiation emanating from cobalt-60, it will reduce the dose rate at a given location by:

To produce X rays, electrons are accelerated to a high velocity by an electrical field and then suddenly stopped by a collision with a solid body. This body is called:

The difference between the densities of two areas of a radiograph is called:

The cause for poor image definition could be considered:

Excessive exposure of film to light prior to development of the film will most likely result in:

Three liquids which are essential to process an exposed film properly are:

During manual film processing, the purpose of the stop bath is to:

The three main steps in processing a radiograph are:

The duration of an exposure is usually controlled by:

An advantage of the pocket dosimeter type of ionization chamber used to monitor radiation received by personnel is:

In order to decrease geometric unsharpness:

The density of a radiograph image refers to:

A section with a significant increase in thickness variation is required to be shown on a single radiograph within a desired film density range. This may be accomplished by:

The primary parts of an atom are:

As a check on the adequacy of the radiographic technique, it is customary to place a standard test piece on the source side of the specimen. This standard test piece is called a:

In order to increase the intensity of X-radiation:

What is sometimes used to change the alternating current from the high voltage transformer to direct current for the purpose of increasing the X-ray machine output:

A curie is the equivalent of:

The most widely used unit of measurement for measuring the rate at which the output of a gamma-ray source decays is the:

A thin metallic sheet (brass, copper, aluminum,etc) placed at the source to reduce effects of softer radiation is known as:

By using a___ transformer, the incoming voltage can be adjusted in order to heat the filament of an x-ray tube; is about ____volts

Which of the following are the process by which x-ray are produced?

Which meter registers indicating x-ray exposure?

Which of the following applies to the filament transformer?

The purpose of the circuit breaker is to

The film for and SSD treatment on a linear accelerator is taken at 133 cm. What is the magnification factor?

A patient is simulated to receive a treatment to cover a tumor volume plus 1 cm on each side. The tumor is 3.5 cm wide and the depth of 4 cm. What will be the necessary field width at the skin surface, using a linear accelerator with the isocentric setup?

What is the field size on a film if the collimator setting is 7X19 CM, and the magnification factor is 1.33X?

What types of diagnostic exams expose patients to ionizing radiation?

A chest X-ray and a CT scan of the chest use similar amounts of radiation while obtaining their images.

In the next few decades, what percentage of cancers will be directly linked to the use of CT scans?

Over the past decade, what percent has CT scan usage increased?

| opt1 | opt2 |
| --- | --- |
| Thorium | Uranium |
| Subclinical | Hemopoietic |
| velocity of the gas stream at the point of sampling | velocity at the center of the main gas stream corrected for temperature and pressure |
| alpha decay | gamma decay |
| supplied air hood | air-purifying respirator equipped with a high efficiency filter |
| mass energy absorption coefficient | mean free path |
| secondary charged particle equilibrium requirements and the thickness of the wall material of the chamber. | ionization in an air-filled ionization chamber to the dose in air |

| | |
|---|---|
| 1.10 R/hour | 0.55 R/hour |
| 5.27 years | 229 years |
| 1 percent | 10 percent |
| Fluoroscopy rooms | General X-ray rooms |
| Perspex | Lead |
| High work function | Ductile |
| 4 - 6 degrees | 15 – 17 degrees |

| Molybdenum | Carbon |
| --- | --- |
| bi-anode | double anode |
| Provides additional X-ray production | Permits greater heat capacity of the anode surface |
| aluminium or copper | aluminium or beryllium |
| improving the quality of the transmitted X-ray beam | improving the quantity of the transmitted X-ray beam |
| It depends on the thickness of the structure being imaged | It depends on the linear attenuation coefficients of the structures being imaged It increases with the tube kV |
| Attenuation of the X-ray beam depends upon the degree of Bremsstrahlung in the tissue | Most structures on a chest radiograph exhibit good radiographic contrast |

| | |
|---|---|
| They should ideally have an absorption edge just to the left of the major part of the beam spectrum | Barium has a K-absorption edge of approximately 23 keV |
| Non Linear, non threshold relationship | Linear, threshold relationship |
| QF | AD |
| REM | RAD |
| The current passing through the filament (cathode) | The distance from the cathode to the anode |
| The size of the discontinuities in a part | The density of the film |
| A bar chart | An exposure chart |
| One-third | One-quarter |

| | |
|---|---|
| Cathode | Filament |
| Radiographic contrast | Subject contrast |
| Too short source-to-film distance | Screens and film not in close contact |
| A foggy film | Poor definition |
| Stop batch, acetic acid, and water | Developer, stop bath, and H2O2 |
| Change the exposed silver salts to black metallic silver | Neutralize the developer and stop the developing process |
| Developing, frilling, and fixation | Developing, fixation, and washing. |
| . Controlling the milliamperage | A timer |
| It provides a permanent record of accumulated dosage | It provides an immediate indication of dosage |

| | |
|---|---|
| Radiation should proceed from as small a focal spot as other considerations will allow | Radiation should proceed from as large a focal spot as other considerations will allow. |
| The thickness of the film | The thickness of the specimen |
| Increasing kilo voltage | Using a coarse grain film |
| . Proton, neutrino, electron | Proton, electron, gamma ray |
| Reference plate | Lead screen |
| The tube current should be increased | The tube current should be decreased |
| Rectifier | Cathode X-ray tubes |
| 0.001 milli curies | 1.000 milli curies |

| | |
|---|---|
| Curie | Roentgen |
| An intensifying screen | A filter |
| Step up, 1000 to 3000 volts | Step up, 500 to 1000 volts |
| Brims | Photoelectric |
| Voltmeter | Line Voltage compensator |
| A step up transformer is needed | A step down transformer is needed |
| Prevent electrical shock to the patient | Decrease exposure to the patient |
| 1.33 cm | 1.53 cm |

| | |
|---|---|
| 5.28 CM | 6.31 CM |
| 8x15 cm | 10x10 cm |
| Computed Tomography | Ultra Sound |
| True | False |
| 10% | 2% |
| 74% | 120% |

| opt3 | opt4 |
| --- | --- |
| Actinium | Neptunium |
| Gastrointestinal | Central Nervous System |
| velocity at the center of the main gas stream | velocity of the gas stream adjacent to the duct wall |
| neutron decay (elastic scatter) | positron decay |
| air-purifying respirator, full face piece, equipped with organic vapor canister | self-contained breathing apparatus equipped with a pressure demand regulator |
| linear attenuation coefficient | Compton cross section |
| ionization of the gas in an ionization chamber to the dose in the wall material | ionization in a gas-filled ionization chamber to the dose in the gas |

| | |
|---|---|
| 5.50 R/hour | 0.94 mR/hour |
| 3.93 years | 30.1 years |
| 0.1 percent | 99 percent |
| Computerised Tomography | Intra-oral X-ray units |
| Borosilicate glass | Aluminium |
| High melting point | High atomic number |
| 20 – 25 degrees | 25 – 28 degrees |

| | |
|---|---|
| Rhenium | Copper |
| Compound anode | Rare earth anode |
| Acts as a safety device within the X-ray tube | Aids in the exposure timing |
| Copper or tin | Tin or lead |
| Reducing the quantity and decreasing quality of the transmitted X-ray beam | Improving the quality and increasing quantity of the transmitted X-ray beam |
| Contrast between low-atomic-number structures (e.g. fat and muscle) is strongly affected by changes in the tube kV | Contrast between air and soft tissue is due to differences in their atomic numbers |
| In principle, contrast media have the same effect on demonstrating contrast between tissues as increasing the peak kV (kVp) | Positive-contrast media should generally have high atomic numbers to maximize the degree of photoelectric absorption |

| | |
|---|---|
| Iodine has a lower atomic number than barium | Iodine most effectively attenuates photons with energies close to 37 keV |
| Linear, non threshold relationship | Non Linear, threshold relationship |
| AF | MA |
| R | C/kg |
| The type of material used in the target | The voltage and waveform applied to-the X-ray tube |
| The amount of the film contrast | The quality of the radiographic technique |
| The characteristic curve | |
| One-half | Three-quarters |

| | |
|---|---|
| Target | Generator |
| Film contrast | Definition |
| Film graininess | All of the above |
| Streaks | Yellow stain |
| Developer,<br>fixer, and water | Acetic acid,<br>fixer, and stop bath |
| Eliminate most<br>water spot and streaks | Note of the<br>above |
| Exposure,<br>developing, and fixation | Developing,<br>reticulating, and fixation |
| Controlling the<br>source-to-film distance | A choke coil in<br>the filament transformer |
| It is the most<br>sensitive detector available | All of the above<br>are advantages |

The film should
be as far as possible from the
object being radiographed

The distance
from the anode to the
material examined should
be as small as is practical.

The weight of
the film

The degree of
film blackening

Both A and B
are correct

Neither A nor
B is correct

Photon, electron,
neutron

Proton, electron,
neutron

Pentameters

Illuminator

The test specimen
should be moved further from
the film.

A lower kilo
voltage should be applied to
the tube

Gas X-ray
tube

Vacuum X-ray
tube

1.000 mega
curies

100 mega
curies

| | |
|---|---|
| Half-life | MeV |
| An electron inducer | A focusing cup |
| Step down, 100 to 200 volts | Step down, 10 to 12 volts |
| Characteristic | A & B are correct |
| Milliamp meter | Dead man switch |
| An auto-transformer is needed | Must have at least four diodes |
| Reduce secondary radiation | Prevent overloading |
| 1.85 cm | 1.75 cm |

4.45 CM

6.67 CM

9x25 cm

11x25 cm

Magnetic Resonace Imaging

All of the above

5%

0%

50%

300%

opt5

opt6

Answer

Uranium

Gastrointestinal

velocity of the gas
stream at the point of sampling

positron decay

self-contained
breathing apparatus equipped with a
pressure demand regulator

mean free path

ionization of the
gas in an ionization chamber to the dose in
the wall material

0.94 mR/hour

5.27 years

99 percent

Intra-oral
X-ray units

Borosilicate
glass

High work
function

15 – 17
degrees

Rhenium

Compound
anode

Acts as a safety
device within the X-ray tube

aluminium or
copper

improving the
quality of the transmitted
X-ray beam

It depends on the thickness of the
structure being imaged

Positive-contrast media should generally
have high atomic numbers
to maximize the degree of photoelectric
absorption

They should
ideally have an absorption edge just to the
left of the major part of the beam spectrum

Non Linear,
non threshold relationship

QF

REM

The current passing
through the filament (cathode)

The quality of the
radiographic technique

An exposure chart

C. One-half

Target

Radiographic
contrast

D. All of the above

A foggy film

Developer,
stop bath, and H2O2

Neutralize the
developer and stop the developing process

Developing,
fixation, and washing.

A timer

It provides an
immediate indication of dosage

Radiation should
proceed from as small a focal spot as other
considerations will allow

The degree of film
blackening

Increasing kilo
voltage

Proton, electron,
neutron

Pentameters

The tube current
should be increased

Rectifier

1.000 milli curies

Curie

A filter

Step down, 10 to
12 volts

A & B are correct

Milliamp meter

A step down
transformer is needed
Prevent
overloading

1.33 cm

A. 5.28 CM

10x10 cm

Computed
Tomography

True

2%

300%

# UNIT 1

# ORIGIN OF BIOPOTENTIALS

# Historical Background

- In 1786, Luigi Galvani found electricity in the muscle of a frog's leg.
- In 19$^{th}$ century other scientists found same effect in animals and man.
- 1903, William Einthoven introduced the string galvanometer, and measured these potentials.

# Biopotential

Definition:

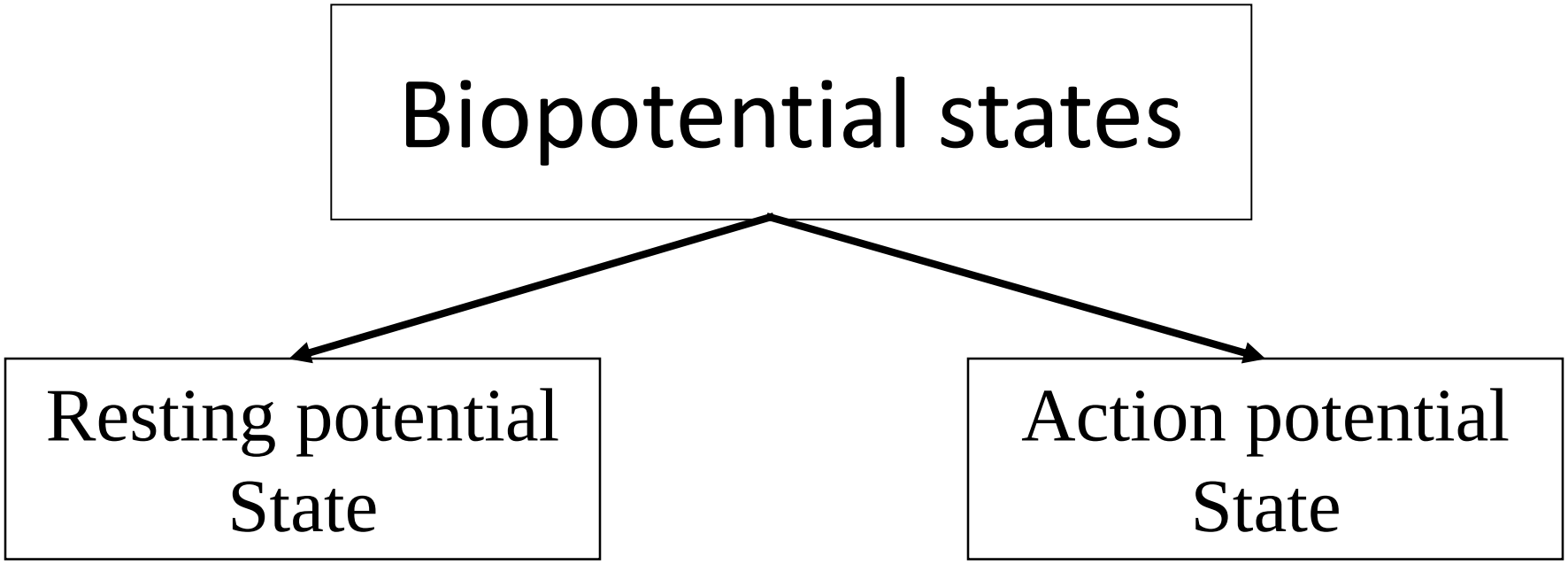
- Ionic voltages produced as a result of the electrochemical activity of *excitable cells.*

Measurement:

- Using transducers to convert ionic potentials into electrical potentials

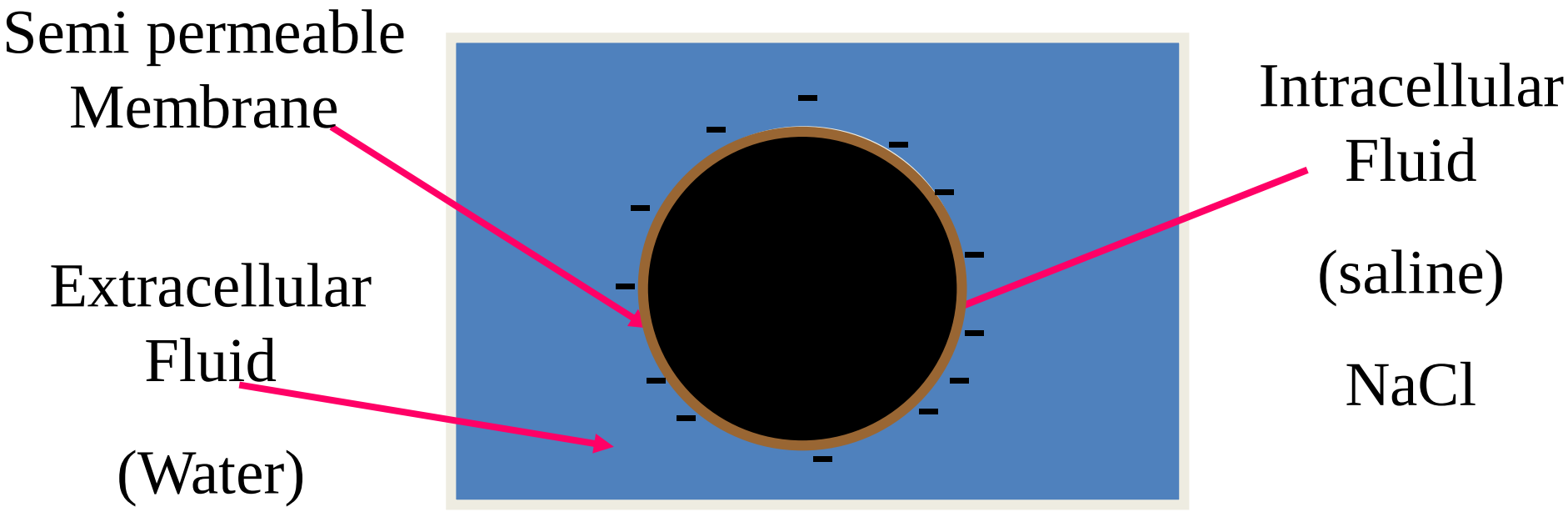
# Excitable Cells

- Are components of nervous, muscular or glandular tissue
- Can produce bioelectric potentials as a result of electrochemical activity.


Biopotential states
Resting potential State
Action potential State

# Origin of Biopotential

- Diffusion Gradient
- Electrostatic force of repulsion



# Living cell properties

- Intra- and Extracellular fluids : Na+, Cl-, K+
- Membrane keeps high $K_i$+ , Low $Na_i$+ and Low $Cl_i$-
- Membrane  7- 15  nm thick lipoprotein
- Membrane impermeable to intracellular protein
- Membrane is moderately permeable to Na+ and freely permeable to K+ and Cl-

# Resting Potential Equation

$$E_{Na} = \frac{RT}{F} \ln \left\{ \frac{Na_O}{Na_I} \right\} \quad = + 60 \text{ mv}$$

$$E_{K} = \frac{RT}{F} \ln \left\{ \frac{K_O}{K_I} \right\} \quad = -85 \text{ mv}$$

$$E_{Cl} = \frac{RT}{F} \ln \left\{ \frac{Cl_I}{Cl_O} \right\} \quad = -66 \text{ mv}$$

- **R**: Universal Gas Constant
- **F**: Faraday Constant
- **T** : Absolute Temp in degree Kelvin
- **P** : Permeability
- $\mathbf{K_o}$, $\mathbf{Na_o}$, $\mathbf{Cl_o}$ : ion concentration outside cell
- $\mathbf{K_i}$, $\mathbf{Na_i}$, $\mathbf{Cl_i}$ : ion concentration inside cell

# Resting Potential Equation

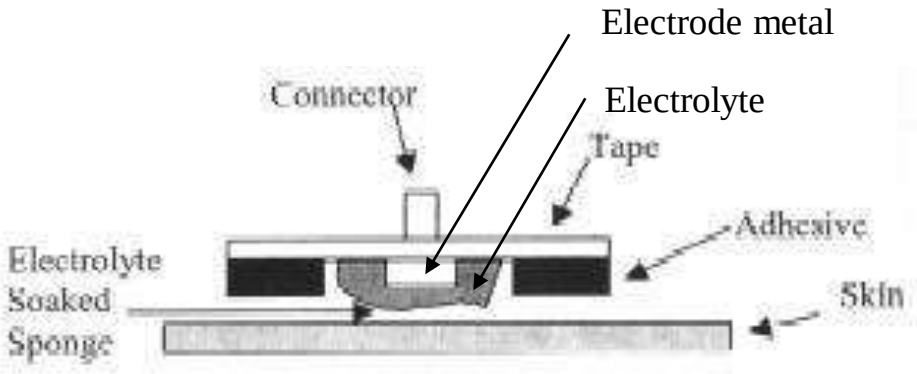
$$E = \frac{RT}{F} \ln \left\{ \frac{P_k\ K_O + P_{Na}\ Na_O + P_{Cl}\ Cl_I}{P_k\ K_I + P_{Na}\ Na_I + P_{Cl}\ Cl_O} \right\}$$

# Notes

- $N_{atoms}$= total charge / electron charge  (electrolysis)
- $N_{moles}$ = $N_{atoms}$ / Avogadros Number
- Weight (in gram) = Molecular Weight * $N_{moles}$
- Avogadro's Number = $6.03 * 10^{23}$  atoms/mole

# BIO-POTENTIAL ELECTRODES

# Body Surface Recording Electrodes

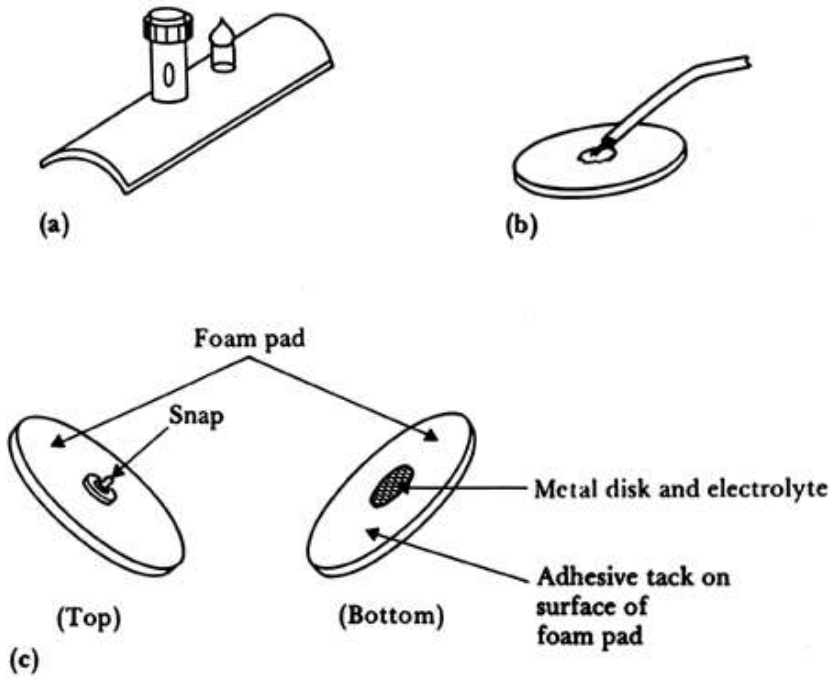



1. Metal Plate Electrodes
2. Suction Electrodes
3. Floating Electrodes
4. Flexible Electrodes

# Commonly Used Biopotential Electrodes

**Metal plate electrodes**

- Large surface: Ancient, therefore still used, ECG
- Metal disk with stainless steel; platinum or gold coated
- EMG, EEG
- smaller diameters
- motion artifacts
- Disposable foam-pad: Cheap!




(a) Metal-plate electrode used for application to limbs.
(b) Metal-disk electrode applied with surgical tape.
(c)Disposable foam-pad electrodes, often used with ECG

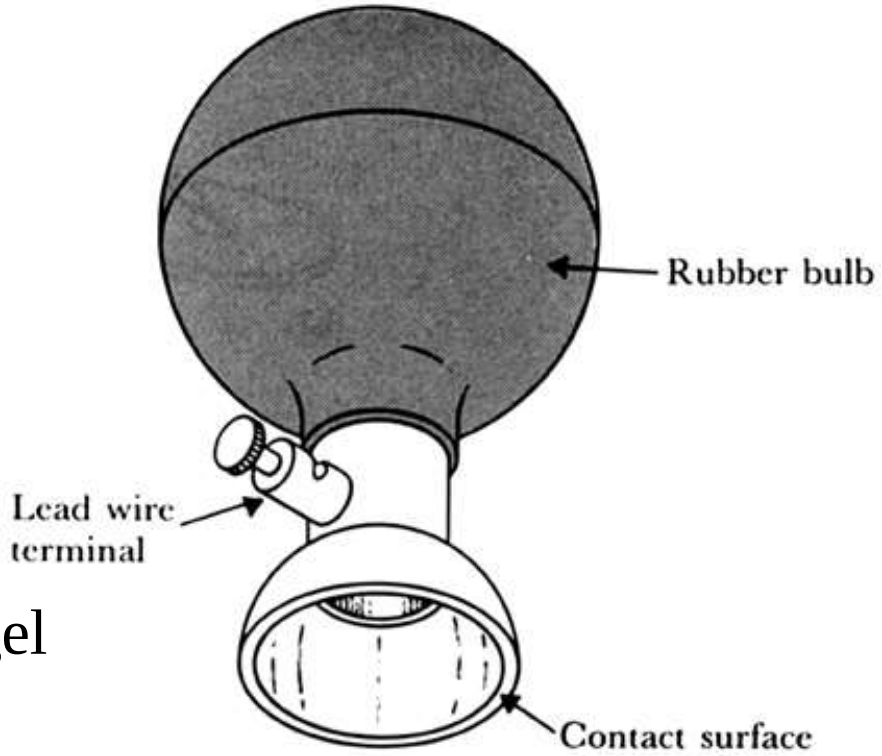
# Commonly Used Biopotential Electrodes

**Suction electrodes**

- No straps or adhesives required
- precordial (chest) ECG
- can only be used for short periods

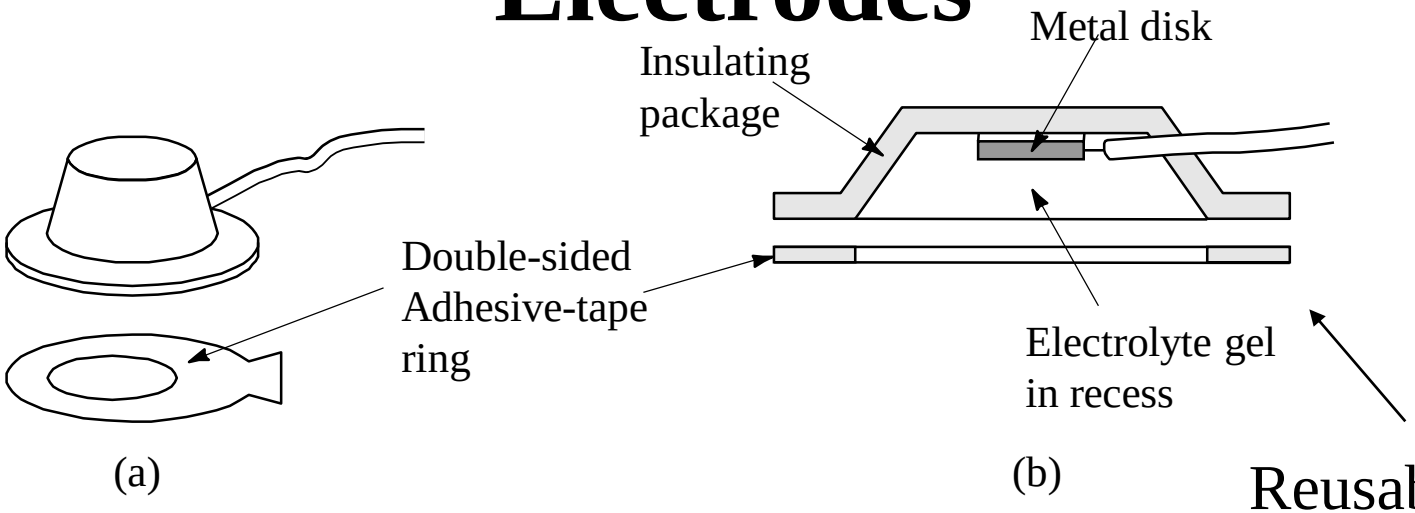
**Floating electrodes**

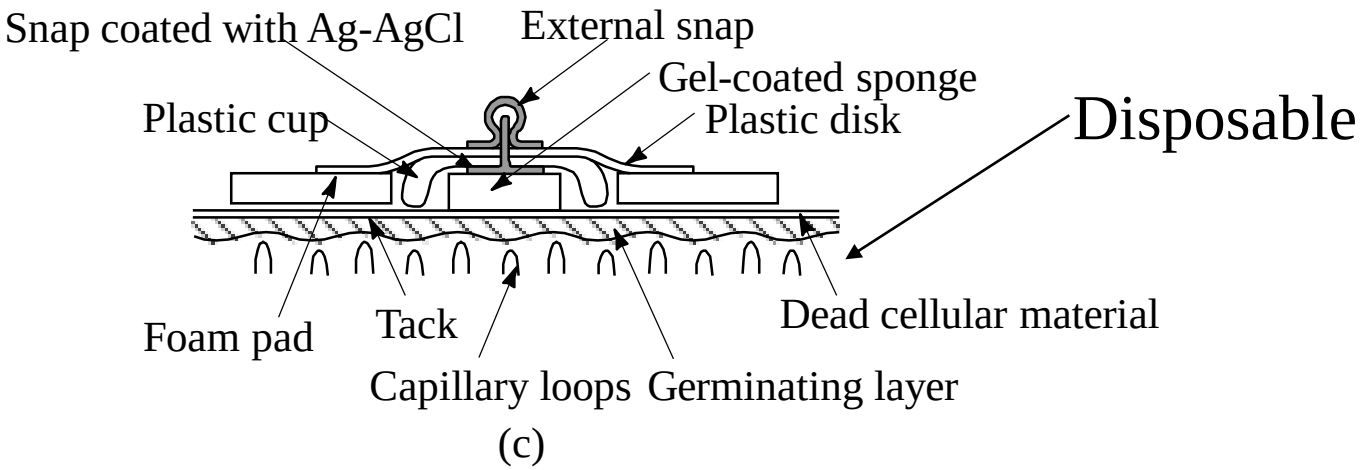
- metal disk is recessed
- swimming in the electrolyte gel
- not in contact with the skin
- reduces motion artifact




Suction Electrode

# Commonly Used Biopotential Electrodes



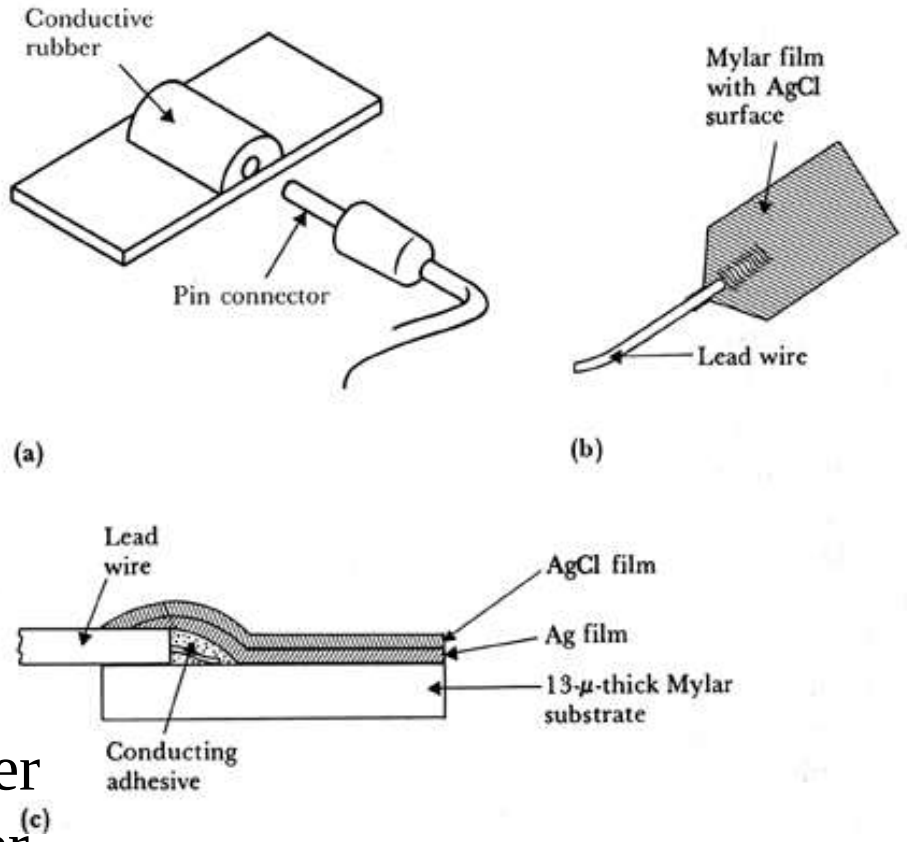




## Floating Electrodes

# Commonly Used Biopotential Electrodes

**Flexible electrodes**

- Body contours are often irregular
- Regularly shaped rigid electrodes
  may not always work.
- Special case : infants
- Material :
  - Polymer or nylon with silver
  - Carbon filled silicon rubber (Mylar film)

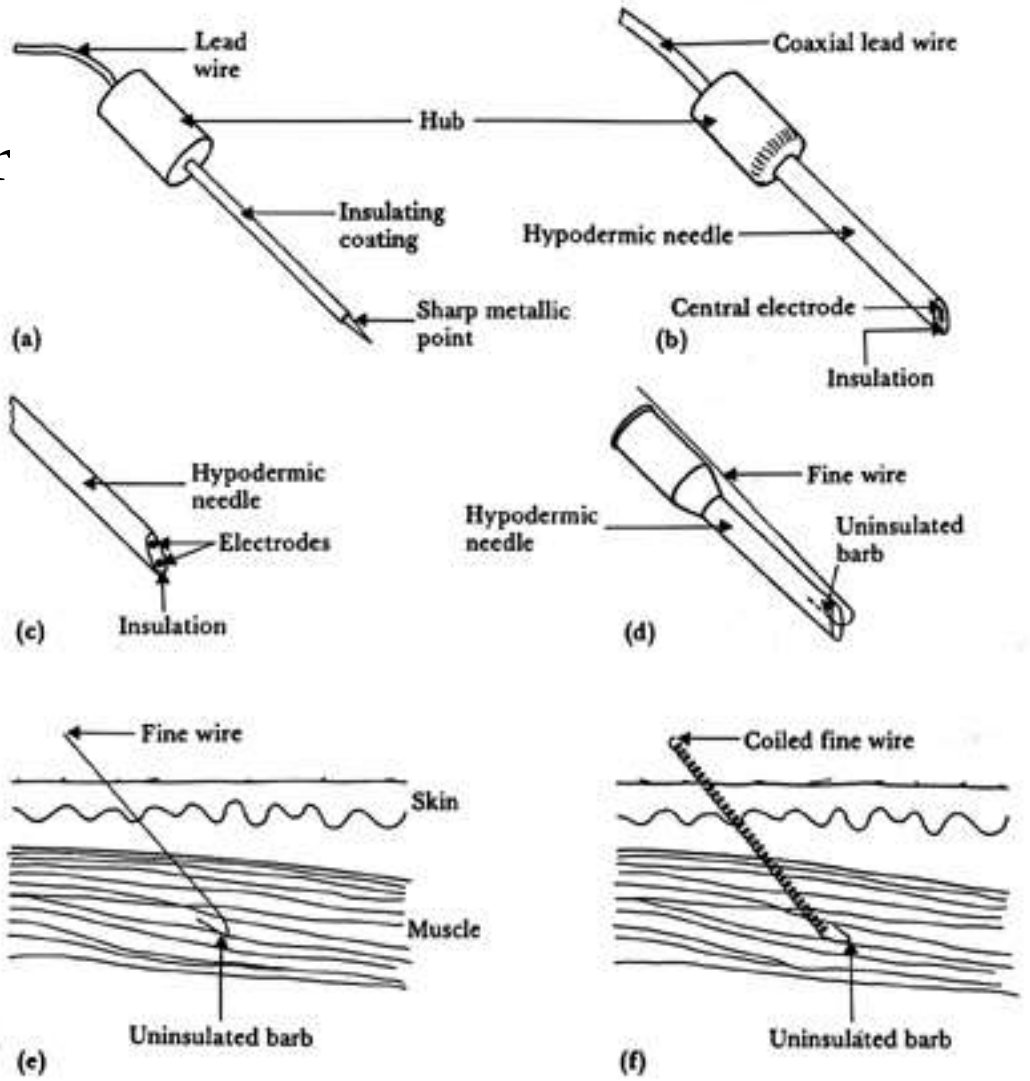



(a) Carbon-filled silicone rubber electrode.
(b) Flexible thin-film neonatal electrode.
(c) Cross-sectional view of the thin-film electrode in (b).

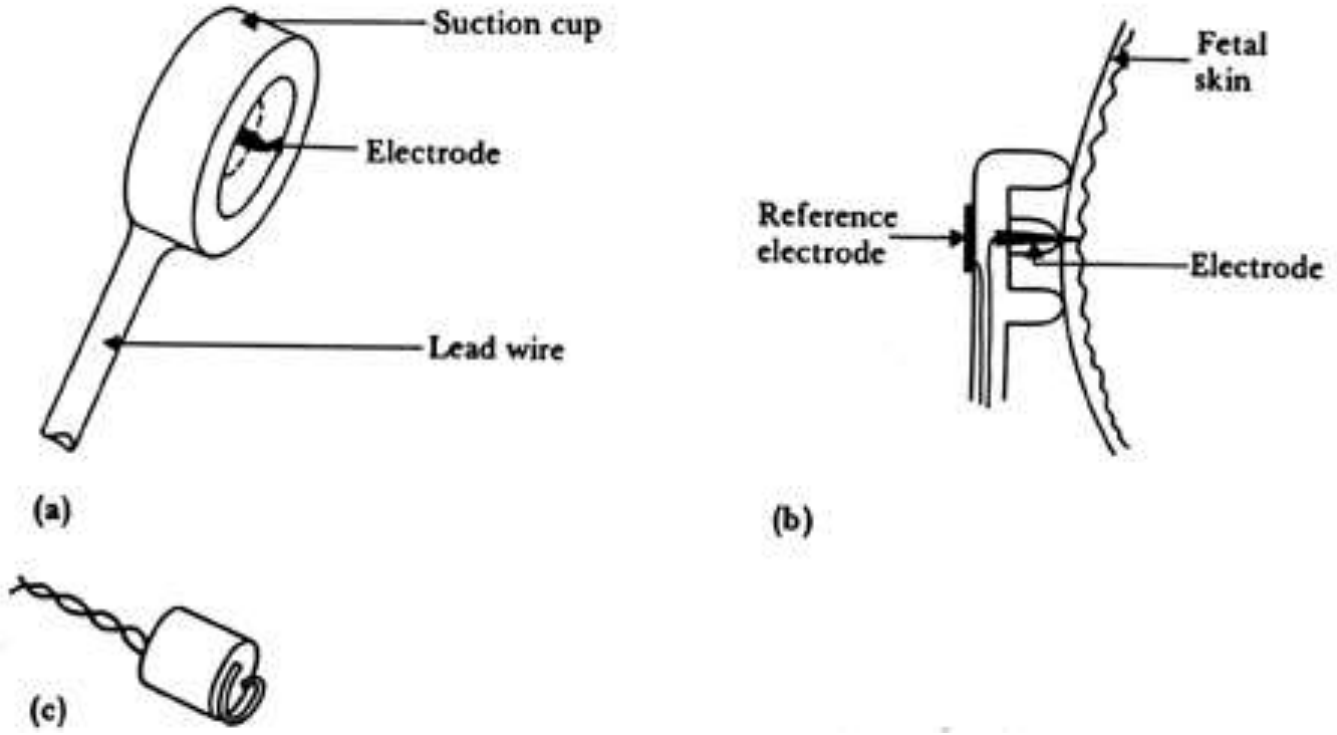
# Internal Electrodes

Needle and wire electrodes for percutaneous measurement of biopotentials

(a) Insulated needle electrode.
(b) Coaxial needle electrode.
(c) Bipolar coaxial electrode.
(d) Fine-wire electrode connected to hypodermic needle, before being inserted.
(e) Cross-sectional view of skin and muscle, showing coiled fine-wire electrode in place.

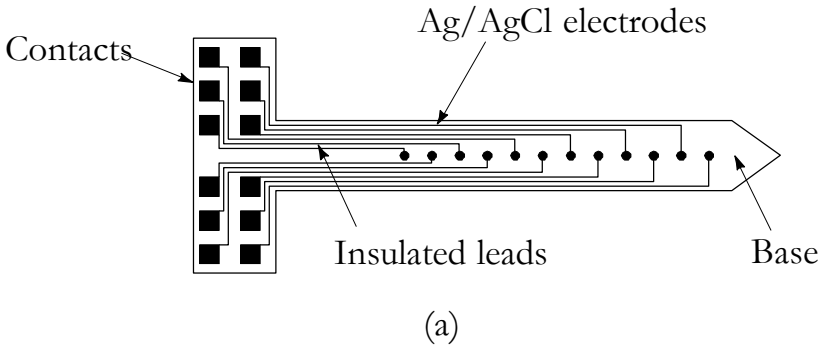


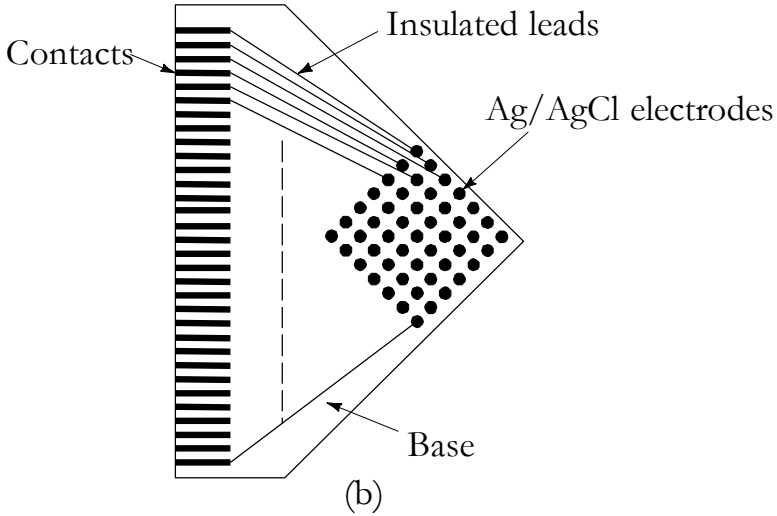
# Fetal ECG Electrodes

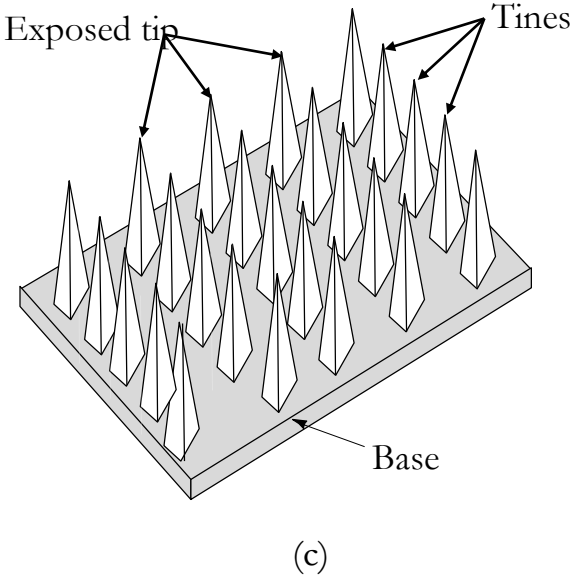



Electrodes for detecting fetal electrocardiogram during labor, by means of intracutaneous needles (a) Suction electrode. (b) Cross-sectional view of suction electrode in place, showing penetration of probe through epidermis. (c) Helical electrode, which is attached to fetal skin by corkscrew type action.

# Electrode Arrays




Examples of microfabricated electrode arrays.
(a) One-dimensional plunge electrode array,
(b) Two-dimensional array, and
(c) Three-dimensional array

# Microelectrodes

Measure potential difference across cell membrane

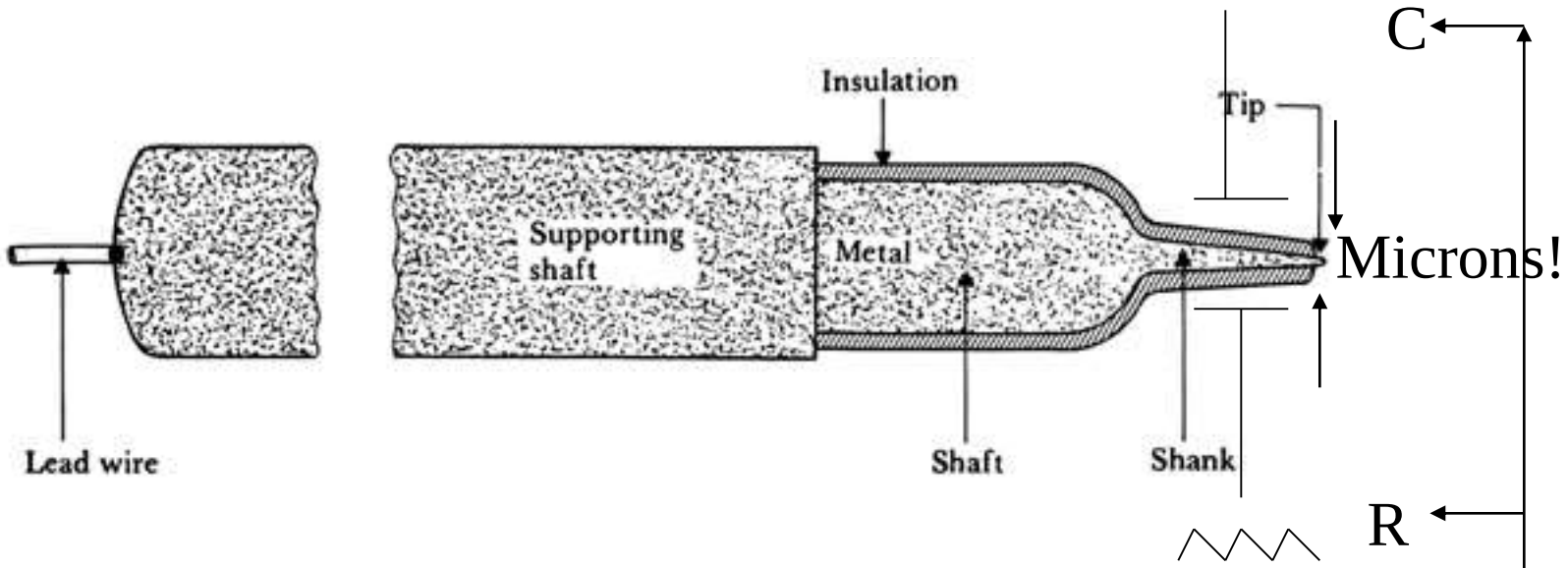
**Requirements**

- Small enough to be placed into cell
- Strong enough to penetrate cell membrane
- Typical tip diameter: 0.05 – 10 microns

**Types**

- Solid metal -> Tungsten microelectrodes
- Supported metal (metal contained within/outside glass needle)
- Glass micropipette -> with Ag-AgCl electrode metal

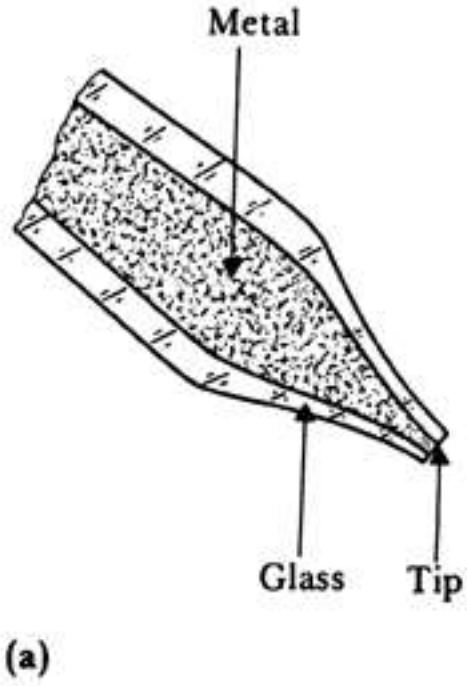
# Metal Microelectrodes

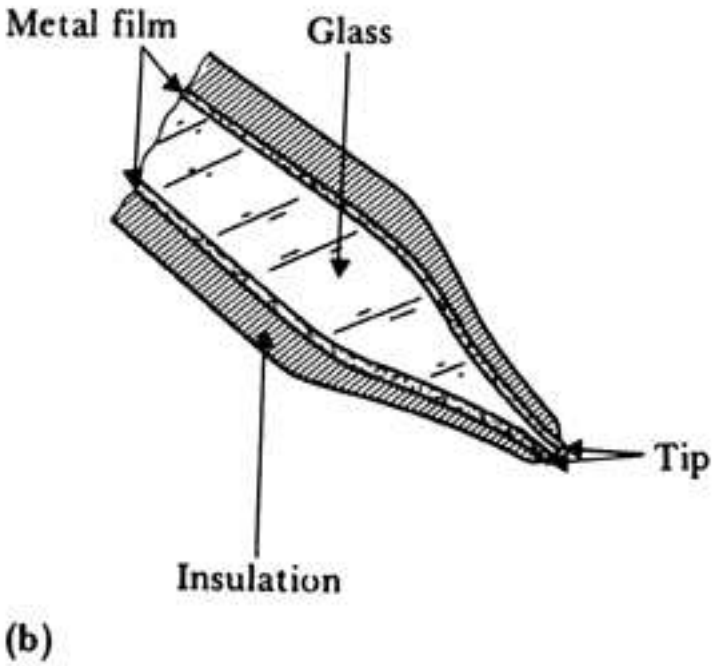



Extracellular recording – typically in brain where you are interested in recording the firing of neurons (spikes).

Use metal electrode+insulation -> goes to high impedance amplifier…negative capacitance amplifier!

# Metal Supported Microelectrodes

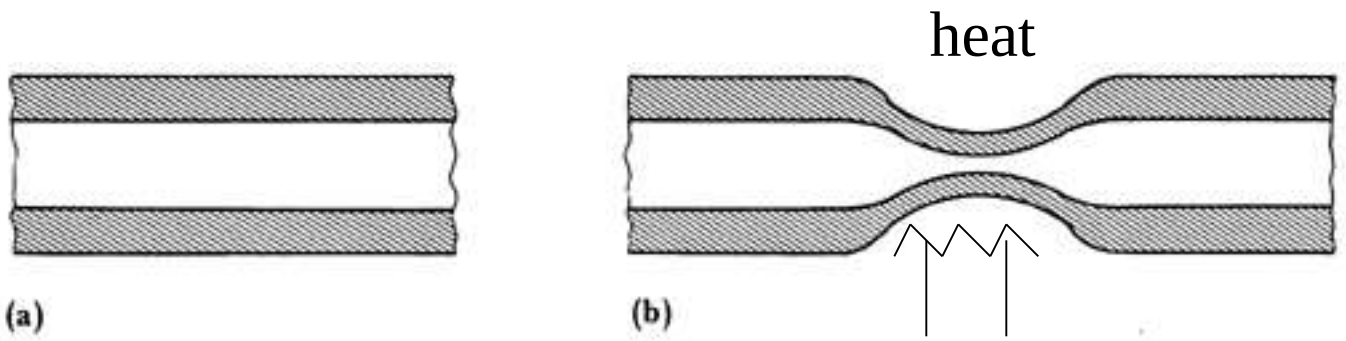


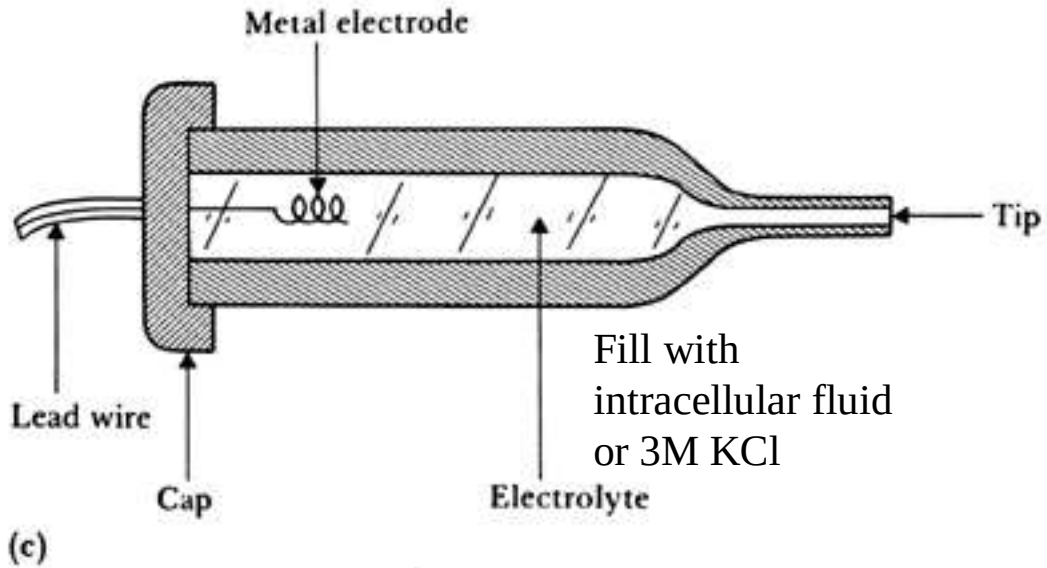




(a) Metal inside glass

(b) Glass inside metal

# Glass Micropipette



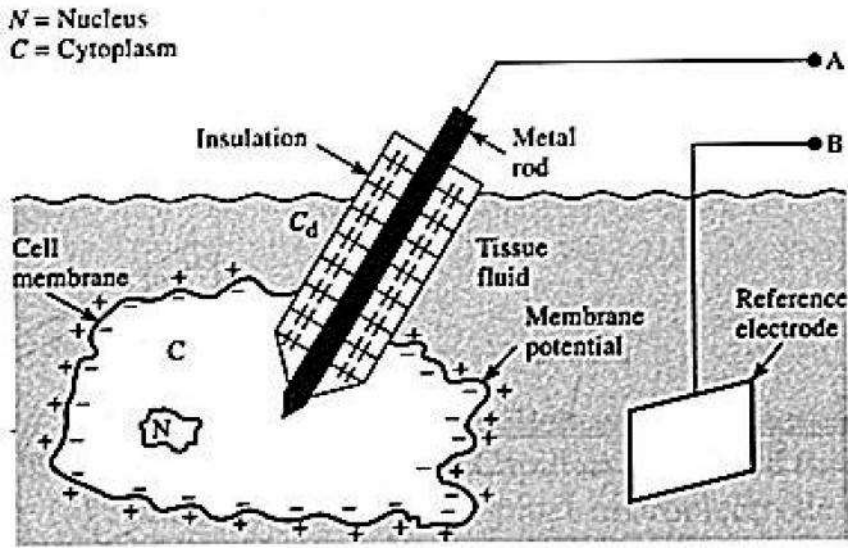

A glass micropipet electrode filled with an electrolytic solution
(a) Section of fine-bore glass capillary.
(b) Capillary narrowed through heating and stretching.
(c) Final structure of glass-pipet microelectrode.

Intracellular recording – typically for recording from cells, such as cardiac myocyte

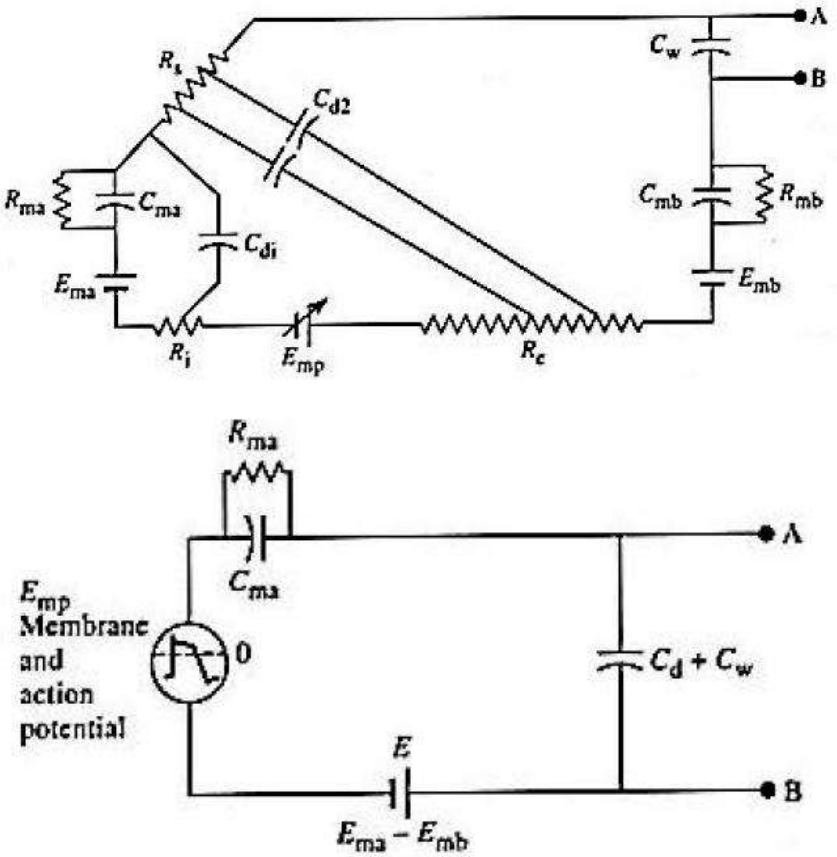
Need high impedance amplifier…negative capacitance amplifier

# Electrical Properties of Microelectrodes

## Metal Microelectrode




Metal microelectrode with tip placed within cell

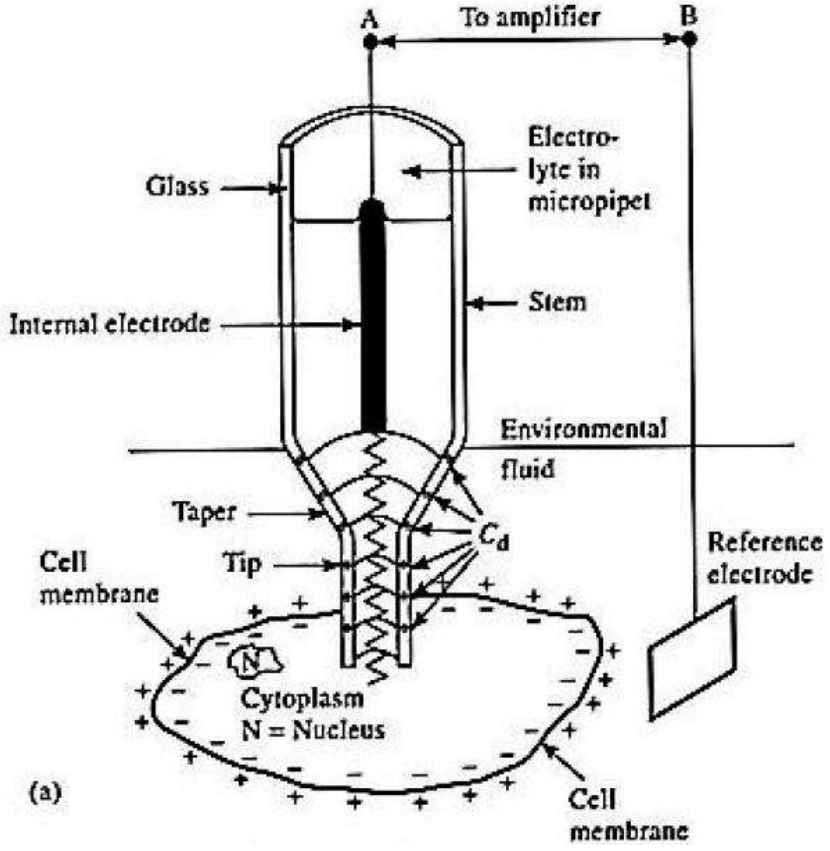


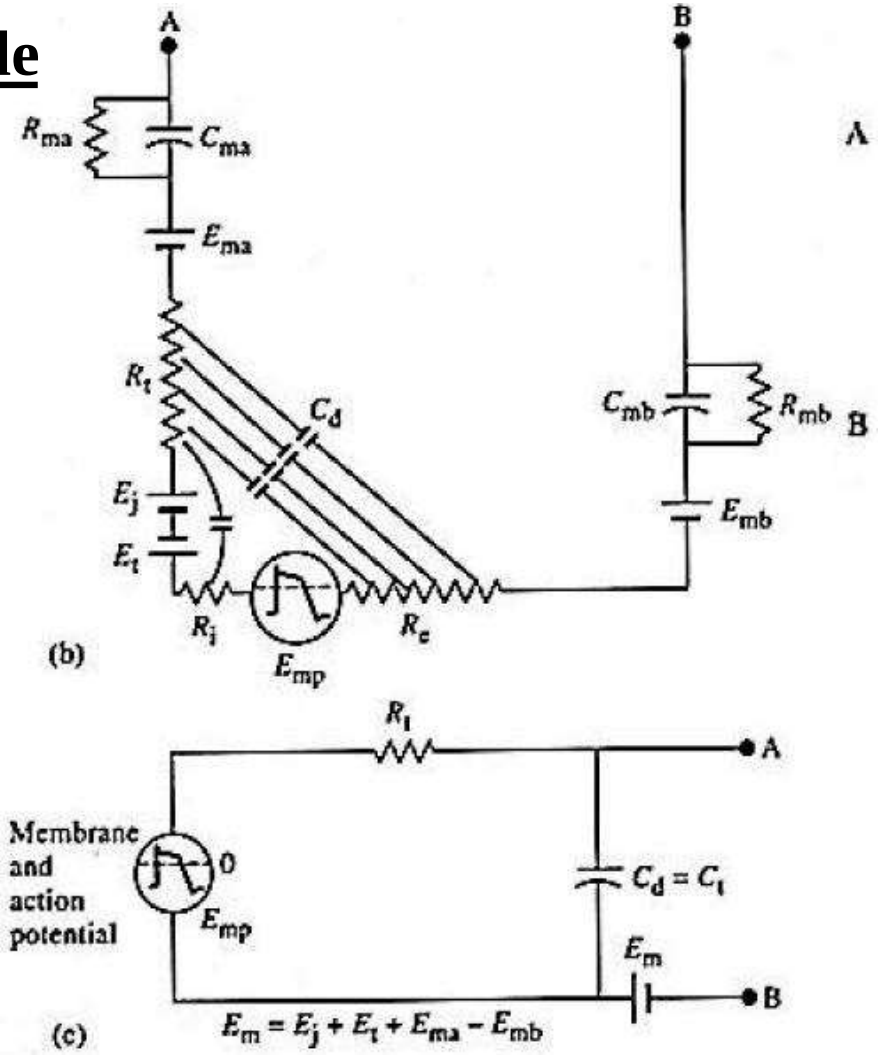

Equivalent circuits

Use metal electrode+insulation -> goes to high impedance amplifier…negative capacitance amplifier!

# Electrical Properties of Glass Intracellular Microelectrodes

## Glass Micropipette Microelectrode



# BIOPOTENTIAL AMPLIFIERS

# Biopotential Amplifiers

- Biopotential amplifier is a term given to amplifiers used to process biopotential signals (e.g., ECG, EMG, EEG, EOG, … etc.).
- The designation applies to a large number of different types of amplifiers (i.e., instrumentation amplifier, isolation amplifier, etc.).
- The basic function of biopotential amplifier is to increase the amplitude of a weak electric signal of biological origin.
- Biopotential amplifiers typically process voltages, but in some cases they also process currents.
- The frequency response of typical bioelectric amplifiers may be from dc (or near dc, i.e., 0.05 Hz) up to 100 kHz.

# Biopotential Amplifiers

- Some biopotential amplifiers are ac-coupled, while some are dc-coupled.
- The dc-coupling is required where input signals are clearly dc or changes very slowly.
- At frequencies as low as 0.05Hz, the ac-coupling should be used instead of dc-coupling.
- This is to overcome the electrode offset potential.
- Also, the skin-electrode interface generates dc offsets.
- The gain of biopotential amplifiers can be low, medium or high (x10, x100, x1000, x10000).

# Biopotential Amplifiers

## Low Gain Biopotential Amplifiers

i. Gain factors x1 and x10.

ii. The unity-gain amplifier is mainly for isolation, buffering and possibly impedance transformation between signal source and readout device.

iii. Used for measurement of action potentials and other relatively high-amplitude bioelectric events.

# Biopotential Amplifiers

## Medium Gain Biopotential Amplifiers

i. Gain factors x100 and x1000.

ii. Used for recording of ECG, EMG, etc.

# Biopotential Amplifiers

## High Gain Biopotential Amplifiers

i. Gain factors over x1000.

ii. Used in very sensitive measurement such as EEG.

# Typical Biopotential Amplifier Requirements

The basic requirements that a biopotential amplifier has to satisfy are:

1. Biopotential amplifiers should have high input impedance i.e., greater than 10 MΩ.

2. Safety: the amplifier should protect the organism being studied.
   Careful design to prevent macro and micro shocks.
   Isolation and protection circuitry to limit the current through the electrode to safe level.

3. Output impedance of the amplifier should be low to drive any external load with minimal distortion.

4. Gain of the amplifier is greater than x1000 as biopotentials are typically less than a millivolt.

# Typical Biopotential Amplifier Requirements

6. Most biopotential amplifiers are differential amplifier as signals are recorded using a bipolar electrodes which are symmetrically located.

7. High common mode rejection ratio (CMMR): biopotentials ride on a large offset signals or noise.

8. Rapid calibration of the amplifier in laboratory conditions.

9. Adjustable gains:

- Often the change in scale is automatic.
- Therefore calibration of the equipment is very important.

# Typical Biopotential Amplifier Requirements

10. The physiological process to be monitored should not be influenced in any way by the amplifier.

11. The measured signal should not be distorted.

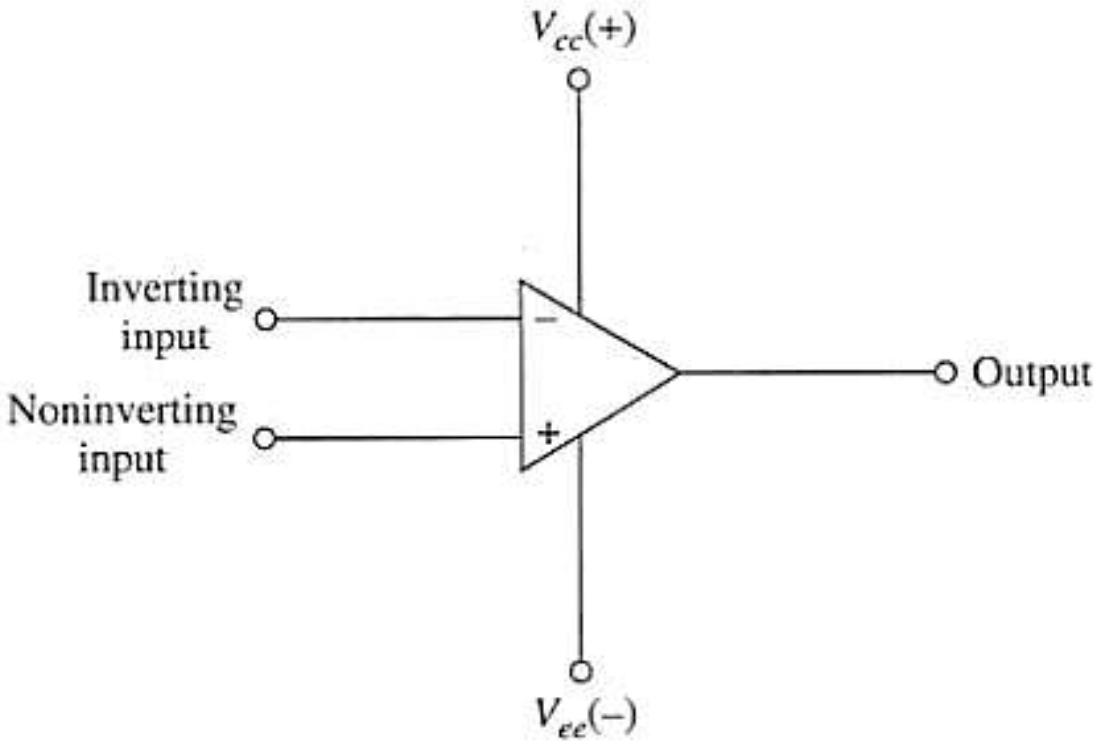
12. The amplifier should provide the best possible separation of signal and interferences.

13. The amplifier has to offer protection of the patient from any hazard of electrical shock.

14. The amplifier itself has to be protected against damages that might result from high input voltages as they occur during the application of defibrillators or electrosurgical instrumentation.

# Operational Amplifiers

**Operational Amplifier Circuit Symbol**



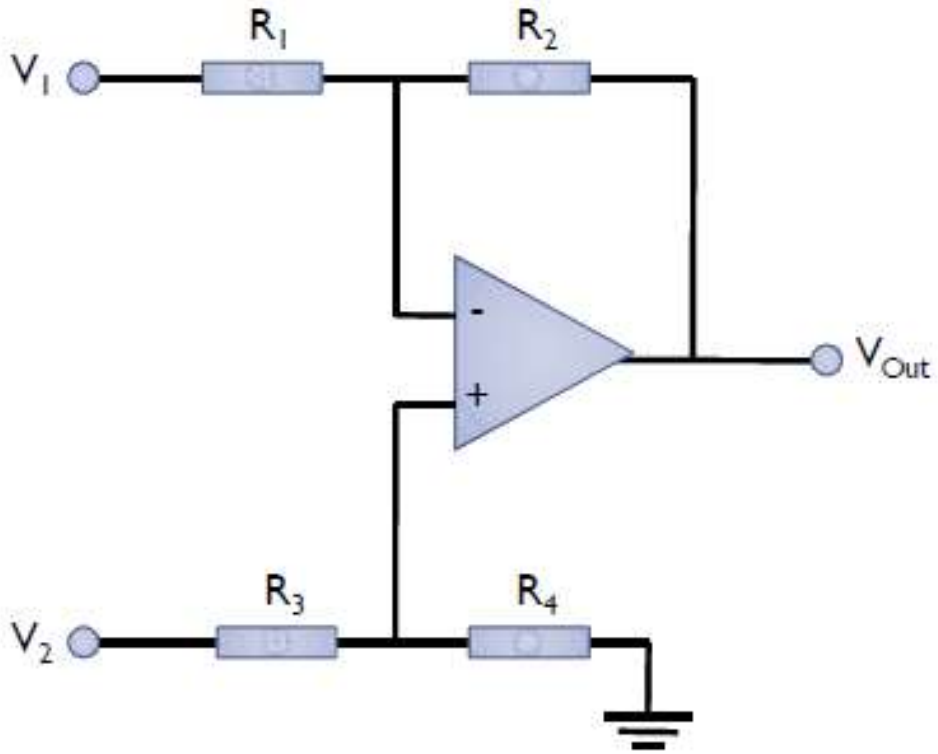
# Operational Amplifiers

## The properties of Ideal Operational Amplifiers

1. Infinite open-loop voltage gain ($A_{vol} = \infty$)
2. Zero output impedance ($Z_o = 0$)
3. Infinite input impedance ($Z_i = \infty$)
4. Infinite frequency response
5. Zero noise contribution

# Differential Amplifier

- A differential amplifier produces an output voltage that is proportional to the difference between the voltage applied to the two input terminals.



# Differential Amplifier

- The voltage gain for the differential signals is the same as for the inverting followers, provided the ratio equality of R2/R1 = R4/R3 is maintained.

- Differential amplifiers are useful because it rejects common voltages while amplifying the differential signal of interest.

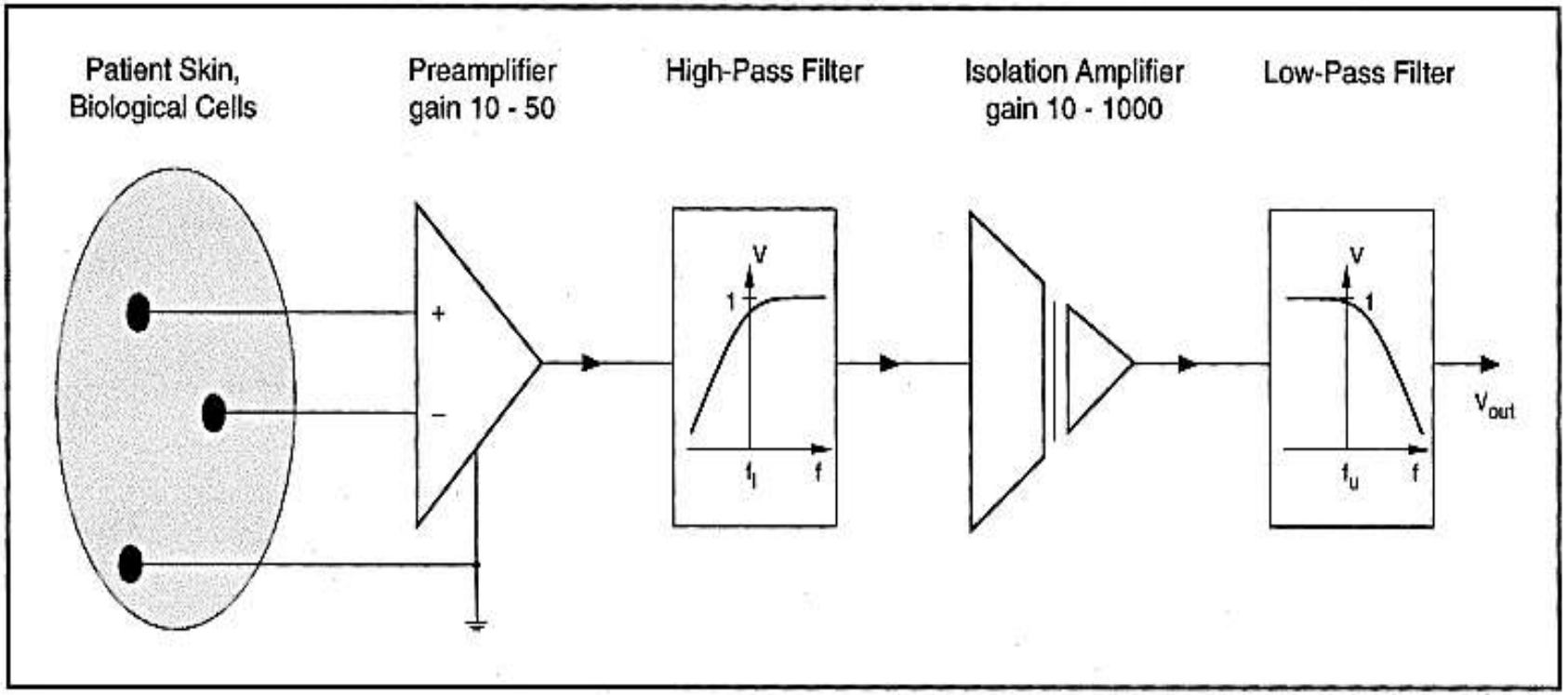
Example:

- Suppose equal 50 Hz supply noise is present on each input of the differential amplifier, and one input is at 5 Vdc while the other is at 1 Vdc.

- The circuit removes the noise and amplifies the 4 Vdc differential signal.

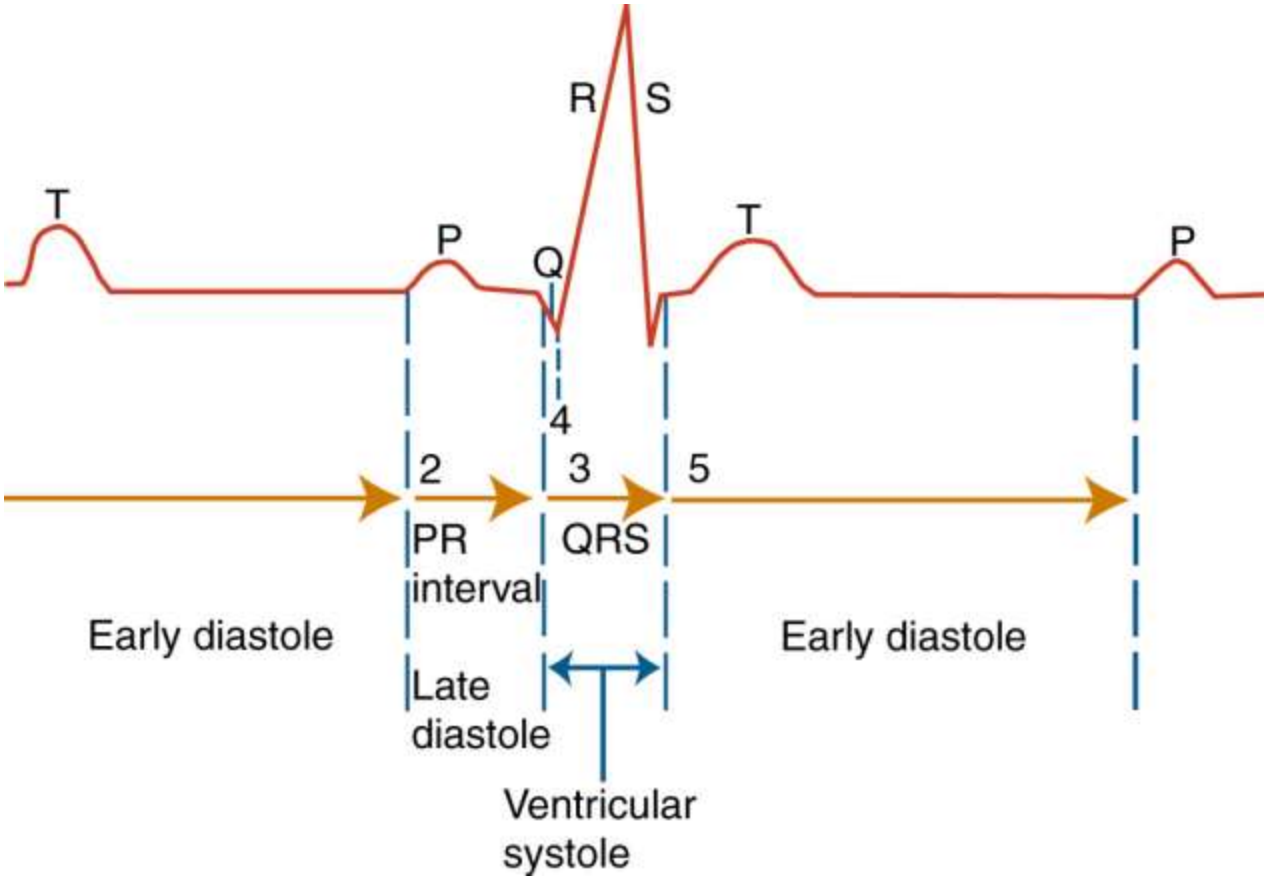
# Main Stages of a Biopotential Amplifier

- Three electrodes connect the patient to a preamplifier stage.
- After removing dc and low-frequency interferences, the signal is connected to an output low-pass filter through an isolation stage which provides electrical safety to the patient, prevents ground loops, and reduces the influence of interference signals.



# Electrocardiography

# ECG Waveform



# Definition of ECG

- The ECG is a graphic representation of the electrical impulses that the heart generates during the cardiac cycle.
- These electrical impulses are conducted to the body's surface, where they are detected by electrodes placed on the patient's limbs and chest.
- The monitoring electrodes detect the electrical activity of the heart from a variety of spatial perspectives.
- The ECG lead system is composed of several electrodes that are placed on each of the four extremities and at varying sites on the chest. Each combination of electrodes is called a *lead*.

# *12-lead ECG*

- It provides a comprehensive view of the flow of the heart's electrical currents in two different planes.
- There are six limb leads (combination of electrodes on the extremities) and six chest leads (corresponding to six sites on the chest).
- standard *limb* leads
- Leads I: records the difference in electrical potential between the left arm (LA) and the right arm (RA).
- Lead II: records the electrical potential between the RA and the left leg (LL).
- Lead III reflects the difference between the LA and the LL. The right leg (RL) electrode is an inactive ground in all leads.

# *Augmented* limb leads

- aVR
- aVL
- aVF
- The augmented leads measure the electrode potential between the center of the heart and the right arm (aVR), the left arm (aVL), and the left leg (aVF).

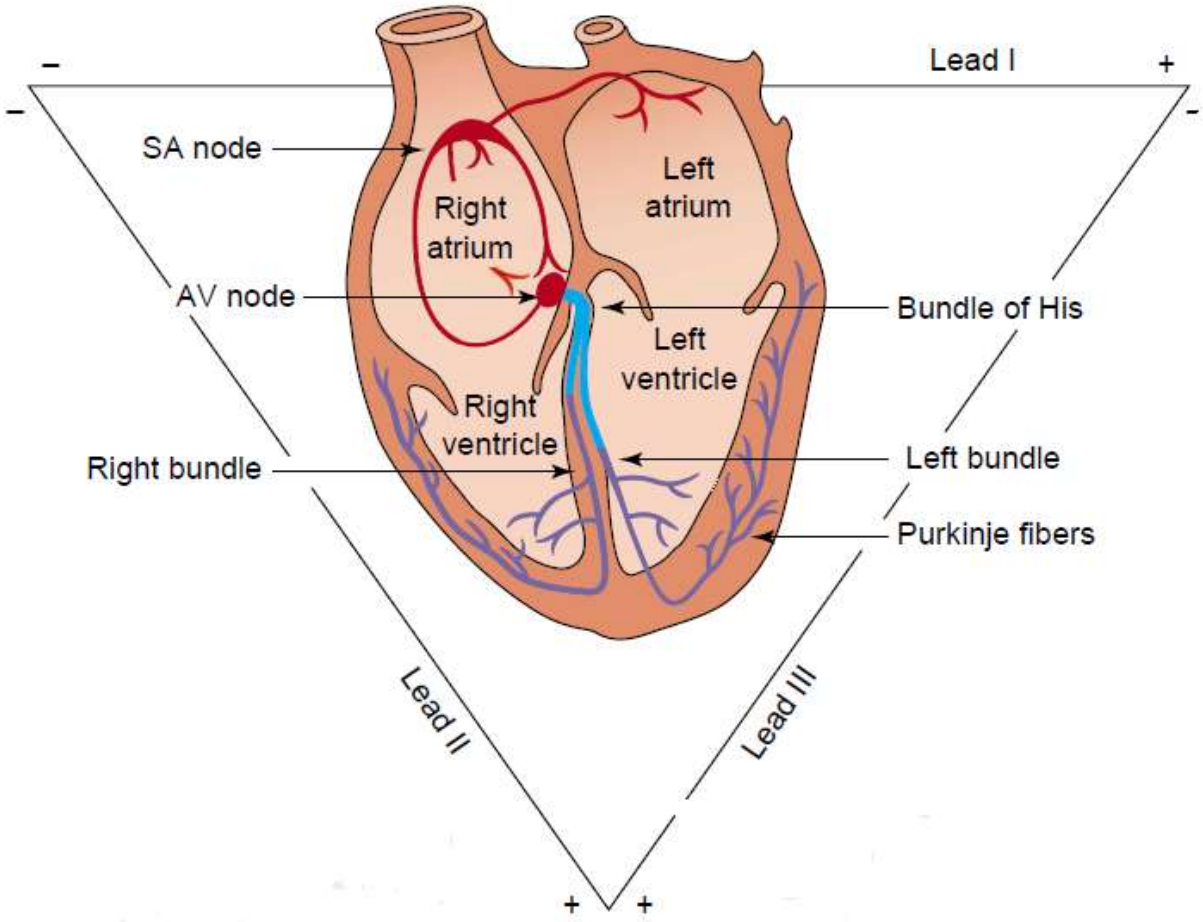
# Limb leads

1. Rt arm (avr) Red color.
2. Lt arm (avl) Yellow color.
3. Lt leg (avf) Green color.
4. Rt leg, black color.

# Chest, or precordial leads

- The six standard, (V1, V2, V3, V4, V5, V6) are placed at six different positions on the chest, surrounding the heart.
- In general, it is said that leads II, III and aVF look at the inferior part of the heart, leads aVL and I look at the lateral part of the heart, and leads V2-V4 look at the anterior part of the heart.

# Einthoven Triangle



# ECG waves

- ***P wave:*** This represents atrial electrical depolarization associated with atrial contraction. It represents electrical activity associated with the spread of the original impulse from the sinoatrial (SA) node through the atria.
- ***PR interval:*** This represents the time required for the impulse to travel from the SA node to the atrioventricular (AV) node.

  If prolonged PR interval: a conduction delay exists in the AV node (e.g., a first-degree heart block).

  If the PR interval is shortened: the impulse must have reached the ventricle through a "shortcut" (as in Wolff-Parkinson-White syndrome).

# ECG waves

- ***QRS complex***. This represents ventricular electrical depolarization associated with ventricular contraction. This consists of:

➢ initial downward (negative) deflection (Q wave)

➢ a large upward (positive) deflection (R wave)

➢ a small downward deflection (S wave).

A widened QRS complex: indicates abnormal or prolonged ventricular depolarization time (as in a bundle-branch block).

# ECG waves

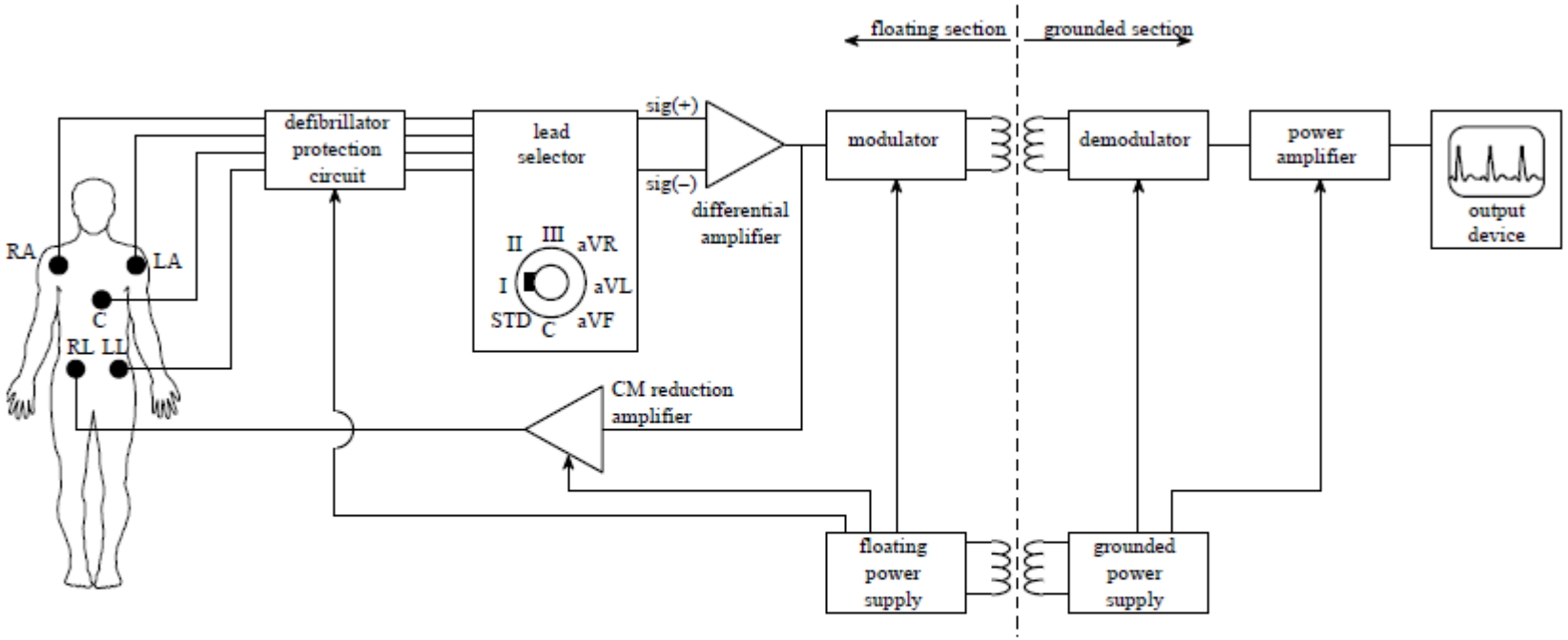
- ***ST segment***. This represents the period between the completion of depolarization and the beginning of repolarization of the ventricular muscle.

  This segment may be elevated or depressed in transient muscle ischemia (e.g., angina) or in muscle injury (as in the early stages of myocardial infarction).

- ***T wave:*** This represents ventricular repolarization (i.e., return to neutral electrical activity).

- ***U wave:*** This deflection follows the T wave and is usually quite small. It represents repolarization of the Purkinje nerve fibers within the ventricles

# Simplified Block Diagram (ECG)



# ECG Graph Paper

- Runs at a paper speed of 25 mm/sec
- Each small block of ECG paper is 1 mm2
- At a paper speed of 25 mm/s, one small block equals 0.04 s
- Five small blocks make up 1 large block which translates into 0.20 s (200 msec)
- Hence, there are 5 large blocks per second
- Voltage: 1 mm = 0.1 mV between each individual block vertically

# ELECTROENCEPHALOGRAPHY

# Electroencephalography

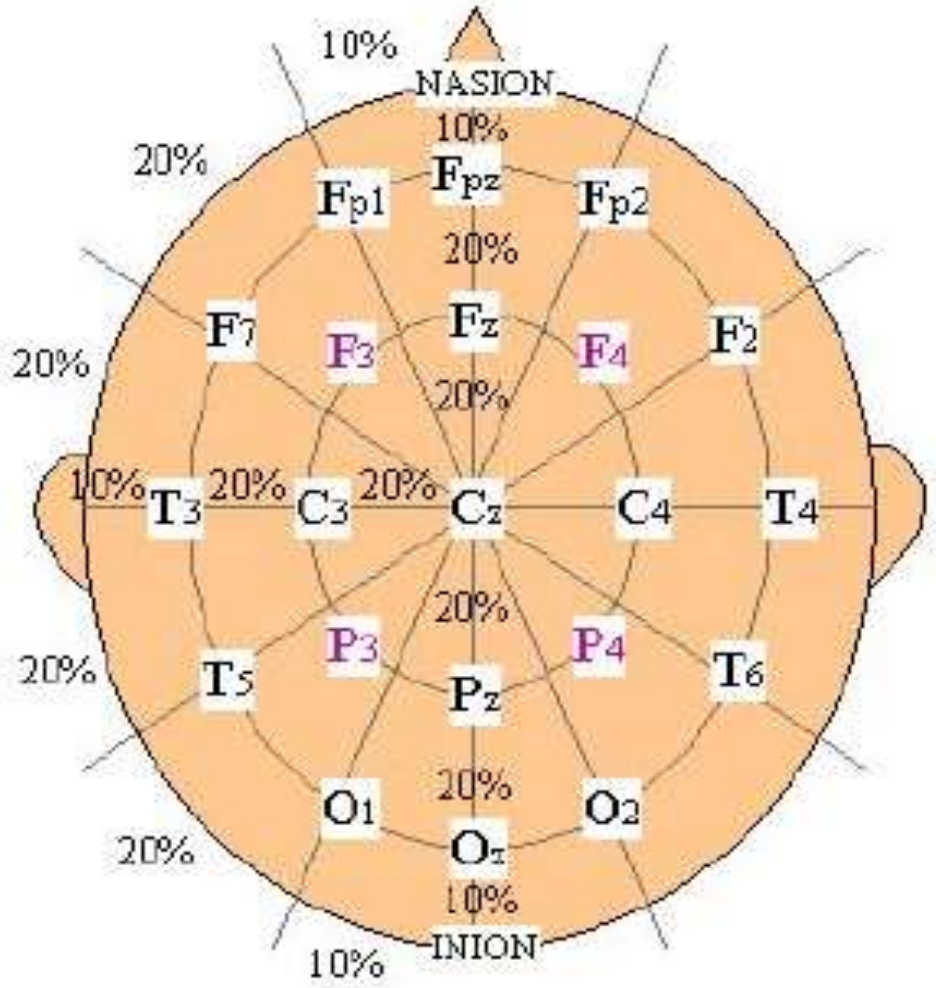
- **Electroencephalography** (**EEG**) is the recording of electrical activity along the scalp.
- EEG refers to the recording of the brain's spontaneous electrical activity over a short period of time, usually 20–40 minutes, as recorded from multiple electrodes placed on the scalp.

# Scalp Electrodes

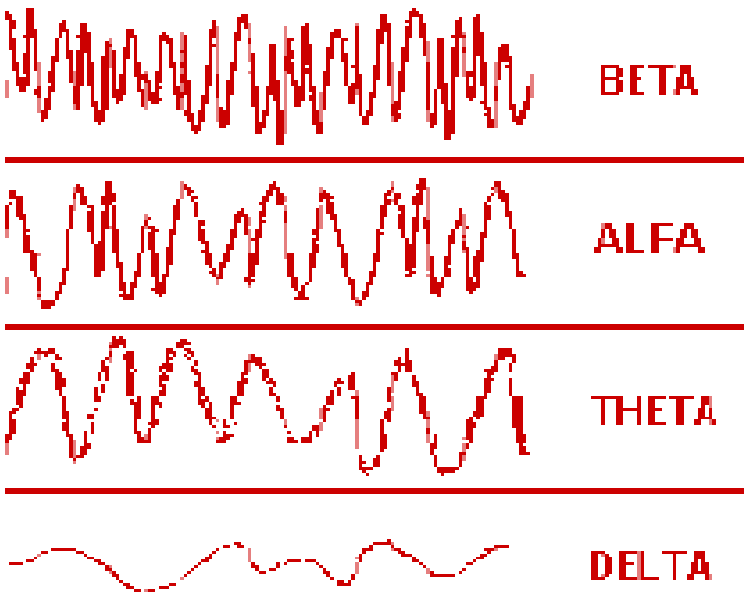
# 10-20 system (EEG)

- The "10" and "20" refer to the fact that the actual distances between adjacent electrodes are either 10% or 20% of the total front–back or right–left distance of the skull.
- Each site has a letter to identify the lobe and a number to identify the hemisphere location. The letters F, T, C, P and O stand for frontal, temporal, central, parietal, and occipital lobes, respectively

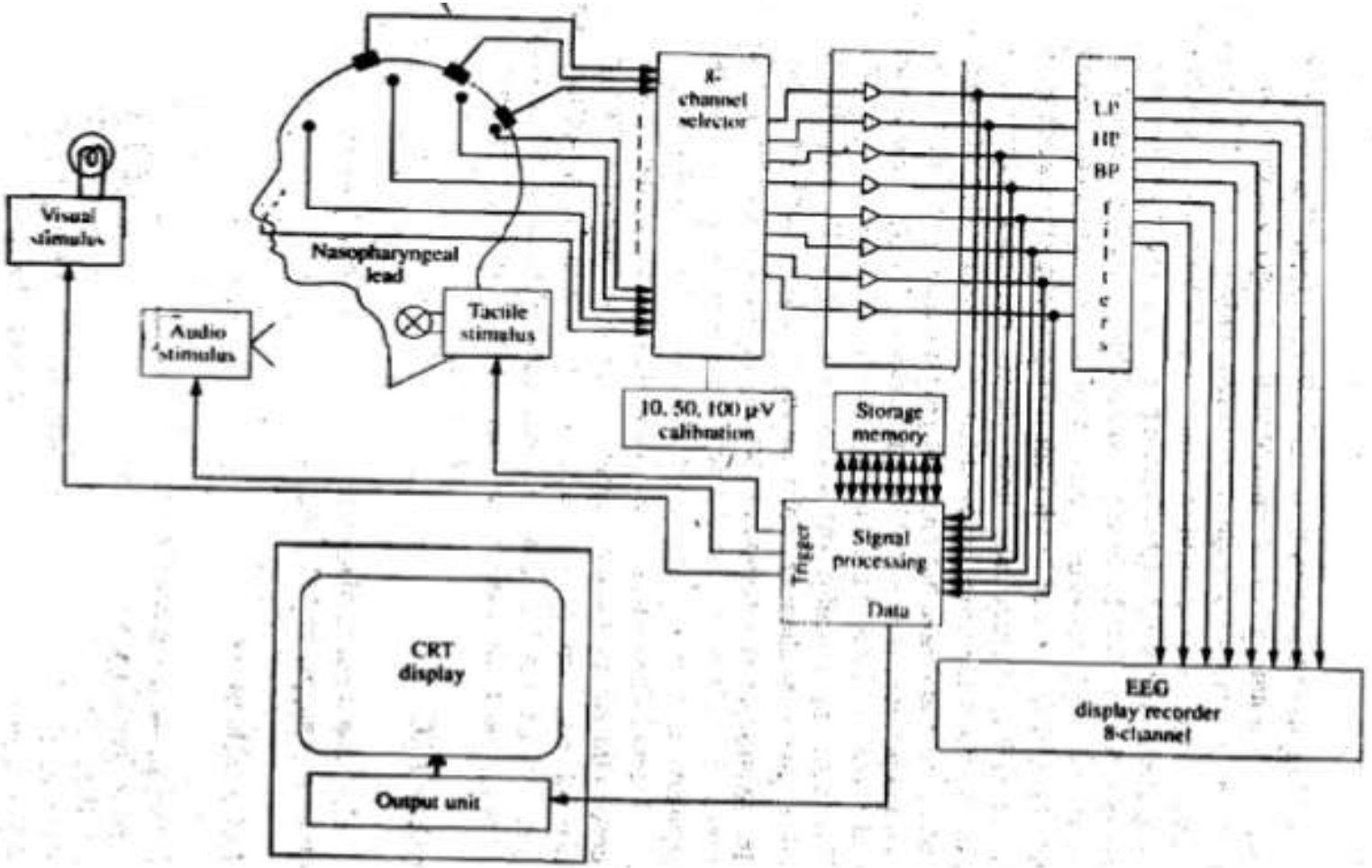
# 10-20 system (EEG)



# EEG Waves



# EEG Recording Setup



# EEG Recording Setup

- Electrodes attached to different parts of the skull of a patient.
- **8 channel EEG recorder**:-
  - Patient cable consists of 21 electrodes
  - Electrodes connected to selector in groups of 8- **Montage of electrodes**
  - Right ear electrode → reference electrode→ right brain electrodes
  - Left ear electrode → reference electrode→ left brain electrodes

# EEG Recording Setup

- Interference problem is reduced by differential amplifier(preamplifiers)
- Filter bank:- consists of appropriate filters to select different types of brain waves.
- Output can be given to 8-channel pen recorder, display unit, computer storage memory for further processing.
- Evoked Potential:- Measure of the “disturbance” in the EEG pattern that results from external stimuli.
- Time delay between stimulus and response can be measured in signal processing unit.

# Artifacts

- Three sources
  - 60-cycle noise
  - Muscle artifact
  - Eye Movements

# Dealing with artifacts

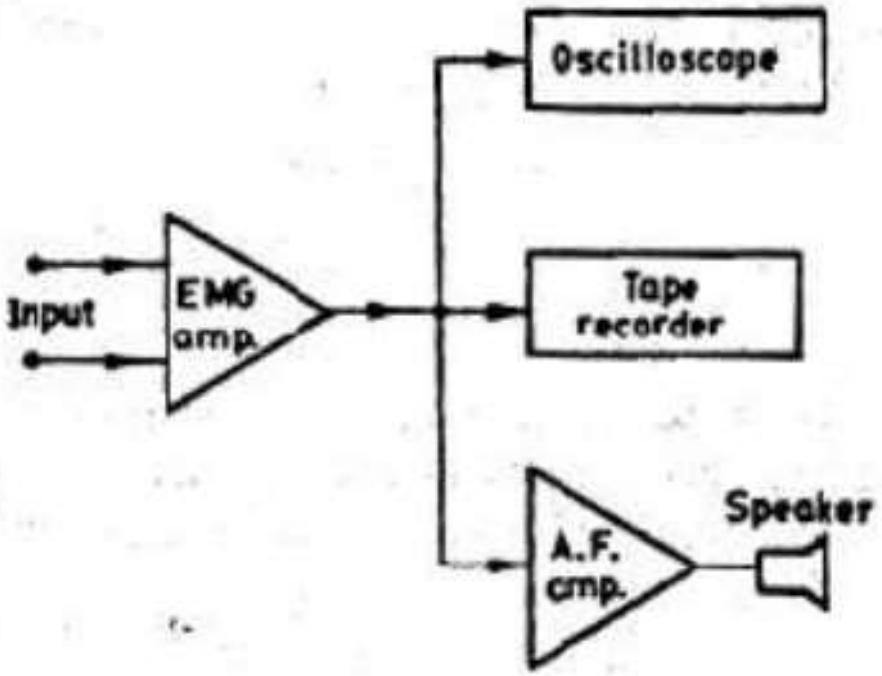
- 60-cycle noise
  - Ground subject
  - 60 Hz Notch filter
- Muscle artifact
  - No gum!
  - Use headrest
  - Measure EMG and reject/correct for influence
  - Statistically control for EMG
  - Hand score
- Eye movements
  - Eyes are dipoles
  - Reject ocular deflections including blinks
  - Computer algorithms for EOG correction

# ELECTROMYOGRAPHY

# Electromyography

- **Electromyography** (**EMG**) is a technique for evaluating and recording the electrical activity produced by skeletal muscles.
- EMG is performed using an instrument called an**electromyograph**, to produce a record called an **electromyogram**.

# EMG Recording Setup



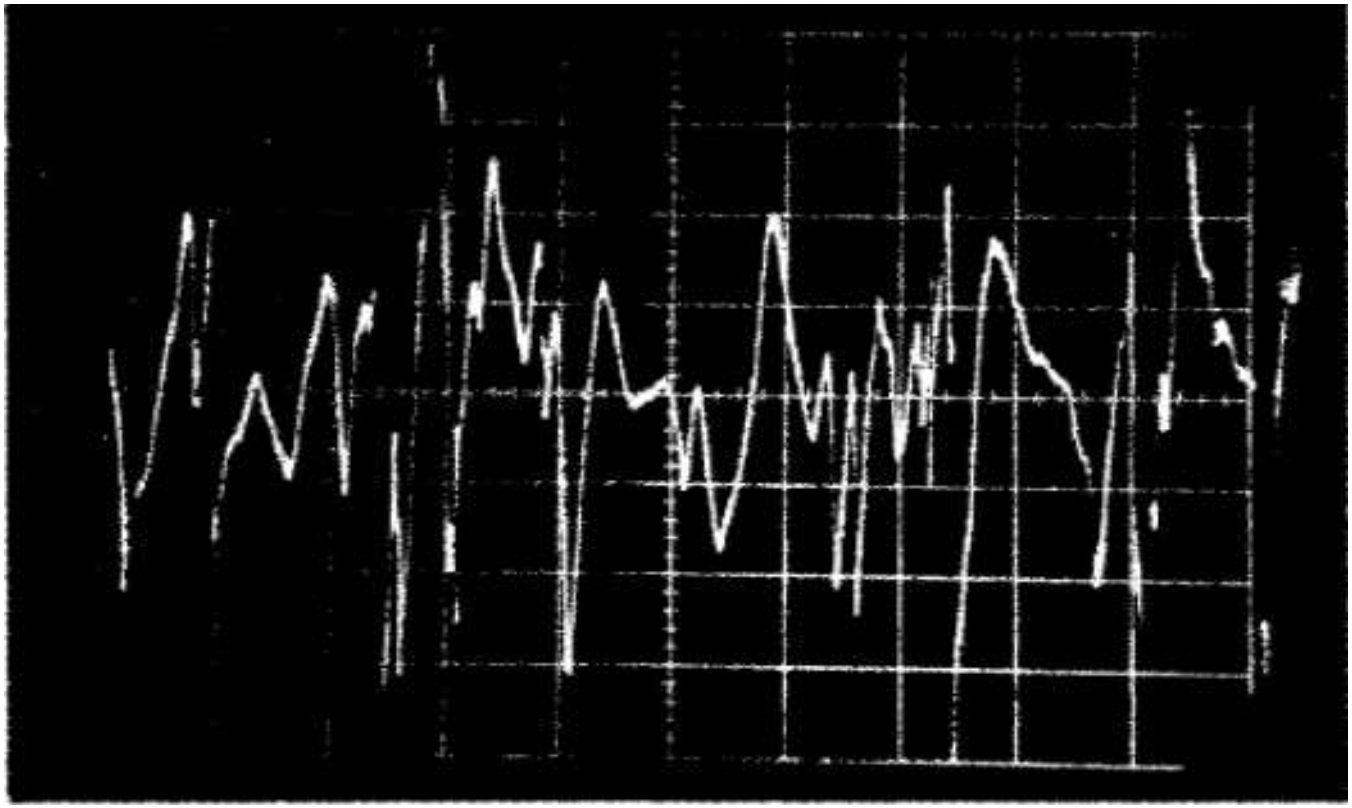
# EMG Recording Setup

- potentials measured by placing surface electrodes on the skin.
- Individual cell potential measured by means of needle electrode
- EMG appears like random noise waveform.
- Contraction of muscle fibers produce action potentials

# EMG Recording Setup

- Amplitude of EMG signals depends
  - Type & placement
  - Degree of muscular exertions
- Normal frequency of EMG signals is 60 Hz
- EMG signal amplitude ranges from 0.1 to 0.5 mV.
- Amplifier with high CMRR and input impedance
- Output can be given to oscilloscope, tape recorder or AF amplifier.

# EMG Waveform



# PHONOCARDIOGRAPHY

# Phonocardiography

- A **Phonocardiogram** or **PCG** is a plot of high fidelity recording of the sounds and murmurs made by the heart with the help of the machine called phonocardiograph
- Recording of the sounds made by the heart during a cardiac cycle
- The sounds are thought to result from vibrations created by closure of the heart valves

# Phonocardiography

- There are at least two: the first when the atrioventricular valves close at the beginning of systole and the second when the aortic valve closes at the end of systole.
- It allows the detection of sub-audible sounds and murmurs, and makes a permanent record of these events.
- In contrast, the ordinary stethoscope cannot detect such sounds or murmurs, and provides no record of their occurrence.

# Phonocardiography

- The ability to quantitative the sounds made by the heart provides information not readily available from more sophisticated tests, and provides vital information about the effects of certain cardiac drugs upon the heart.
- It is also an effective method for tracking the progress of the patient's disease.

# ELECTRO-OCULOGRAPHY

# DEFINITION

- The clinical electro-oculogram is an electrophysiological test of function of the outer retina and retinal pigment epithelium in which the change in the electrical potential between the cornea and the fundus is recorded during successive periods of dark and light adaptation.

# HISTORY

- Emil du Bois-Reymond (1848) observed that the cornea of the eye is electrically positive relative to the back of the eye.

- Elwin Marg named the electrooculogram in 1951 and Geoffrey Arden (Arden et al. 1962) developed the first clinical application

- The eye has a standing electrical potential between front and back, sometimes called the corneo-fundal potential. The potential is mainly derived from the retinal pigment epithelium (RPE), and it changes in response to retinal illumination

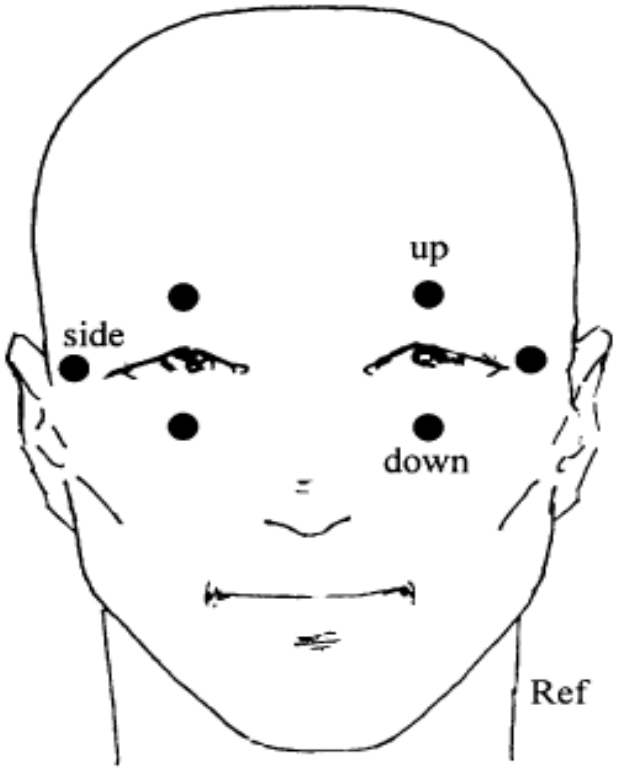
- The potential decreases for 8–10 min in darkness. Subsequent retinal illumination causes an initial fall in the standing potential over 60–75 s (the fast oscillation (FO)), followed by a slow rise for 7–14 min (the light response). These phenomena arise from ion permeability changes across the basal RPE membrane.

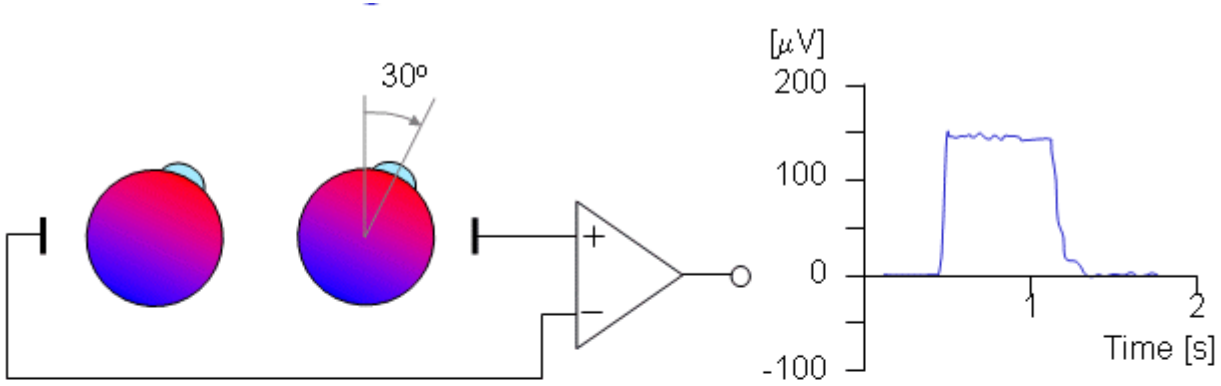
- The clinical electro-oculogram (EOG) makes an indirect measurement of the minimum amplitude of the standing potential in the dark and then again at its peak after the light rise. This is usually expressed as a ratio of ‘light peak to dark trough’ and referred to as the Arden ratio.

# Measurement of the clinical EOG

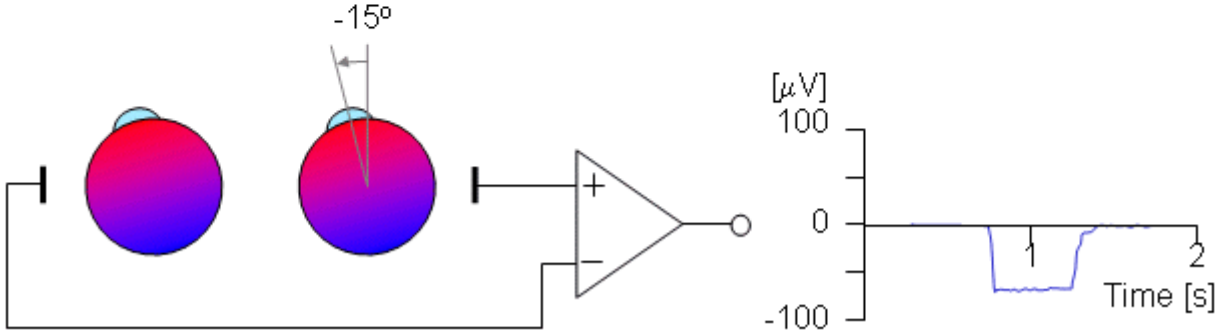
- The calibration of the signal may be achieved by having the patient look consecutively at two different fixation points located a known angle apart and recording the concomitant EOGs .
- By attaching skin electrodes on both sides of an eye the potential can be measured by having the subject move his or her eyes horizontally a set distance .
- Typical signal magnitudes range from 5-20 μV/°.

# Electrode Placement






Eyes moving 30º to the right




Eyes moving 15º to the left

- A ground electrode is attached usually to either the forehead or earlobe.
- Either inside a Ganzfeld, or on a screen in front of the patient, small red fixation lights are place 30 degrees apart .
- The distance the lights are separated is not critical for routine testing.

- The patient should be light adapted such as in an well-illuminated room, and their eyes dilated

- The patient keeps his or her head still while moving the eyes back and forth alternating between the two red lights.

- The movement of the eyes produces a voltage swing of approximately 5 milli volts between the electrodes on each side of the eye, which is charted on graph paper or stored in the memory of a computer.

## EOG eye movement recordings

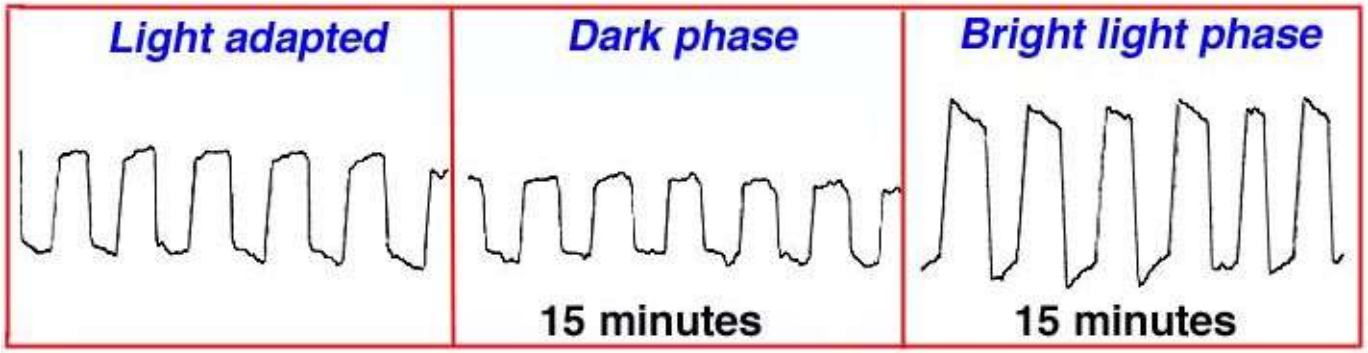



*Fig. 47. Light adapted pre-EOG, dark adaptation phase and light-rise phase.*

# The standard method

- After training the patient in the eye movements, the lights are turned off.
- About every minute a sample of eye movement is taken as the patient is asked to look back and forth between the two lights .
- After 15 minutes the lights are turned on and the patient is again asked about once a minute to move his or her eyes back and forth for about 10 seconds.

# EOG recording of a normal person

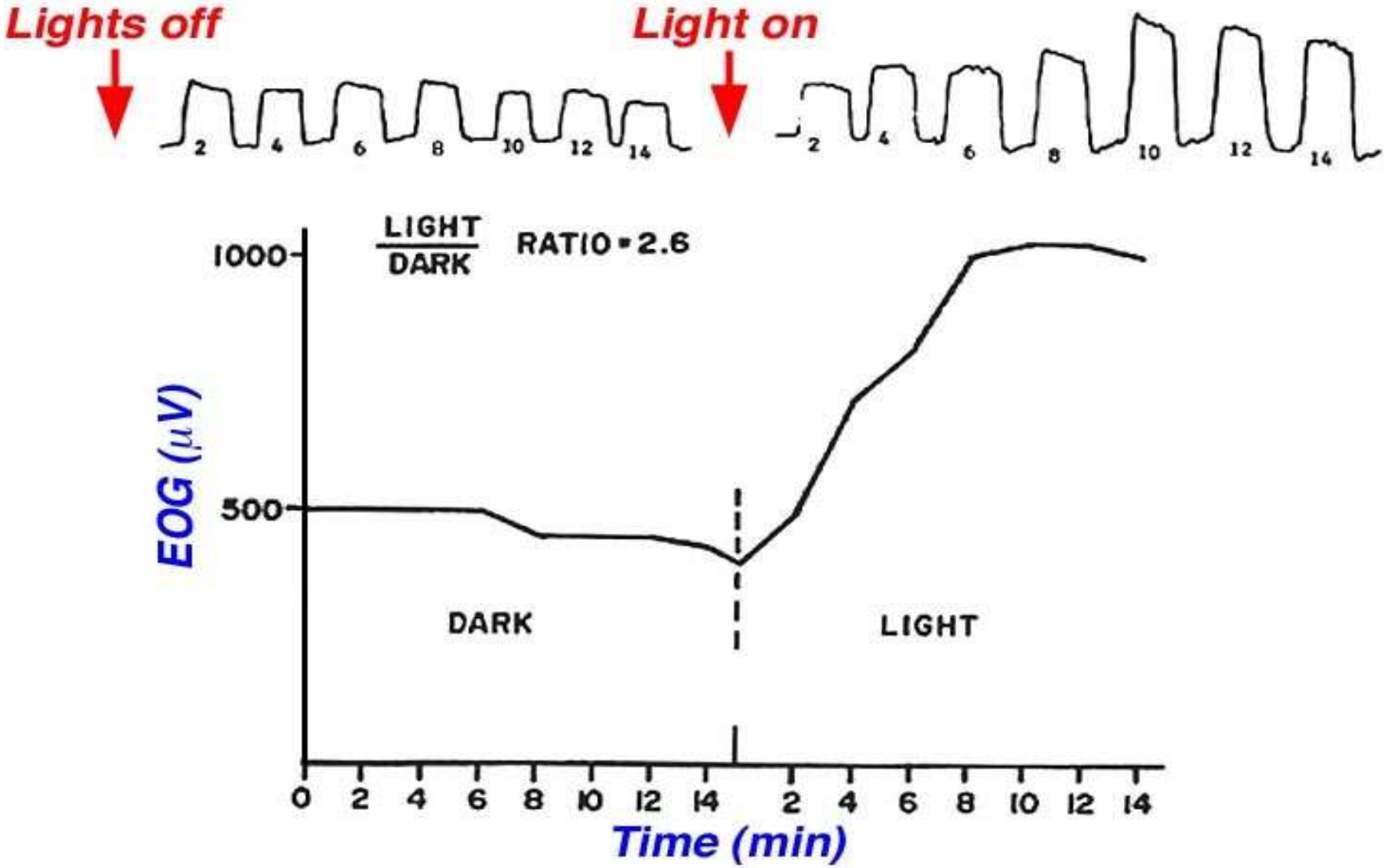



*Fig. 48. Normal EOG recording.*

# The standard method

- Typically the voltage becomes a little smaller in the dark reaching its lowest potential after about 8-12 minutes, the so-called “dark trough”.
- When the lights are turned on the potential rises, the light rise, reaching its peak in about 10 minutes.
- When the size of the "light peak" is compared to the "dark trough" the relative size should be about 2:1 or greater .
- A light/dark ratio of less than about 1.7 is considered abnormal.

# APPLICATIONS

- The light response is affected in:
  - diffuse disorders of the RPE and the photoreceptor layer of the retina including some characterized by rod dysfunction
  - chorio-retinal atrophic and inflammatory diseases

- In most of these there is correlation with the electroretinogram (ERG), except notably in the case of Best's vitelliform maculopathy, in which the clinical EOG is usually highly abnormal in the presence of a normal ERG

- May be an early indicator of Chloroquine toxicity

# Other diseases

- The curves of the EOG of the depressed patients have lower amplitude.
- The normalised mean EOG amplitudes obtained from a group of amblyopic eyes were significantly lower that the normalised mean amplitudes from the fellow eyes at all time points during the EOG recording
- ↓ed Amplitude of EOG seen with use of :

  Mannitol,Acetazolamide,Bicarbonate

# UNIT 2

# CHEMICAL ELECTRODES
# Arterial Blood Gases

## Equipment

**Blood Gas Analyzer**

- Electronic Circuitry
- Electrolyte Solution
- Electrodes

# Arterial Blood Gases

## Equipment

### Electronic circuitry

- Takes electrical current changes produced in the electrodes and provides a visual display

### Electrolyte Solution

- Helps to promote chemical reactions and electrical current

# Arterial Blood Gases

## Equipment

### Electrodes

- Utilized to measure values of ABG

**$pH$, $PCO_2$, $PO_2$**

**All other blood gas values are calculated**

# Arterial Blood Gases

## Equipment

### pH Electrode

- **Sanz Electrode**

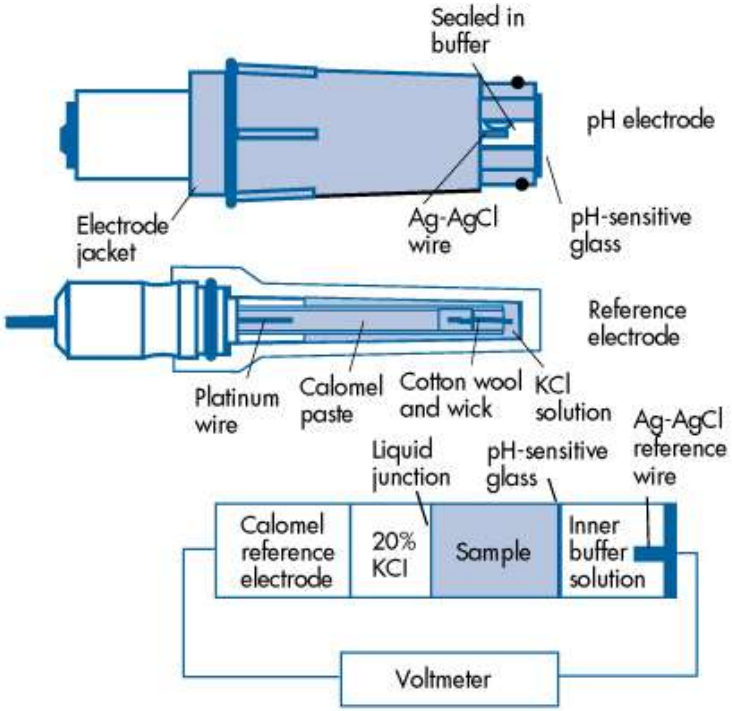
Consists of two electrodes:

- sampling/measuring electrode
- reference electrode and electrolyte solution

# Arterial Blood Gases

The pH electrode is a microelectrode, shown here with its plastic jacket. At the tip is a **silver-silver chloride** wire in a sealed-in buffer behind PH-sensitive quartz glass. The reference electrode contains a **platinum wire** in calomel paste that rests in a 20% **KCL solution**. The blood sample is introduced in such a way that it contacts the measuring electrode tip and the KCL. A voltmeter measure the potential difference across the sample, which is proportional to the pH

## Sanz Electrode (pH)



# Arterial Blood Gases

## Equipment

### $PCO_2$ Electrode

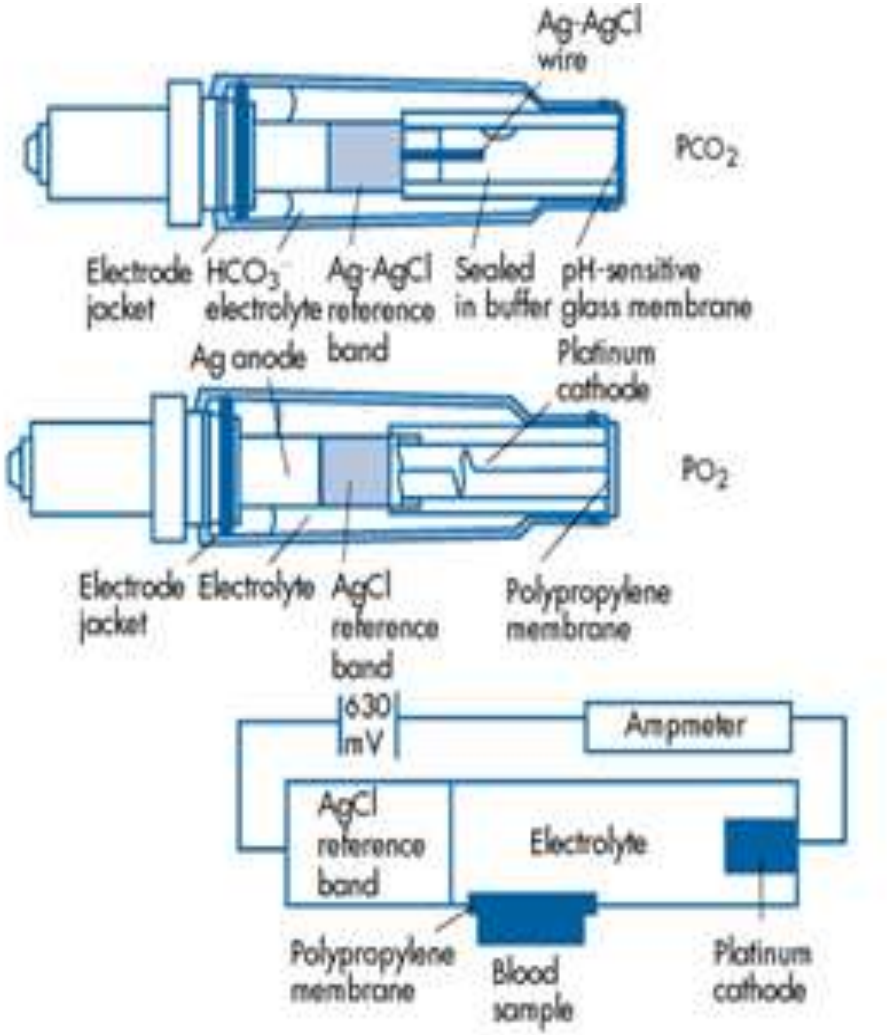
- **Severinghaus Electrode**

  - May also be referred to as a modified Sanz electrode

# Arterial Blood Gases

- The PCO2 electrode is a modified pH electrode.
- The electrode has a sealed-in buffer; an Ag-AgCl reference band is the other half-cell.
- The entire electrode is encased in **Lucite jacket** filled with bicarbonate electrolyte.
- The jacket is capped with a **Teflon membrane** that is permeable to CO2.
- **nylon mesh** covers the pH-sensitive glass, acting as a **spacer** to maintain contact with the electrolyte.
- CO2 diffuses through the Teflon membrane, combines with electrolyte, and alter the pH.
- The change in pH is displayed as partial pressure of CO2.

# Severinghaus Electrode (PCO2)



# Arterial Blood Gases

## Equipment

### PO2 Electrode

- **Clark Electrode**

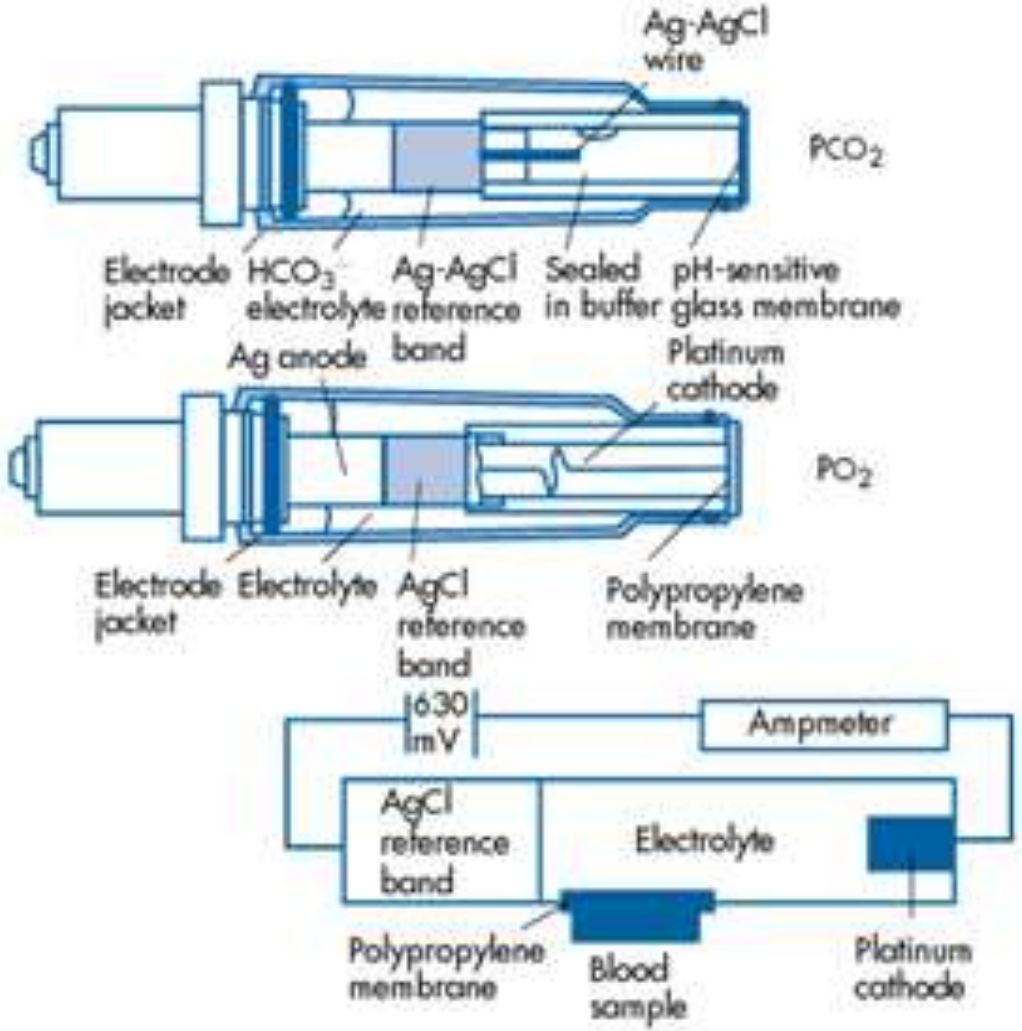
  - May also be referred to as a **polarographic** electrode

    - Periodic/routing cleaning of the tip with **pumice** is required because polypropylene attracts protein

# Arterial Blood Gases

- The PO2 electrode contains a **platinum cathode** and a **silver anode**.
- The electrode is polarized by applying a slightly negative voltage of approximately 630 mV.
- The tip is protected by a **polypropylene membrane** that allows O2 molecules to diffuse but prevents contamination of the platinum wire.
- O2 migrates to the cathode and is reduced, picking up free electrons that have come from the anode through a phosphate-potassium chloride electrolyte.
- Changes in the current flowing between the anode and cathode result from the amount of O2 reduced in the electrolyte and are proportional to partial pressure of O2.

# Clark Electrode (PO2)



# Arterial Blood Gases

## Calibration Procedures

To assure appropriate electronic function of the electrodes, calibration procedures are performed

- Performed automatically every 30 minutes by the ABG machine
- Performed on the pH, $PCO_2$, $PO_2$ electrodes
- Specific procedure for each electrode

# Arterial Blood Gases

## Calibration Procedures

- 2-Point Calibration
  - A “low” concentration and a “high” concentration is used at both ends of the physiological range to be measured
- Multiple-Point Calibration (3 or more points)
  - Verifies whether the gas analyzer is linear or not

# Arterial Blood Gases

## Calibration Procedures

### pH Electrode

- Uses two specific buffers with approximate values of:
  - 6.840 buffer
    - referred to as the zero point or low point buffer
  - 7.384 buffer
    - high point or slope point buffer

# Arterial Blood Gases

## Calibration Procedures

### pH Electrode

- Each buffer is injected into the sample chamber, one at a time
- The values of the buffer that is injected, should be displayed on the ABG machine within a specific SD (standard deviation)

# Arterial Blood Gases

## Calibration Procedures

### pH Electrode

- Standard deviation for pH is ± .005
- If value displayed is within the SD, machine is electronically calibrated
- If value displayed is outside of the SD, machine needs to be adjusted to assure electronic function

# Arterial Blood Gases

## Calibration Procedures

### $PO_2$ & $PCO_2$ Electrode

- Uses two specific concentration of gases for each electrode with approximate concentrations of $CO_2$ and $O_2$
- Uses two different tanks of gas to accomplish this

# Arterial Blood Gases

## Calibration Procedures

### $PO_2$ & $PCO_2$ Electrode

- **Tank One**
  - Low $CO_2$ (5%) - balance
  - High $O_2$ (12% or 20%)
  - Balance Nitrogen

- **Tank Two**
  - High $CO_2$ (10%) – slope
  - $O_2$ (0%)
  - Balance Nitrogen

# Arterial Blood Gases

## Calibration Procedures

### PO2 & PCO2 Electrode

- **Must convert tank concentration from % to mm Hg**

**($P_B - P_{H_2O}$) x tank concentration = mm Hg**

**(760 – 47) x 0.12 = 85.65 mm Hg**

# Arterial Blood Gases

## Calibration Procedures

### $PO_2$ & $PCO_2$ Electrode

- The values calculated for the $CO_2$ and $O_2$ concentration should be displayed on the ABG analyzer within a specific SD (standard deviation)

# Arterial Blood Gases

## Calibration Procedures

### PO2 & PCO2 Electrode

- Standard deviation for $PO_2$ and $CO_2$ is $\pm$ 0.5
- If values displayed are within the SD, machine is electronically calibrated
- If value displayed is outside of the SD, machine needs to be adjusted to assure electronic function

# Arterial Blood Gases

## Calibration Procedures

### Troubleshooting

- **If the ABG machine will not calibrate, check:**
  - The buffers
  - The mixed gases
  - The electrode's membrane
  - The electrode itself

# Arterial Blood Gases

## Quality Control

### Calibration vs. Quality Control

- Calibration is when the **equipment is adjusted or corrected** to match the control standards
- Quality Control testing must be performed on a regular basis to determine the **accuracy** and **precision** of the equipment against a known standard

# Arterial Blood Gases

## Quality Control

### Accuracy vs. Precision

- Accuracy refers to the mean (average) value of several measurements
- Precision refers to how consistently the same measurement will produce the same results

# Arterial Blood Gases

**Quality Control**

- Must be run every shift
- Utilize a known concentration of gases and buffers in a vial of liquid
- Run three levels of QC
  - Level 1 – Acidosis
  - Level 2 – Normal
  - Level 3 - Alkalosis

# Arterial Blood Gases

**Quality Control**

- When QC is run it must be recorded and maintained onsite; in the ABG laboratory

- Must be available for review by State agencies on demand

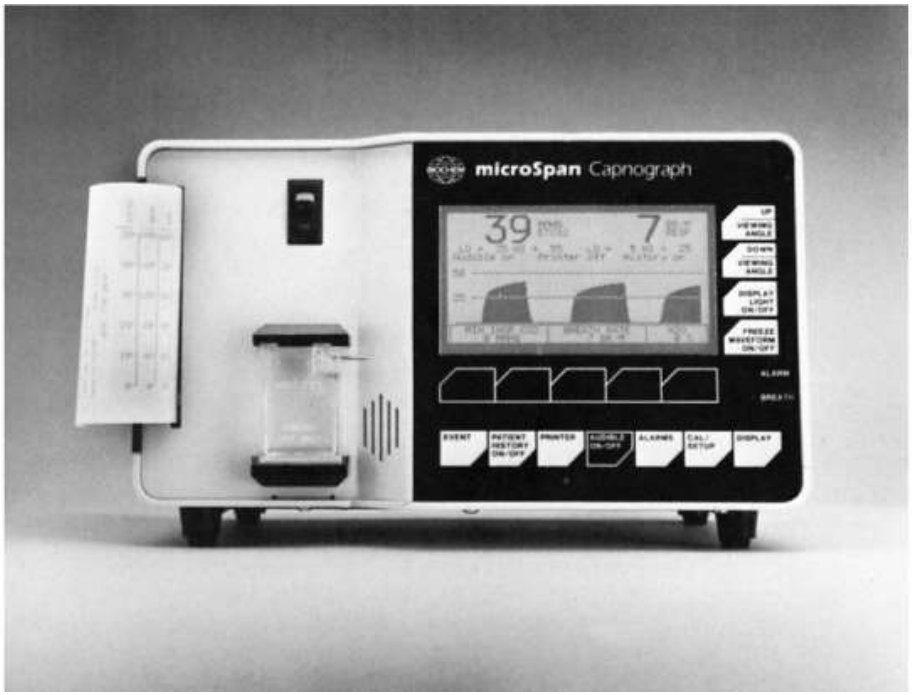
# Arterial Blood Gases

**Quality Control Plotting**

- In control
- Trend
- Random Error
- Out of Control

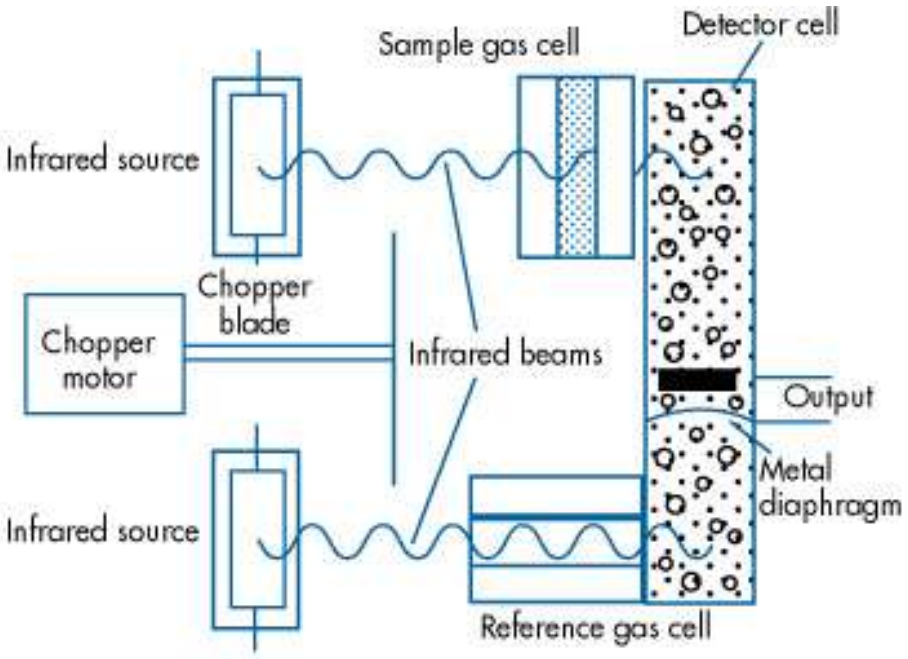
# Capnography

- **Capnography is the continuous, noninvasive monitoring of expired CO2 and analysis of the single-breath CO2 waveform**



# Capnography

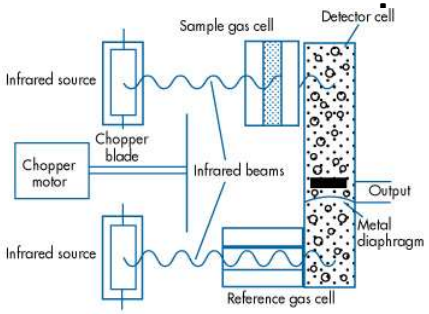
- **Capnography is performed utilizing:**
  - **Infrared analyzer**
    - **CO and CO2 absorb infrared radiation**



# Capnography

- **Capnography is performed utilizing:**
  - **Infrared analyzer**
    - **Requires accurate calibration**
      - **2 gas concentrations used**
        - **Room air**
        - **5% CO2 mixture**

    - **Inaccurate reading can occur when:**
      - **Condensation of water in sample tubing, connectors, or sample chamber**
      - **Flow changes after calibration**
      - **Saturation of a desiccant column**
      - **g sampling lines can cause waveform damping**



# ELECTROPHORESIS

# DEFINITIONS

## Electrophoresis

- Migration of charged solutes in a liquid medium under an electrical field
- Many biological molecules have ionisable groups eg. amino acids, proteins, nucleotides, nucleic acids
- Under an electric field -> charged particles migrate to anode (+) or cathode (-)

# Zone Electrophoresis

- Migration of charged molecules
- Support medium
  - porous eg. CA or agarose
  - can be dried & kept
- Same pH & field strength thru'out
- Separation based on electrophoretic mobility
- Separates macromolecular colloids eg. proteins in serum, urine, CSF, erythrocytes; nucleic acids

# Isotachophoresis

- Migration of small ions
- Discontinuous electrolyte system
  - leading electrolyte ($L^-$ ions) &
  - trailing electrolyte ($T^-$ ions)
- Apply sample solution at interphase of L & T
- Apply electric field -> each type of ion arrange between L and T ions -> discrete zones
- Separates small anions, cations, organic & amino acids, peptides, nucleotides, nucleosides, proteins

# THEORY of ELECTROPHORESIS

- Many biological molecules exist as
  (a) cations or (b) anions

- Solution with pH < pI
  -> ampholyte/zwitterion has overall +ve charge

- Solution with pH > pI
  -> ampholyte has overall –ve charge

- Under an electric field
  -> cations/overall +ve migrate to cathode
  -> anions/overall -ve migrate to anode

# THEORY of ELECTROPHORESIS

- Rate of migration depends on:
  - Net electrical charge of molecule
  - Size & shape of molecule
  - Electric field strength
  - Properties of supporting medium
  - Temperature of operation

# ELECTROPHORETIC TECHNIQUE

Instrumentation & Reagents

- Buffer boxes with buffer plates -> holds buffer
- Platinum or carbon electrode -> connected to power supply
- Electrophoresis support -> with wicks to contact buffer
- Cover -> minimize evaporation (Fig 7-1)

## Power Supplies

- Power pack: supply current between electrodes
- Flow of current -> Heat produced
  - increase in migration rate -> broadening of separated samples
  - formation of convection currents -> mixing of separated samples
  - thermal instability of heat sensitive samples
  - water loss -> concn of ions -> decrease of buffer viscosity -> decrease in resistance
- To minimize problems: use constant-current power supply

## Buffers

- To carry applied current & to fix the pH
  => determine electrical charge & extent of ionization => which electrode to migrate
- Ionic strength of buffer
  - thickness of ionic cloud -> migration rate -> sharpness of electrophoretic zones
  - [ion] ↑ -> ionic cloud ↑ -> movement of molecules ↓
- Barbital buffers & Tris-boric acid-EDTA buffers

## Protein Stains

- To visualize/locate separated protein fractions
- Dyes: amount taken up depends on
  - Type of protein
  - Degree of denaturation of proteins by fixing agents

Types of stains:  Table 7-1

# GENERAL PROCEDURES

Separation

- Place support material in EP chamber
- Blot excess buffer from support material
- Place support in contact with buffer in electrode chamber
- Apply sample to support

- Separate component using constant voltage or constant current for length of time

- Remove support, then
  -> dry or place in fixative
  -> treat with dye-fixative
  -> wash excess dye
  -> dry (agarose) or put in clearing agent (CA membs)

## Detection & Quantitation

- Express as
  - % of each fraction present or
  - absolute concn

- By densitometry
  - electrophoretic strip moved past an optical system
  - absorbance of each fraction displayed on recorder chart

# TYPES OF ELECTROPHORESIS

a. Agarose Gel Electrophoresis
b. Cellulose Acetate Electrophoresis
c. Polyacrylamide Gel Electrophoresis
d. Isoelectric Focusing
e. Two-dimensional Electrophoresis

# Agarose Gel Electrophoresis (AGE)

- Use agarose as medium
  - low concns -> large pore size
  - higher concns -> small pore size
- Serum proteins, Hb variants, lactate dehydrogenase, CK isoenzymes, LP fractions
- Pure agarose - does not have ionizable groups -> no endosmosis

- Advantages:
  - low affinity for proteins
  - shows clear fractions after drying
  - low melting temp -> reliquify at 65$^{o}$C

- Disadvantage:
  - poor elasticity

    -> not for gel rod system

    -> horizontal slab gels

# Cellulose Acetate Electrophoresis (CAE)

- Cellulose + acetic anhydride -> CA
- Has 80% air space -> fill with liquid when soaked in buffer
- Can be made transparent for densitometry
- Advantages:
  - speed of separation
  - able to store transparent membranes
- Disadvantages:
  - presoaking before use
  - clearing for densitometry

- Method:
  - wet CA in EP buffer
  - load sample about 1/3 way along strip
  - stretch CA in strips across a bridge
  - place bridge in EP chamber -> strips dip directly into buffer
  - after EP, stain, destain, visualise proteins

- For diagnosis of diseases
  - change in serum protein profile

# Polyacrylamide Gel Electrophoresis (PAGE)

- Tubular-shaped EP cell
  -> pour small-pore separation gel
  -> large-pore spacer gel cast on top
  -> large-pore monomer solution + ~3ul sample
  on top of spacer gel

- Electrophoresis
  -> all protein ions migrate thru large-pore gels
  -> concentrate on separation gel
  -> separation due to retardation of some
  proteins

- Average pore size in 7.7% PAGE separation gel about 5nm
  -> allow most serum proteins to migrate
  -> impedes migration of large proteins eg
  fibrinogen, $\beta_1$-lipoprotein, $\alpha_2$-macroglobulin
- Advantages:
  - thermostable, transparent, strong, chemically inert
  - wide range of pore sizes
  - uncharged -> no endosmosis
- Disadvantages:
  - carcinogenic

# Isoelectric Focusing

- To separate amphoteric cpds eg. proteins
- Proteins moves to zone where:

  pH medium = pI protein => charge = 0

- pI of protein confined in narrow pH range -> sharp protein zones
- Method:
  - use horizontal gels on glass/plastic sheets
  - introduce ampholytes into gel -> create pH gradient

- apply a potential difference across gel
- anode -> area with lowest pH
- cathode -> area with highest pH
- proteins migrate until it arrives at pH = pI
- wash with fixing solution to remove ampholytes
- stain, destain, visualise

- Separations of proteins with 0.01 to 0.02pH unit differences (Fig 7-4)

# Two-Dimensional (2D) EP (ISO-DALT)

- 1st D using IEF EP -> in large-pore medium
  -> ampholytes to yield pH gradient
- 2nd D using molecular weight-dependent EP
  -> in polyacrylamide -> linear or gradient
- O'Farrell method:
  - use β-mercaptoethanol (1st D) & SDS (2nd D)
- Detect proteins using Coomassie dyes, silver stain, radiography, fluorography
- Separates 1100 spots (autoradiography)

# AUTO ANALYSER

# Purpose of Autoanalyzer

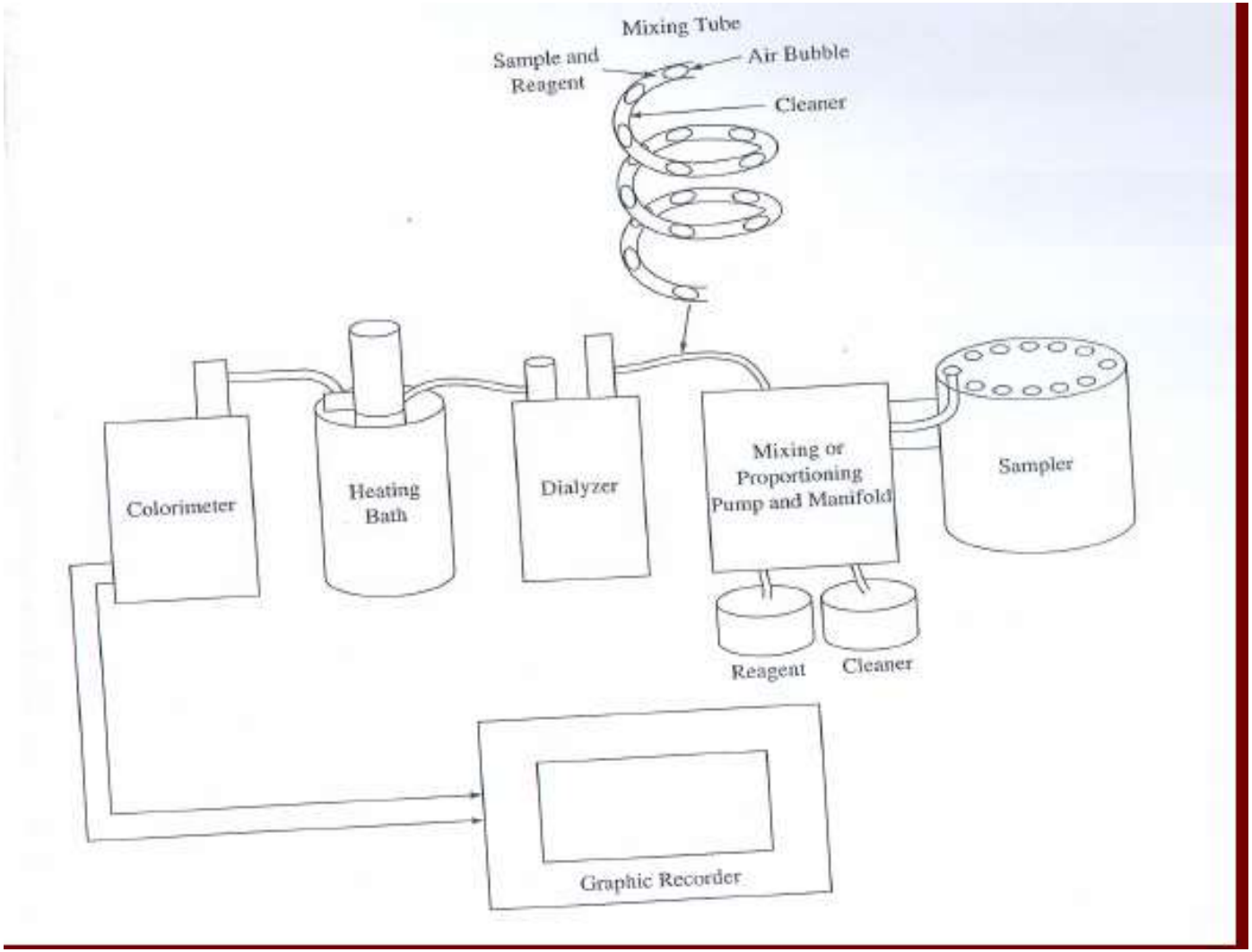
- The autoanalyzer is sequentially measures blood chemistry and displays this on a graphic readout
- This is accomplished by

– Mixing
– reagent
– Reaction
– Colorimetric measurement in continuous stream

# Elements of Autoanalyzer

- Sampler
- Proportioning pump and manifold
- Dialyzer
- Heating bath
- Colorimeter
- Record

# Schematic


Mixing Tube
Sample and Reagent
Air Bubble
Cleaner
Colorimeter
Heating Bath
Dialyzer
Mixing or Proportioning Pump and Manifold
Sampler
Reagent
Cleaner
Graphic Recorder

# Sampler

- Aspirates samples, standards, and wash solutions to the auto analyzer system.

# Proportioning pump

- Introduces samples with reagents to effect the proper chemical color reaction to be read by the colorimeter.
- Pumps fluids at precise flow rates to other modules, as proper color development depends on reaction time and temperature

# Dialyzer

- Separates interfacing substances from the sample material by permitting selective passage of sample components through a Semi-permeable membrane

# Heating bath

- Heats fluids continuously to exact temperature (37 degree).

# Colorimeter

- Monitors the changes in optical density of the fluid stream flowing through a tubular flow cell.
- Color intensities proportional to substance concentrations
- Colorimeter convert the color intensity to equivalent electrical voltages

# Recorder

- Converts the electrical signal from the colorimeter into a graphic display on moving chart

# Problems

- Identification of samples
- Sterilization for sample and glassware and equipment parts

# Maintenance

- Calibration and adjustment
- Mechanical
  - Tubing
  - Moving pump parts
- Electrical
  - Switches
  - Motors
- Electronic failures are few

# Note

- A patient’ s life may hinge on accurate measurement obtained by clinical instrumentation.
- Biomedical equipment technician must complete the manufacturer’s schools.

# CARDIAC OUTPUT

# Cardiac Output, Venous Return and their Regulation

- Cardiac output is controlled to maintain the proper amount of flow to tissues and to prevent undue stress on the heart.

# Cardiac Output

- Generally proportional to body surface area.
- Cardiac Index (CI): Approximately 3 liters/min/$m^2$ of body surface area.
- CI varies with age, peaking at around 8 years.

# Frank-Starling Law

- What goes into the heart comes out.

- Increased heart volume stretches muscles and causes stronger contraction.

- Stretch increases heart rate as well.
- Direct effect on sino-atrial node
- Bainbridge reflex (through the brain)

# Cardiac Output

- Depends on venous return, which, in turn, depends on the rate of flow to the tissues.

- Rate of flow to tissues depends on tissue needs (i.e. it depends on Total Peripheral Resistance). Therefore, cardiac output is proportional to the energy requirements of the tissues.

# Limit of Cardiac Output

- Normal CO – 5 L/min
- Plateau – 13 L/min
- Hypereffective heart plateau – 20 L/min
- Hypoeffective heart plateau – 5 L/min

# Hypereffective Heart

- Effected by:

1. Nervous excitation.
2. Cardiac Hypertrophy
   - Exercise – Marathon runners may get 30 to 40 L/min
   - Aortic Valve Stenosis

# Hypoeffective Heart

- Valvular disease
- Increased output pressure
- Congential heart disease
- Myocarditis
- Cardiac anoxia
- Toxicity

# Autonomic Nervous System

- Causes increased cardiac output when vessels become dilated (dinitrophenol).

- Causes venous constriction during exercise.

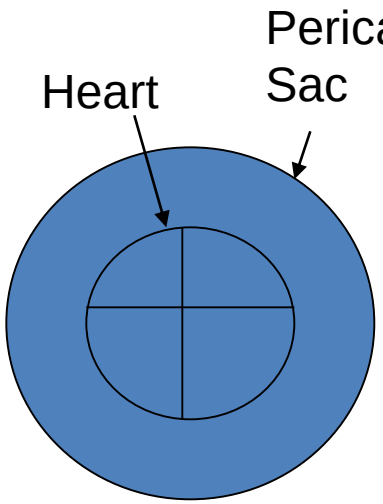
# Disease States Lowering Total Peripheral Resistance

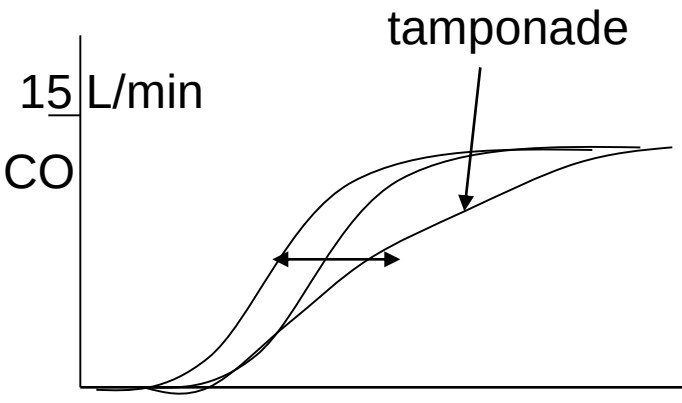
- Beriberi: insufficient thiamine – tissues starve because they cannot use nutrients.
- AV fistula: e.g. for dialysis.
- Hyperthyroidism: Reduced resistance caused by increased metabolism
- Anemia (lack of RBCs): effects viscosity and transport of $O_2$ to the tissues.

# Disease States Lowering Cardiac Output

- Heart attack, valvular disease, myocarditis, cardiac tamponade, shock.
- **Shock:** Nutritional deficiency of tissues.
- Decreased venous return caused by:
  - Reduced blood volume
  - Venous dilitation (increased circulatory volume)
  - Venous obstruction

# Changes in Intrapleural Pressure

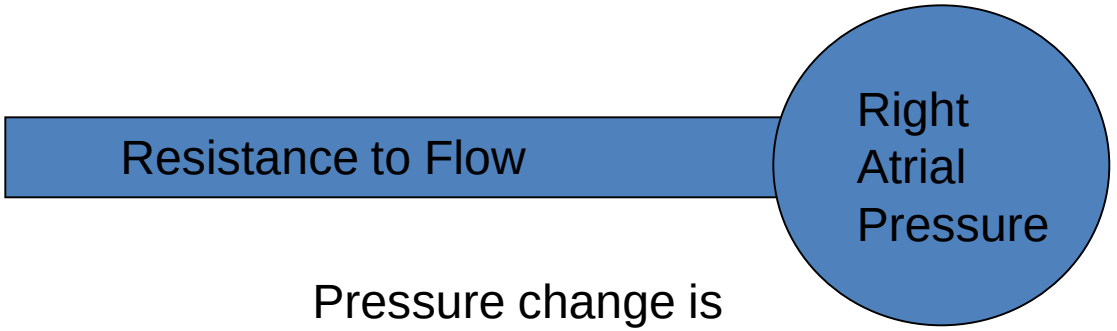



- Generally shift the cardiac output curve in proportion to pressure change (*breathing*, *Valsalva maneuver*).
- Cardiac Tamponade (filling of pericardial sac with fluid) lowers rate of change of CO with right atrial pressure

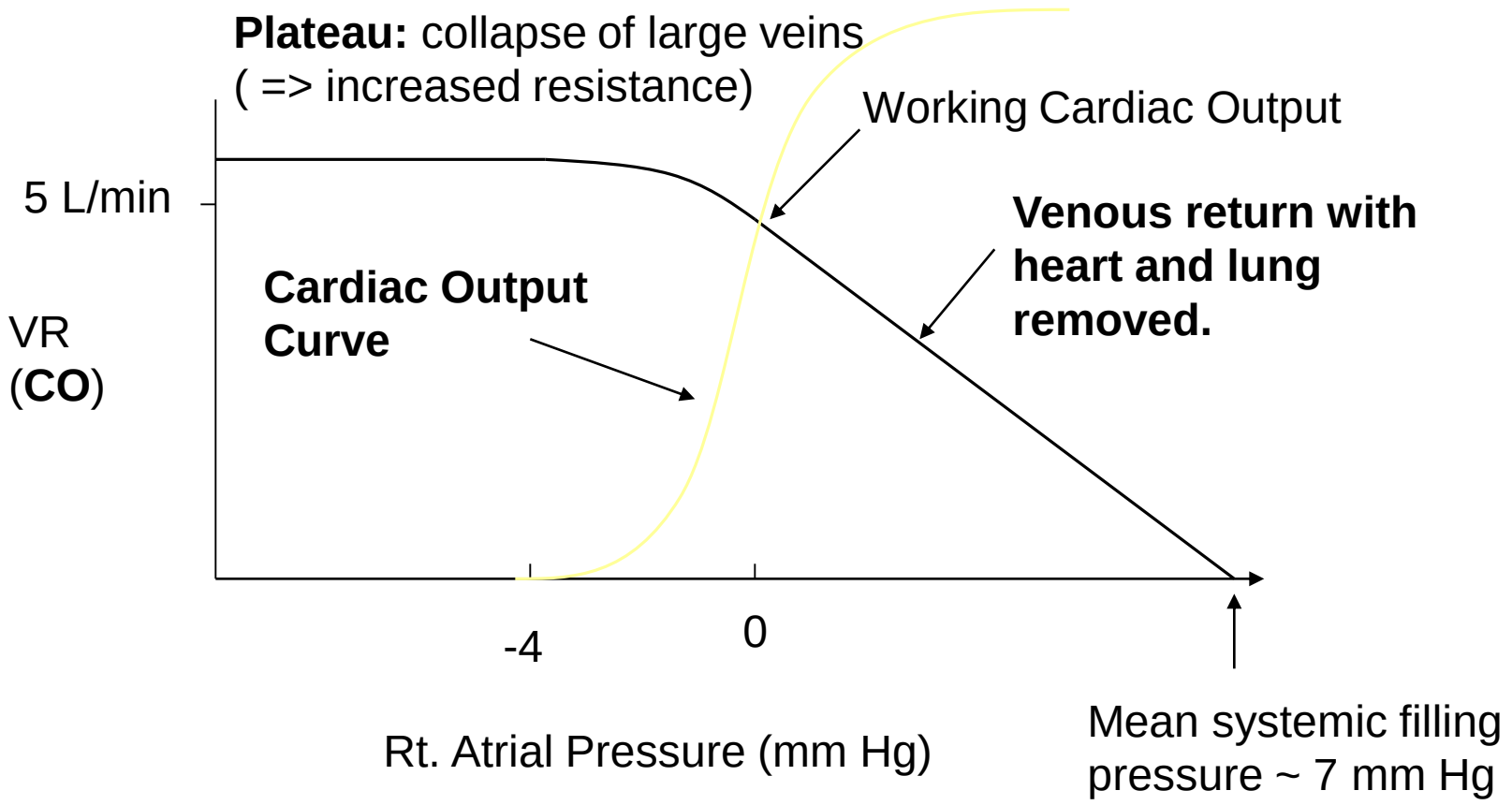
# Determinants of Venous Return

Mean systemic filling pressure




Pressure change is slight. Thus, small increase in RA Pressure causes dramatic reduction in venous return. (mean systemic filling pressure).

# Normal Venous Return Curve



# Filling Pressure

- Mean Circulatory: The pressure within the circulatory system when all flow is stopped (e.g. by stopping the heart).

- Mean Systemic: Pressure when flow is stopped by clamping large veins.

- The two are close numerically.

# Venous Return & Cardiac Output

- Cardiac output increases with atrial pressure.
- Normal atrial pressure is about 0 mm Hg.
- Venous return (with heart and lungs removed) decreases with atrial pressure.
- Working cardiac output is where venous return curve meets cardiac output curve.

# Compensation for Increased Blood Volume

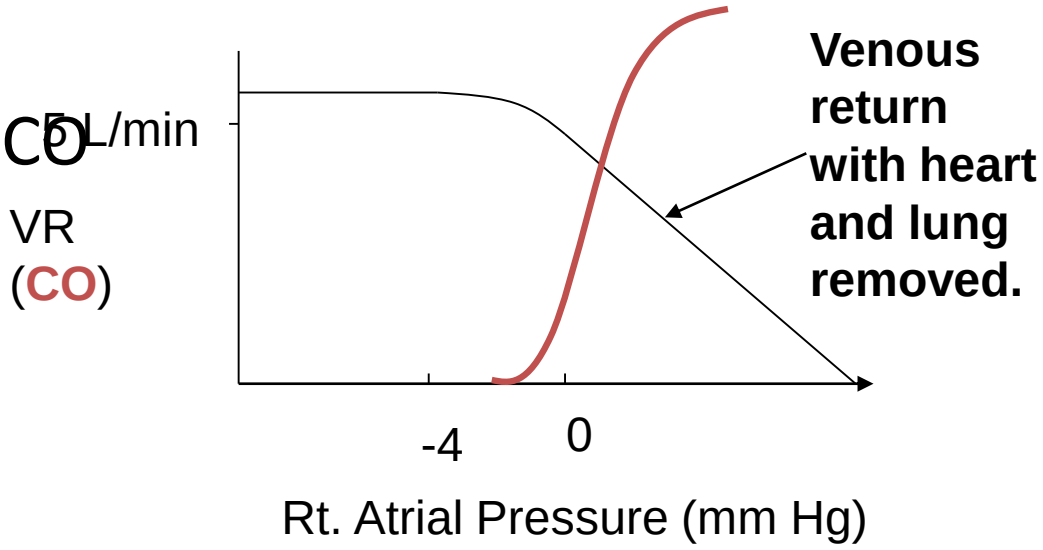
1. Increased CO increases capillary pressure, sending more fluid to tissues.
2. Vein volume increases
3. Pooling of blood in the liver and spleen
4. Increased peripheral resistance reduces cardiac output.

# Effects of Sympathetic Stimulation

- Increases contractility of the heart.
- Decreases volume by contracting the veins.
- Increases filling pressure
- Increases resistance

# Effects of Sympathetic Inhibition

- Shifts CO to the right
- Shifts venous return down and to the left
- - Reduced CO



# Effects of AV Fistula

1. Decreased VR resistance.
2. Slight increased CO because of reduced peripheral resistance.
3. After restoration of pressure (sympathetic)
4. Further CO increase.
5. Increased filling pressure.
6. Decreased kidney output (leads to higher fluid volume and more increase in CO).
7. Cardiac hypertrophy (caused by increased workload).

- Electromagnetic/ultrasonic (transit time) flow meter.
- **Oxygen Fick method:**
- $$CO = \frac{\text{(Rate of O2 absorbed by lungs)}}{[O2]_{la} - [O2]_{rv}}$$

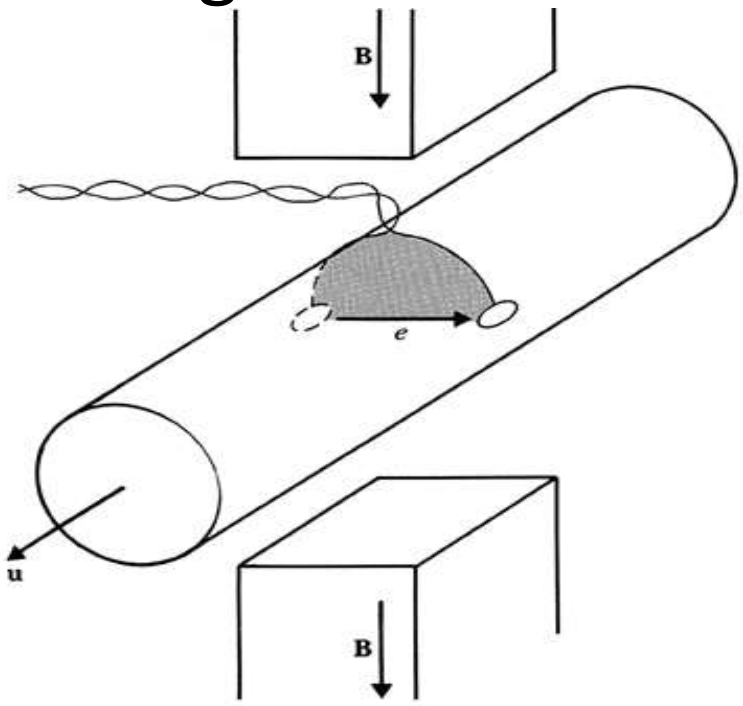
- **Indicator dilution method:**
- Inject cold saline (or dye) into RA, measure temperature (or concentration) in aorta.

# BLOOD FLOWMETER

# Electromagnetic Flowmeters

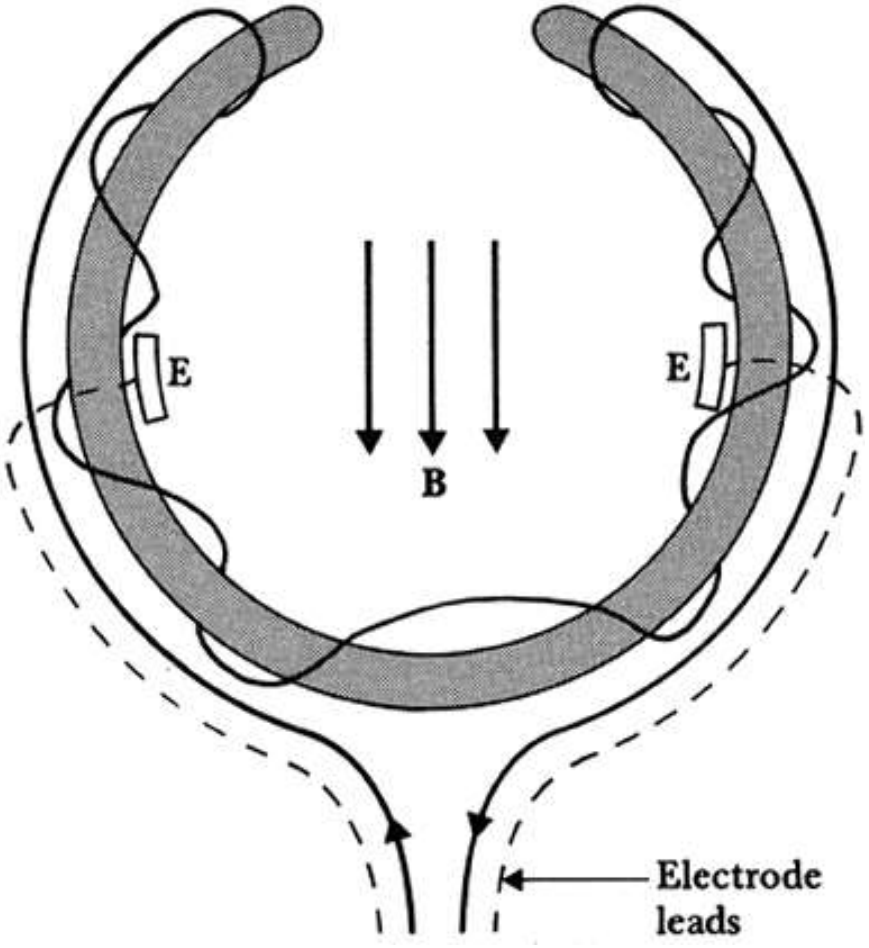
- Based on Faraday's law of induction that a conductor that moves through a uniform magnetic field, or a stationary conductor placed in a varying magnetic field generates *emf* on the conductor:

$$e = \int_0^L \mathbf{u} \times \mathbf{B} \cdot d\mathbf{L}$$




For uniform **B** and uniform velocity profile **u**, the induced emf is $e=BLu$. Flow can be obtained by multiplying the blood velocity $u$ with the vessel cross section $A$.

# Electromagnetic Flowmeter Probes



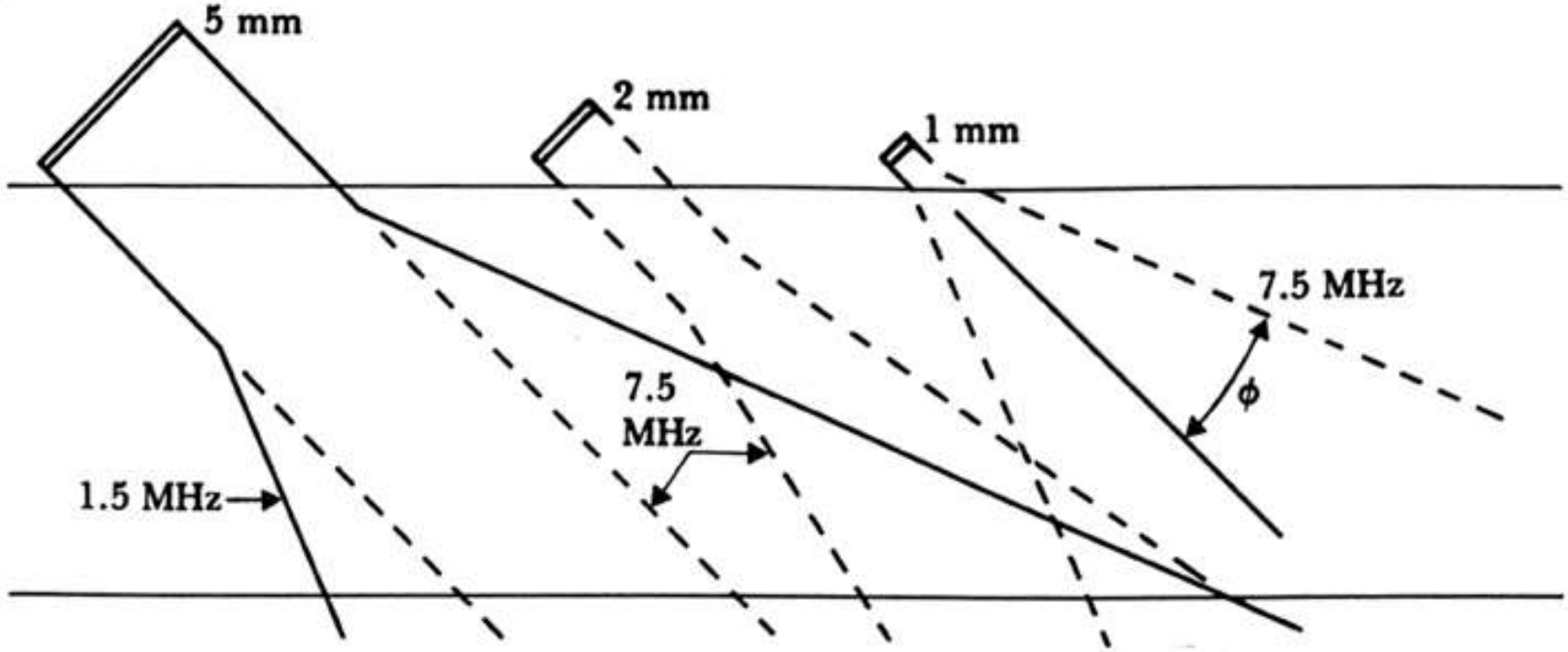

- Comes in 1 mm increments for 1 ~ 24 mm diameter blood vessels
- Individual probes cost $500 each
- Made to fit snuggly to the vessel during diastole
- Only used with arteries, not veins, as collapsed veins during diastole lose contact with the electrodes
- Needless to say, this is an INVASIVE measurement!!!
- A major advantage is that it can measure instantaneous blood flow, not just average flow

# Ultrasonic Flowmeters

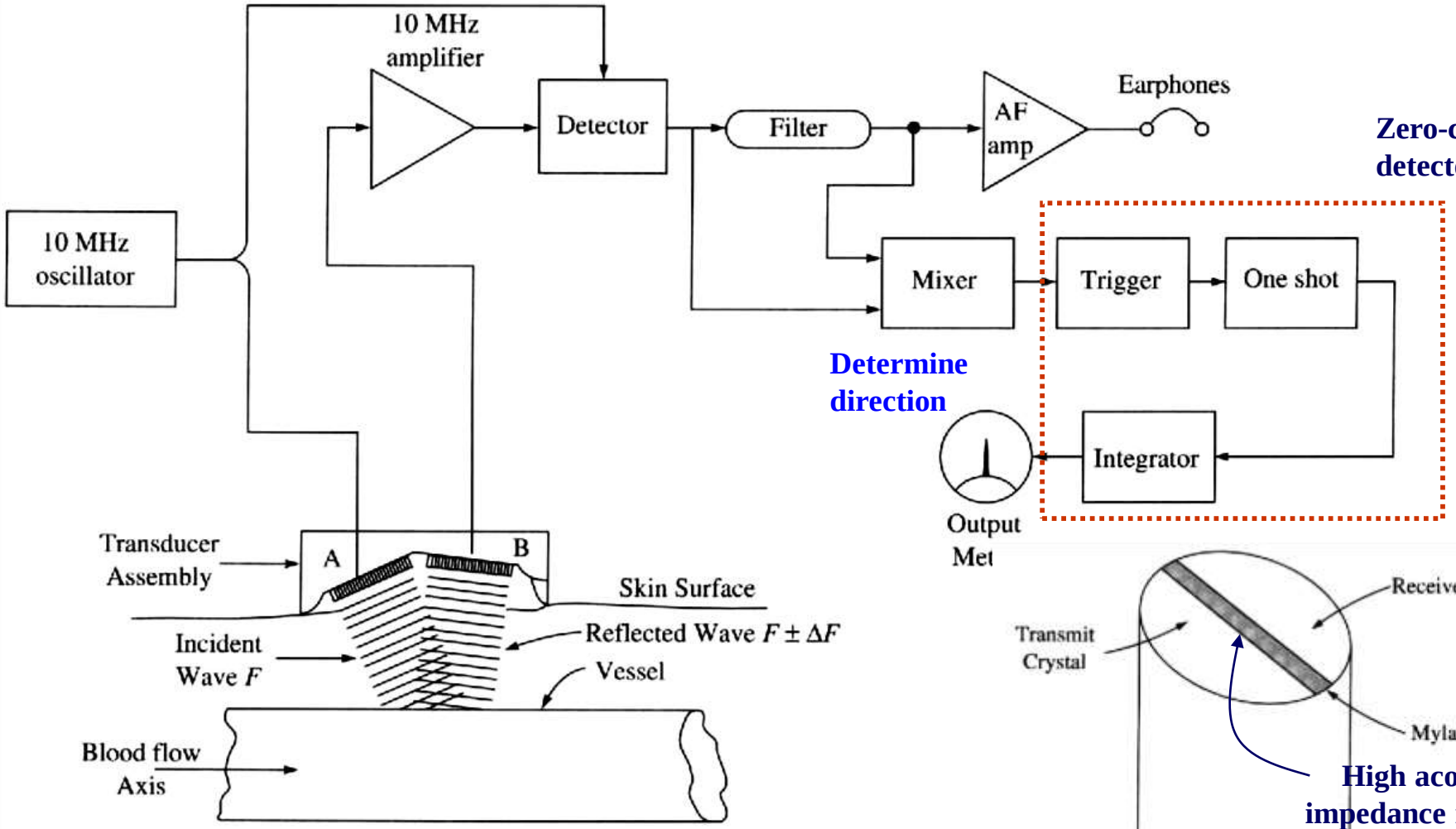
- Based on the principle of measuring the time it takes for an acoustic wave launched from a transducer to bounce off red blood cells and reflect back to the receiver.
- All UT transducers, whether used for flowmeter or other applications, invariably consists of a piezoelectric material, which generates an acoustic (mechanical) wave when excited by an electrical force (the converse is also true)
- UT transducers are typically used with a gel that fills the air gaps between the transducer and the object examined

# Near / Far Fields

- Due to finite diameters, UT transducers produce diffraction patterns, just like an aperture does in optics.
- This creates near and far fields of the UT transducer, in which the acoustic wave exhibit different properties
  - The near field extends about $d_{nf}=D^2/4\lambda$, where $D$ is the transducer diameter and λ is the wavelength. During this region, the beam is mostly cylindrical (with little spreading), however with nonuniform intensity.
  - In the far field, the beam diverges with an angle $\sin\theta=1.2\ \lambda/D$, but the intensity uniformly attenuates proportional to the square of the distance from the transducer


5 mm
2 mm
1 mm
7.5 MHz
ϕ
7.5
MHz
1.5 MHz

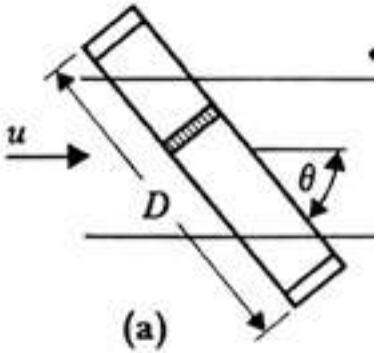
# UT Flowmeters



# Transit time flowmeters

Effective velocity of sound in blood: velocity of sound (c) + velocity of flow of blood averaged along the path of the ultrasound (û)

û=1.33ū for laminar flow, û=1.07ū for turbulent flow
ū: velocity of blood averaged over the cross sectional area, this is different than û because the UT path is along a single line not over an averaged of cross sectional area



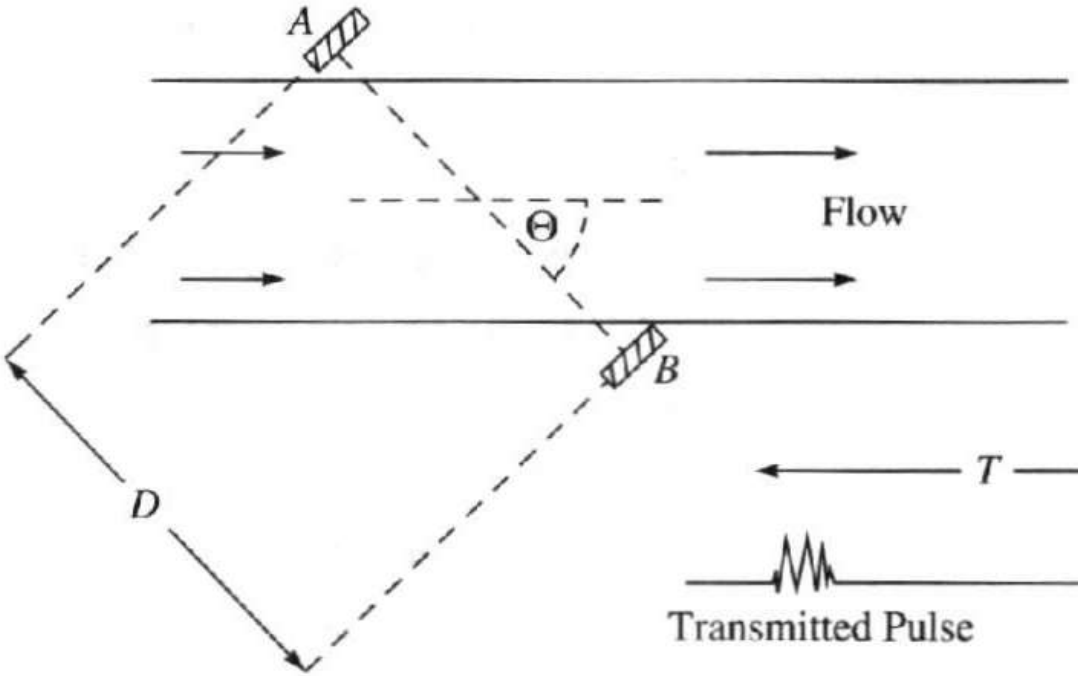

Transit time in up/down stream direction:

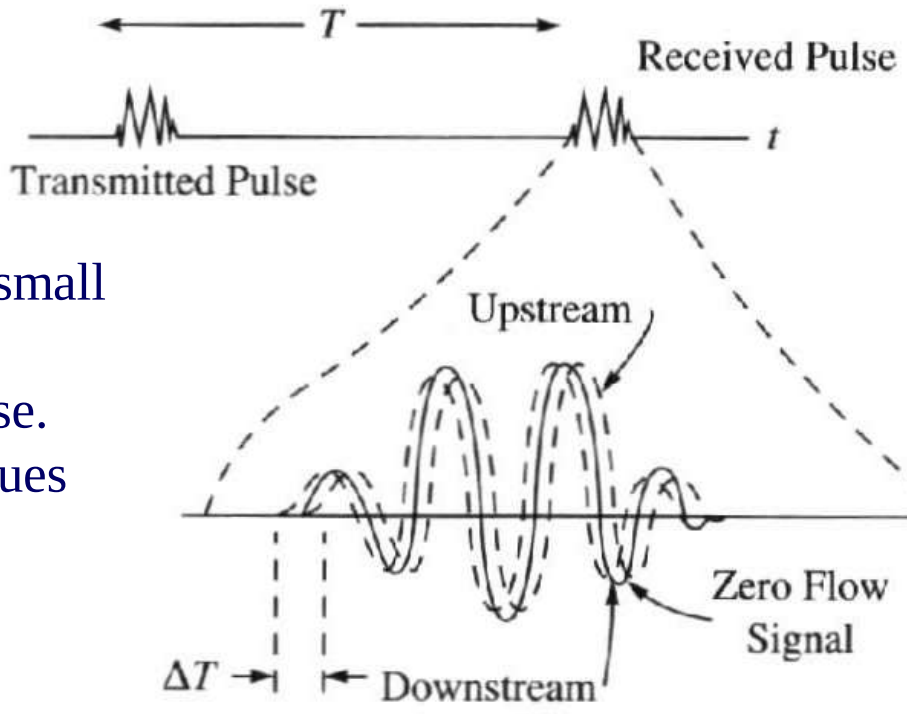
$$t = \frac{\text{distance}}{\text{conductionvelocity}} = \frac{D}{c \pm \hat{u}\cos\theta}$$

Difference between upstream and downstream directions

$$\Delta t = \frac{2D\hat{u}\cos\theta}{(c^2 - \hat{u}^2\cos^2\theta)} \cong \frac{2D\hat{u}\cos\theta}{c^2}$$

# Transit Time Flowmeters

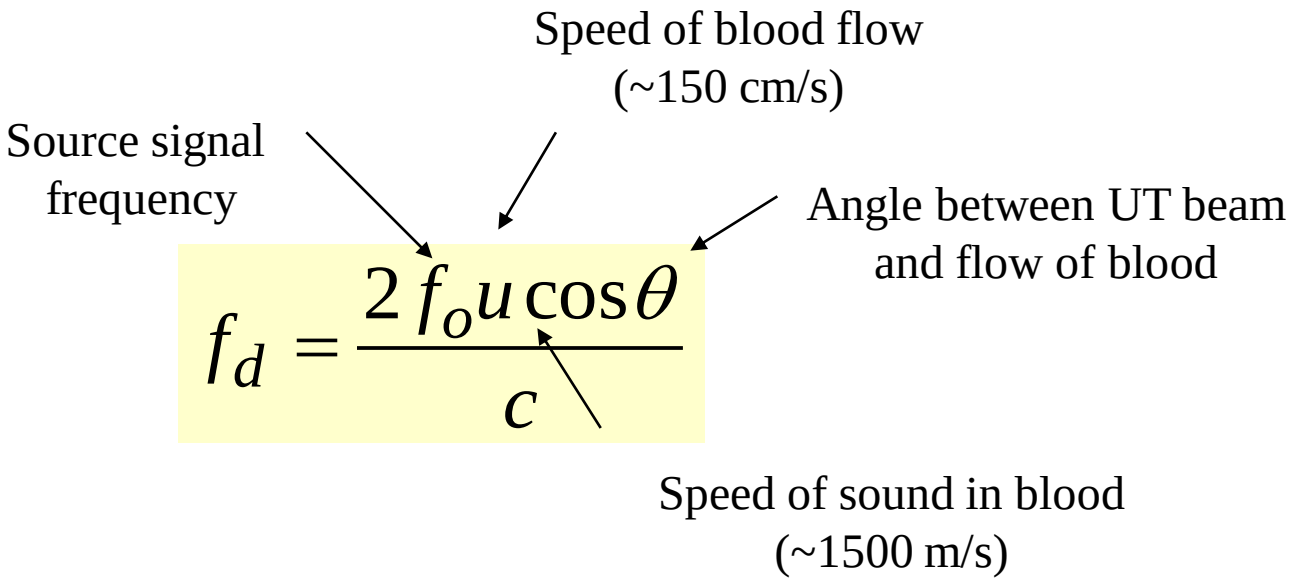


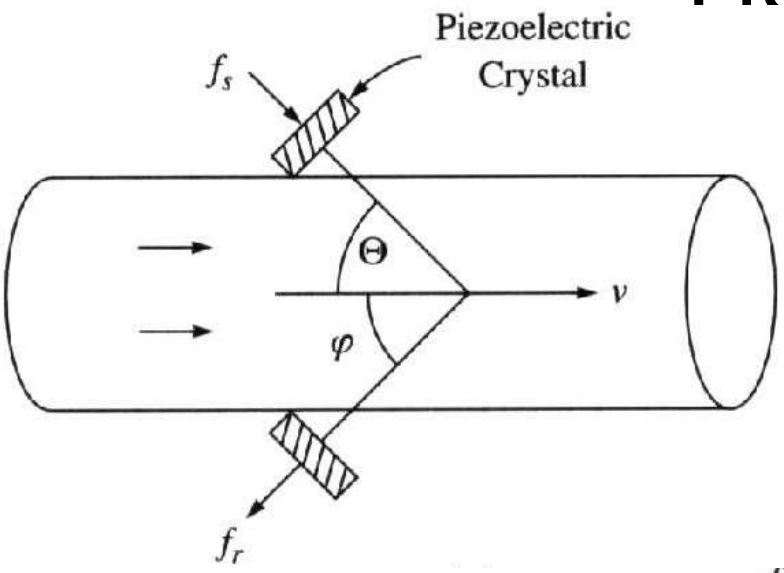

The quantity $\Delta T$ is typically very small and very difficult to measure, particularly in the presence of noise. Therefore phase detection techniques are usually employed rather then measuring actual timing.

# Doppler Flowmeters

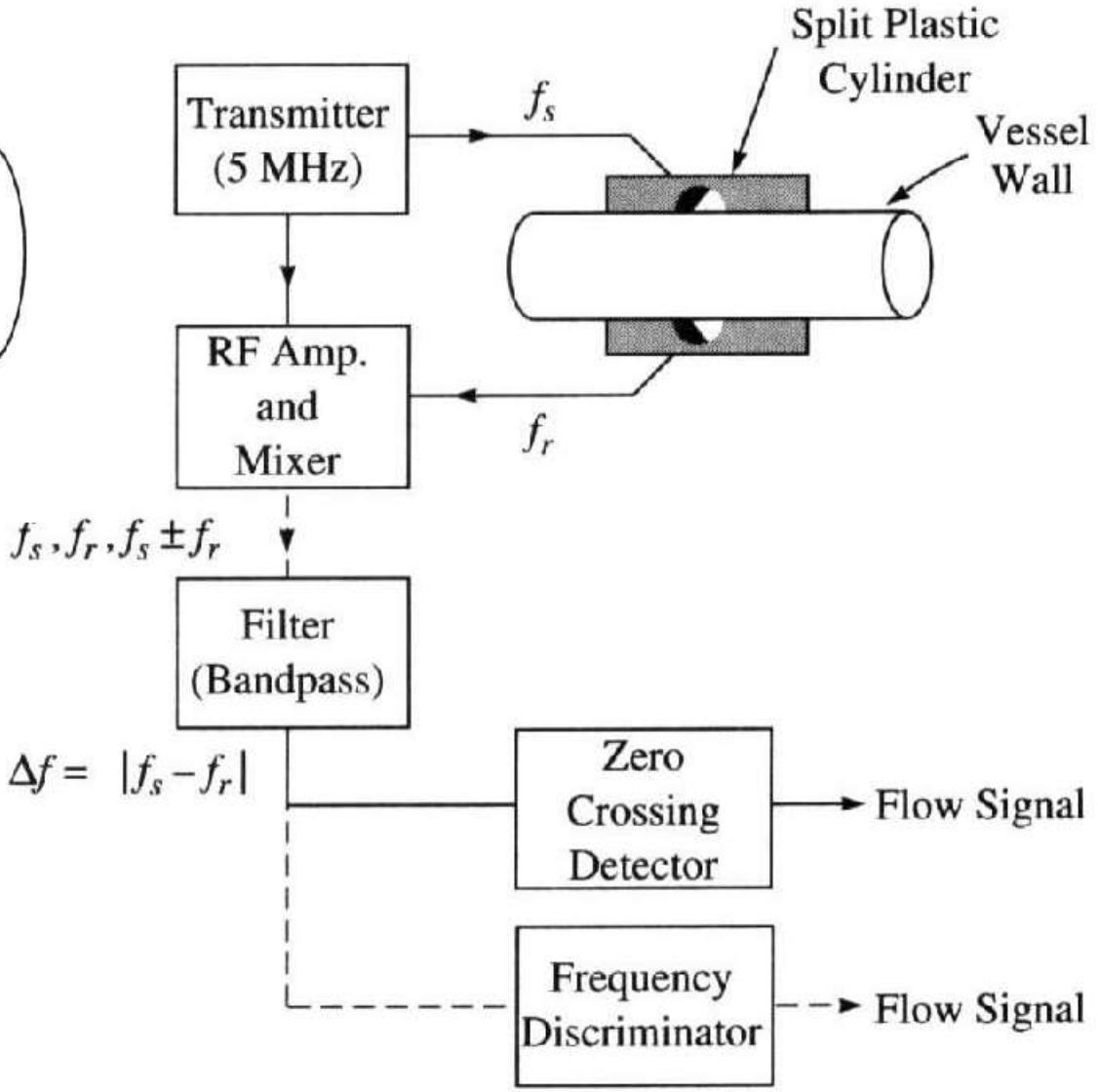
- The Doppler effect describes the change in the frequency of a received signal , with respect to that of the transmitted signal, when it is bounced off of a moving object.
  - Doppler frequency shift



# Doppler Flowmeters




$$\Delta F = \pm f_s(\cos\theta + \cos\phi)\frac{u}{c}$$



# Problems Associated with Doppler Flowmeters

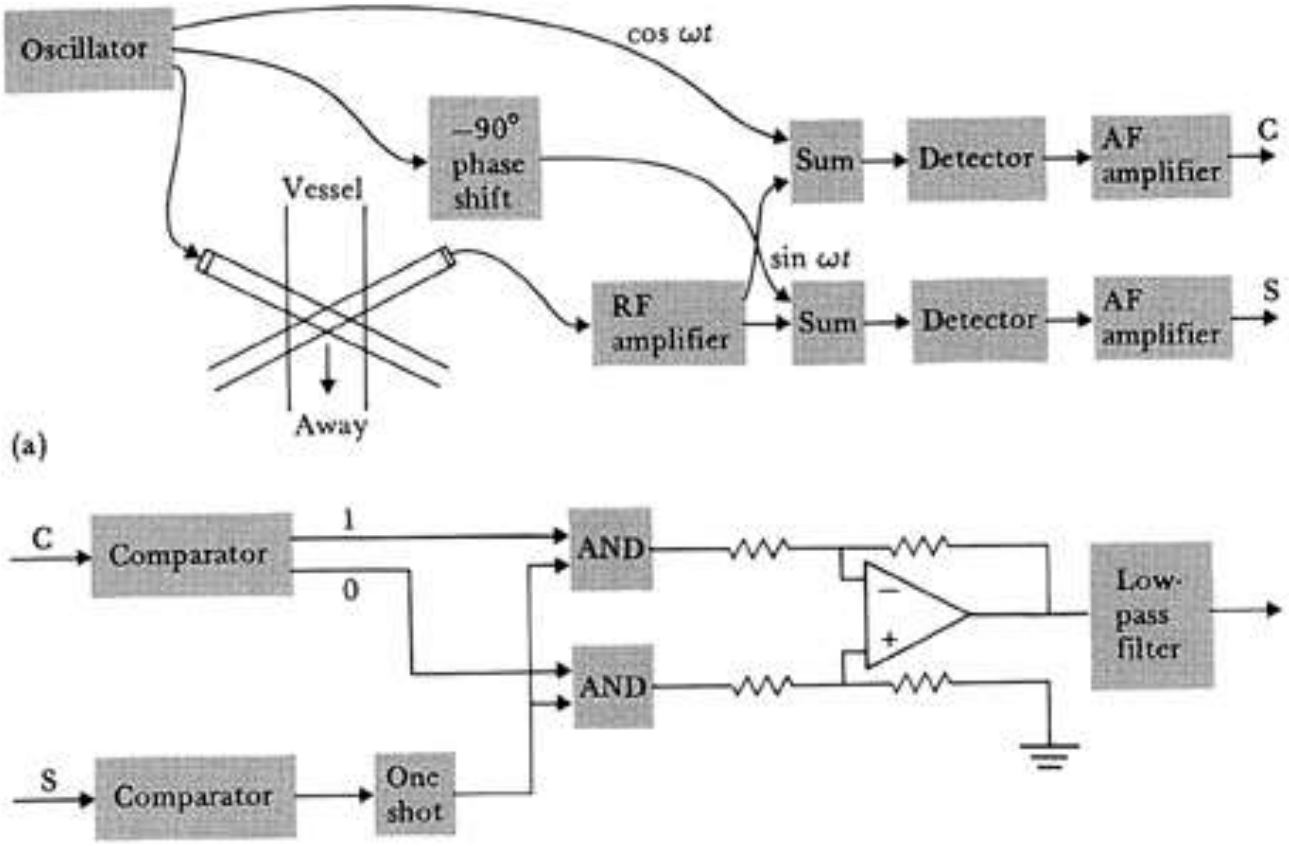
- There are two major issues with Doppler flowmeters
  - Unlike what the equations may suggest, obtaining direction information is not easy due to very small changes in frequency shift that when not in baseband, removing the carrier signal without affecting the shift frequency becomes very difficult

- Also unlike what the equation may suggest, the Doppler shift is not a single frequency, but rather a band of frequencies because
  - Not all cells are moving at the same velocity (velocity profile is not uniform)
  - A cell remains within the UT beam for a very short period of time; the obtained signal needs to be gated, creating side lobes in the frequency shift
  - Acoustic energy traveling within the beam, but at an angle from the bam axis create an effective $\Delta\theta$, causing variations in Doppler shift
  - Tumbling and collision of cells cause various Doppler shifts

# Directional Doppler

- Directional Doppler borrows the ***quadrature phase detector*** technique from radar in determining the speed and direction of an aircraft.
- Two carrier signals at $90^{o}$ phase shift are used instead of a single carrier. The +/- phase difference between these carriers after the signal is bounced off of the blood cells indicate the direction, whereas the change in frequency indicate the flowrate

# Directional Doppler




*(a) Quadrature-phase detector. Sine and cosine signals at the carrier frequency are summed with the RF output before detection. The output C from the cosine channel then leads (or lags) the output S from the sine channel if the flow is away from (or toward) the transducer. (b) Logic circuits route one-shot pulses through the top (or bottom) AND gate when the flow is away from (or toward) the transducer. The differential amplifier provides bi-directional output pulses that are then filtered.*

# BLOOD PRESSURE

# BLOOD PRESSURE

- The force at which blood is pumped against the walls of the arteries (mmHg)
- Two pressure measurements
  - Systolic pressure – measure of pressure when left ventricle contracts
  - Diastolic pressure
    - Measure of pressure when heart relaxes
    - Minimum pressure exerted against the artery walls at all times

# BLOOD PRESSURE

- **Systolic Pressure-**
  - Contraction of left ventricle
  - Top or first number
- **Diastolic Pressure**
  - Heart at rest
  - Bottom or second number

# BLOOD PRESSURE

**Hypertension**

- Low blood pressure
- Normal for some people
- Severely low blood pressure readings occur with:
  - Shock
  - Heart failure
  - Severe burns
  - Excessive bleeding

**Hypotension**

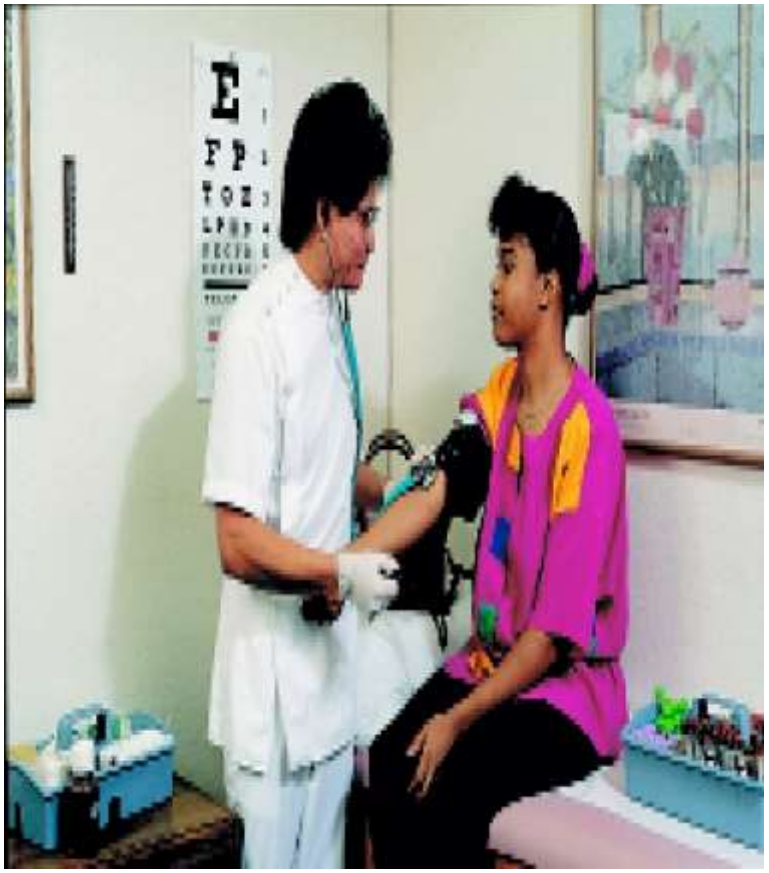
- High blood pressure readings
- Major contributor to heart attacks and strokes

# BLOOD PRESSURE

- Equipment
  - Sphygmomanometer
    - Inflatable cuff
    - Pressure bulb or other device for inflating cuff
    - Manometer
  - Types of sphygmomanometers
    - Aneroid
    - Electronic
    - Mercury

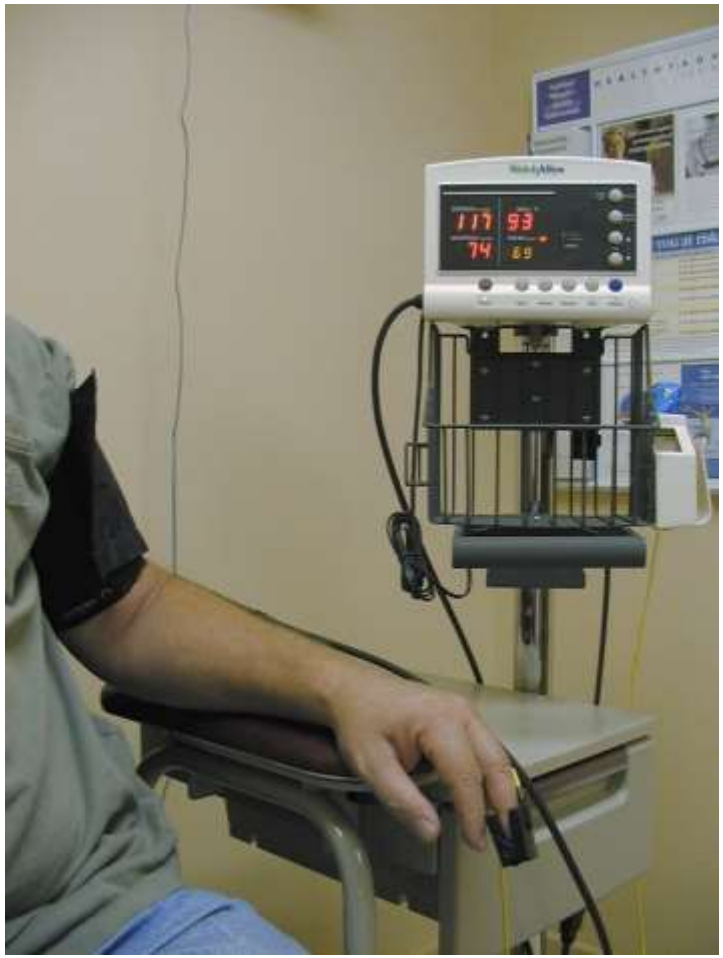
# BLOOD PRESSURE

- Aneroid sphygmomanometers
  - Circular gauge for registering pressure
  - Each line 2 mmHg
  - Very accurate
  - Must be checked, serviced, and calibrated every 3 to 6 months



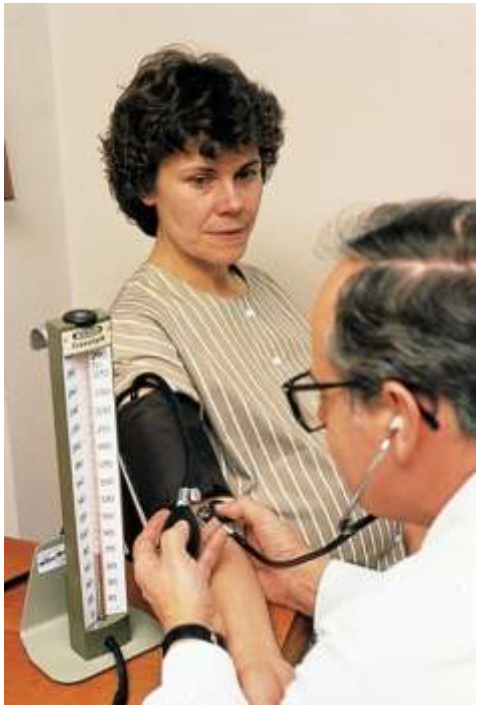
# BLOOD PRESSURE

- Electronic sphygmomanometers
  - Provides a digital readout of the blood pressure
  - No stethoscope is needed
  - Easy to use
  - Maintain equipment according to manufacturer's instructions



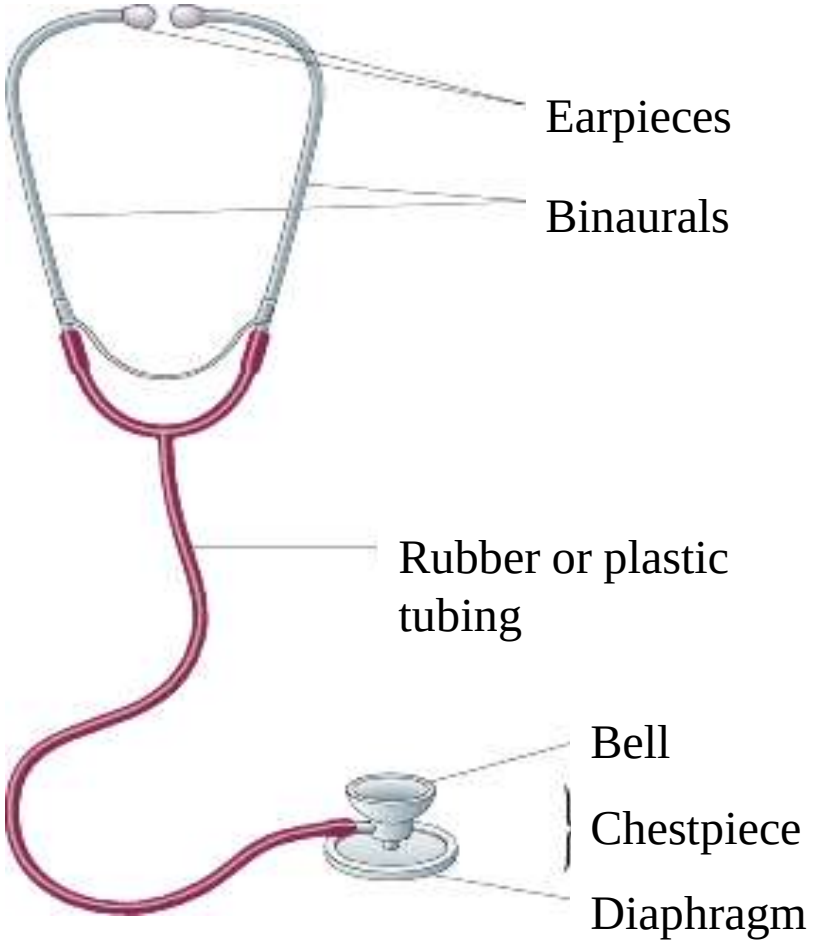
# BLOOD PRESSURE

- Mercury sphygmomanometers
  - A column of mercury rises with an increased pressure as the cuff is inflated
  - No longer available for purchase
  - If in use, must be checked, serviced, and calibrated every 6 to 12 months



# BLOOD PRESSURE

- Stethoscope
  - Amplifies body sounds
  - Earpieces
  - Binaurals and tubing
  - Chestpiece
    - Bell – low-pitched sounds
    - Diaphragm – high-pitched sounds



# BLOOD PRESSURE

- Measuring blood pressure
  - Place cuff on the upper arm above the brachial pulse site
  - Inflate cuff about 30 mmHg above palpatory result or approximately 180 mmHg to 200 mmHg
  - Release the air in cuff and listen for the first heartbeat (systolic pressure) and the last heartbeat (diastolic pressure)
  - Record results with systolic as the top number and diastolic as the bottom number (i.e., 120/76)

# BLOOD PRESSURE

- Special considerations in adults
  - Post exercise, ambulatory disabilities, obese, known blood pressure problems
  - Anxiety or stress
  - Avoid measurement in an arm
    - Injury or blocked artery is present
    - History of mastectomy on that side
    - Implanted device is under the skin
  - Proper cuff size – improper size results in inaccurate reading

# BLOOD PRESSURE

- Special considerations in children
  - Not routinely taken on each visit
  - Take before other tests or procedures
  - Cuff size important
  - Palpatory method not used with children
  - Heartbeat may be heard to zero; record diastolic when strong heartbeat becomes muffled

# BLOOD PRESSURE

- Orthostatic or postural hypotension
  - Blood pressure becomes low and pulse increases when the patient moves from lying to standing
  - Indicates fluid loss or malfunction of cardiovascular system
  - Vital signs are taken in different positions
  - Positive tilt test – increase in pulse > 10 bpm and a drop in BP > 20 mmHg

# BLOOD CELL COUNTERS

# Blood cell counter

- The blood cell counter count the number of RBC or WBC per unit of volume of blood using either of two method:
  - Electrical method called aperture impedance change
  - Optical method called flow cytometry

# Aperture impedance change

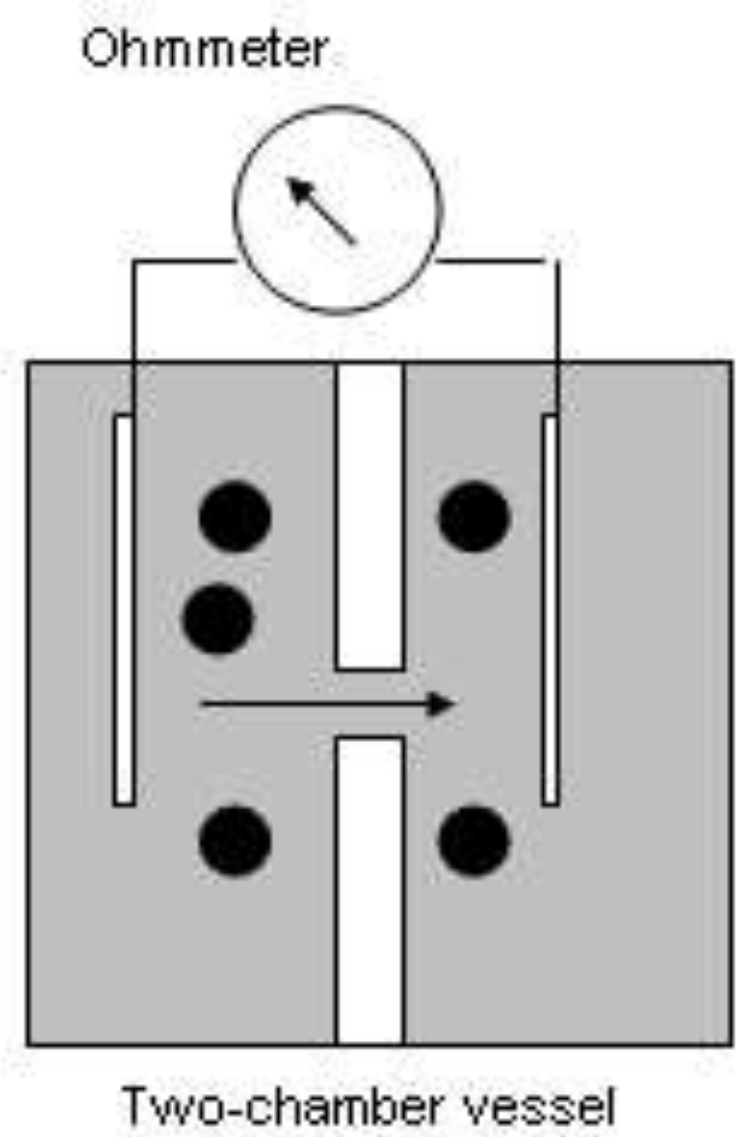
- When blood is diluted in the proper type of solution, the electrical resistivity of blood cells ($\rho_c$) is higher then the resistivity of the surrounding fluid ($\rho_f$)
- By contriving a situation in which these resistivities can be differentiated from each other, we can count cells

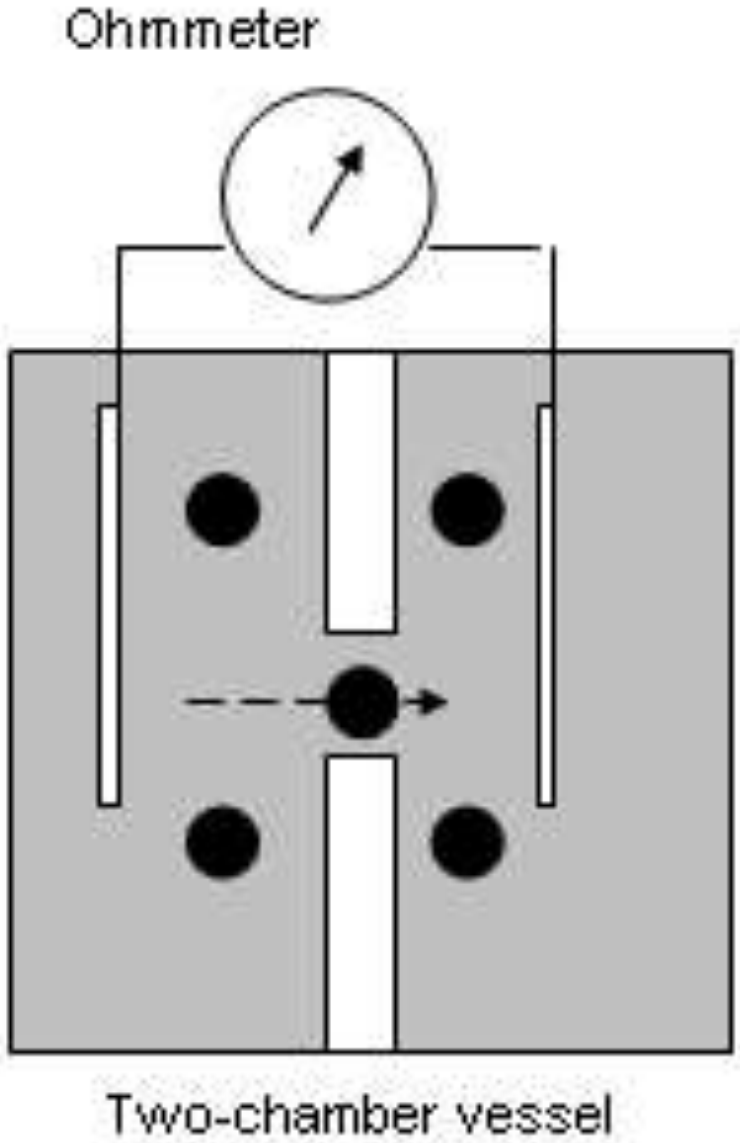
# Aperture impedance change

## *Blood cell sensing*

- **The sensor consist of a two-chamber vessel in which the dilute incoming blood is on one side of barrier, and the waste blood to be discarded is on the other**
- **A hole with a small diameter (50µm) is placed in the partition between the tow halves of the cell**
- **Ohmmeter measure the change on the resistance when the blood cell pass the aperture**

# Blood cell sensing

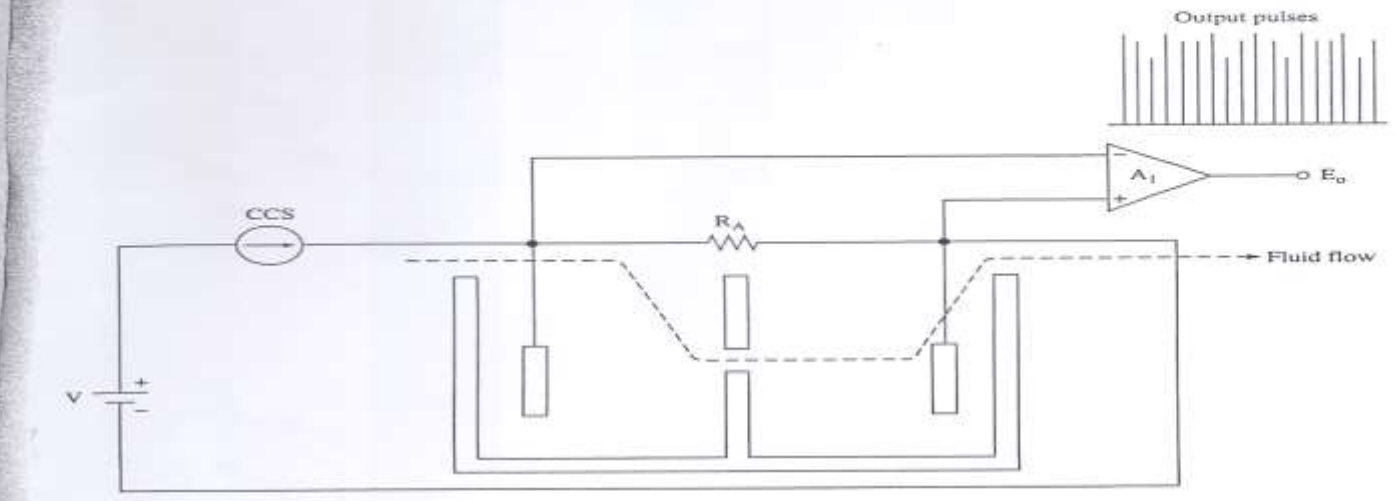


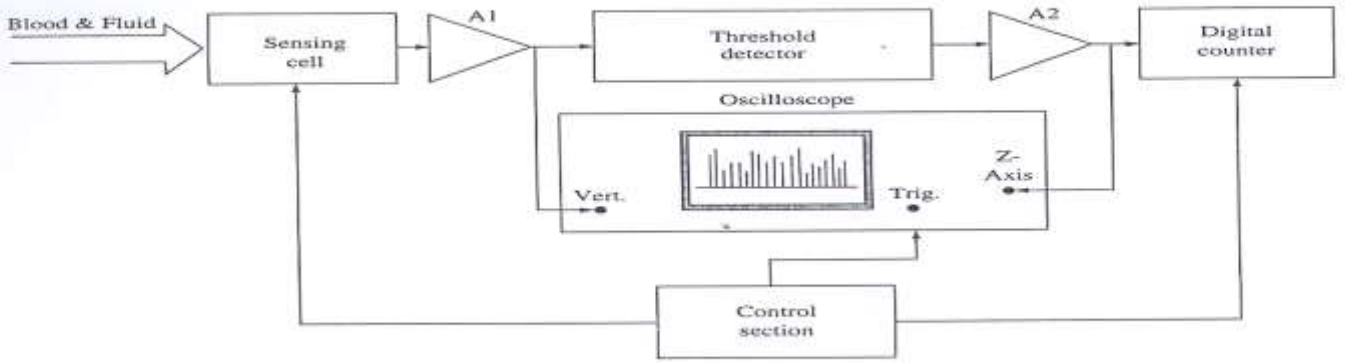
# Coulter Counter

- Constant current source (CCS) and voltage amplifier replace the ohmmeter
- $R_A$ is the resistance of the aperture and will be either high or low, depending on whether or not the blood cell is inside the aperture.
- Amplifier convert the current pulse to voltage pulse

# Schematic




Blood cell counters. *(a)* Coulter model F. *(b)* Coulter model senior.




Impedance aperture cell counter.

# Flow cytometry cell counters

## optical flow cytometry sensing

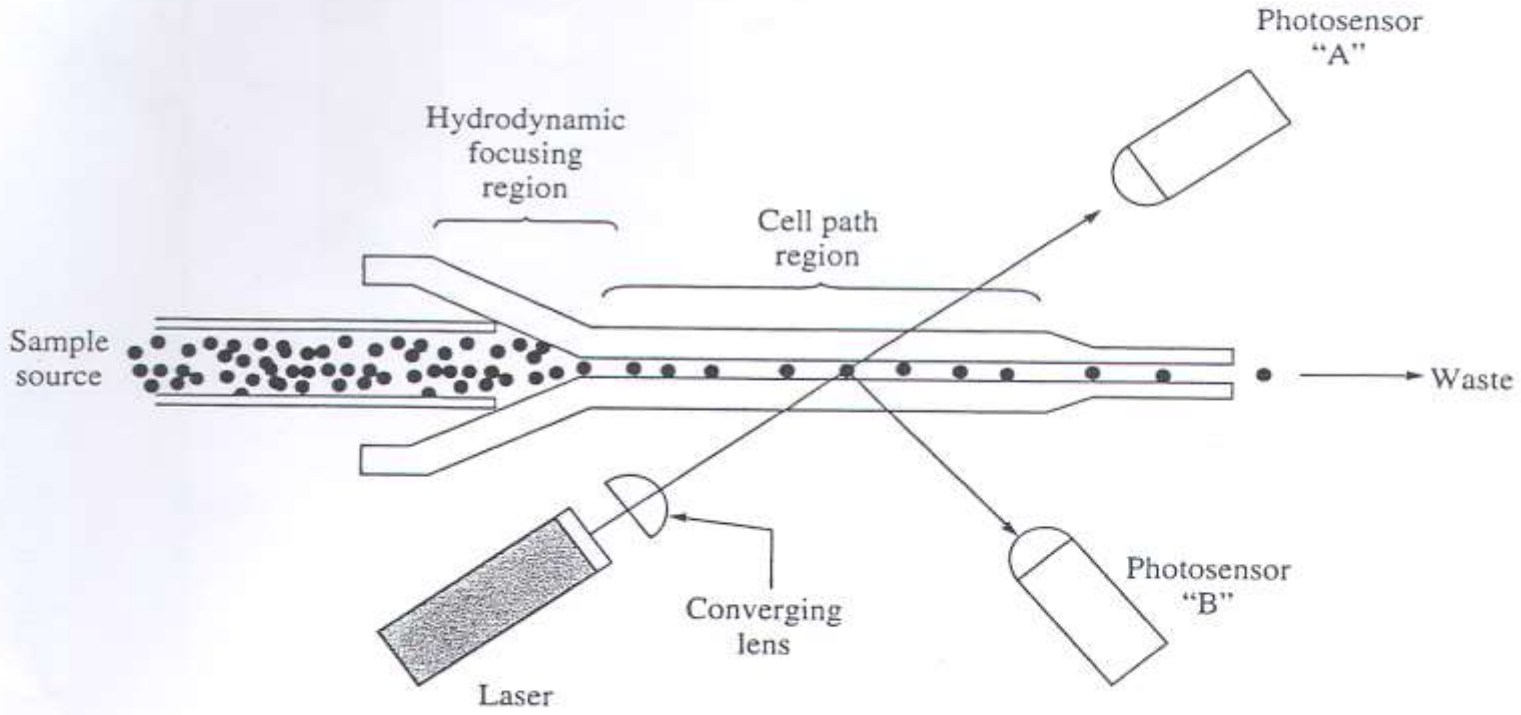
- The optical cytometry sensor consists of a quartz sensing sheath designed with a
  - hydrodynamic focusing region
  - cell path region that passes only a single cell at time.
- Focusing is done by decreasing the diameter of the aperture.
- Light source is (He-Ne) Laser

# Flow cytometry cell counters

## optical flow cytometry sensing

- Two Photodetectors (photosensors)
  - Photodetector A detects forward scatted light
  - Photodetector B detects orthogonal scatted light
- blood sample enters the analyzer
  - Optical counter → WBC count
  - Colorimeter → hemoglobin
  - Optical flow sensor → RBC count

# Schematic




Optical flow cytometry sensor.

# UNIT 3

# CARDIAC PACEMAKERS

# History

- First pacemaker implanted in 1958
- First ICD implanted in 1980
- Greater than 500,000 patients in the US population have pacemakers
- 115,000 implanted each year

# Pacemakers Today

- **Single or dual chamber**
- **Multiple programmable features**
- **Adaptive rate pacing**
- **Programmable lead configuration**

# Chronic AVHB

- **Especially if symptomatic**

  **Pacemaker most commonly indicated for:**
- **Type 2 2º**
  - **Block occurs within or below the Bundle of His**
- **3º Heart Block**
  - **No communication between atria and ventricles**

# Chronic Bifascicular and Trifascicular Block

- **Differentiation between uni, bi, and trifascicular block**
- **Syncope common in patients with bifascicular block**
- **Intermittent 3º heart block common**

# AVHB after Acute MI

- **Incidence of high grade AVHB higher**
- **Indications for pacemaker related to intraventricular conduction defects rather than symptoms**
- **Prognosis related to extent of heart damage**

# Sinus Node Dysfunction

- **Sinus bradycardia, sinus pause or arrest, or sinoatrial block, chronotropic incompetence**
- **Often associated with paroxysmal SVTs (bradycardia-tachycardia syndrome)**
- **May result from drug therapy**
- **Symptomatic?**
- **Often the primary indication for a pacemaker**

# Hypersensitive Carotid Sinus Syndrome

**Syncope or presyncope due to an exaggerated response to carotid sinus stimulation**

- **Defined as a systole greater than 3 sec due to sinus arrest or AVHB, an abrupt reduction of BP, or both**

# Neurally Mediated Syncope

- **10-40% of patients with syncope**
- **Triggering of a neural reflex**
- **Use of pacemakers is controversial since often bradycardia occurs after hypotension**

# Device Selection

- **Temporary pacing (invasive vs. noninvasive)**
- **Permanent pacemaker**

# Pacemaker Characteristics

**Adaptive-rate pacemakers**

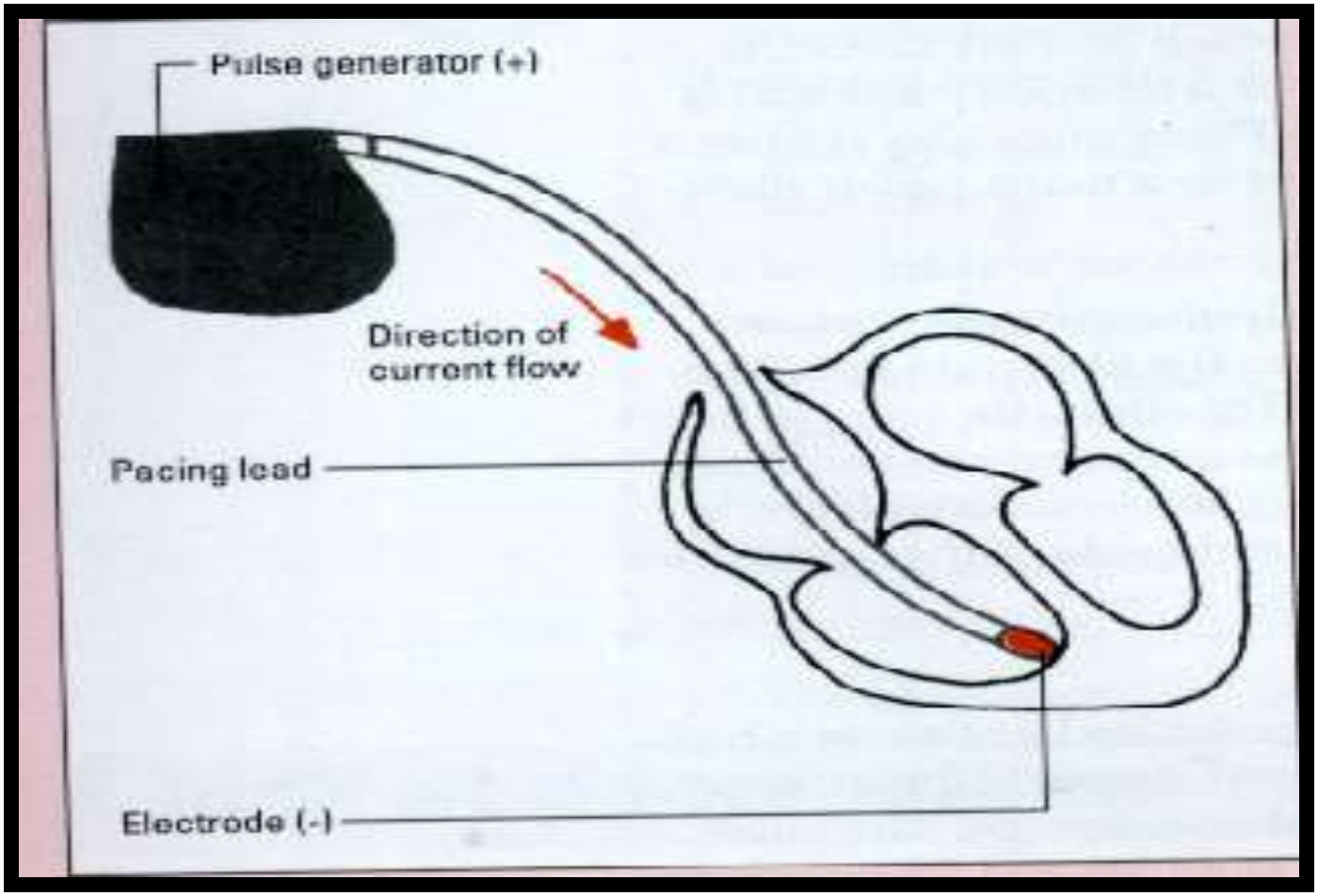
- **Single-pass lead Systems**
- **Programmable lead configuration**
- **Automatic Mode-Switching**
- **Unipolar vs. Bipolar electrode configuration**

# Mechanics

- Provide the rhythm heart cannot produce
- Either temporary or permanent
- Consists of external or internal power source and a lead to carry the current to the heart muscle
- Batteries provide the power source
- Pacing lead is a coiled wire spring encased in silicone to insulate it from body fluids

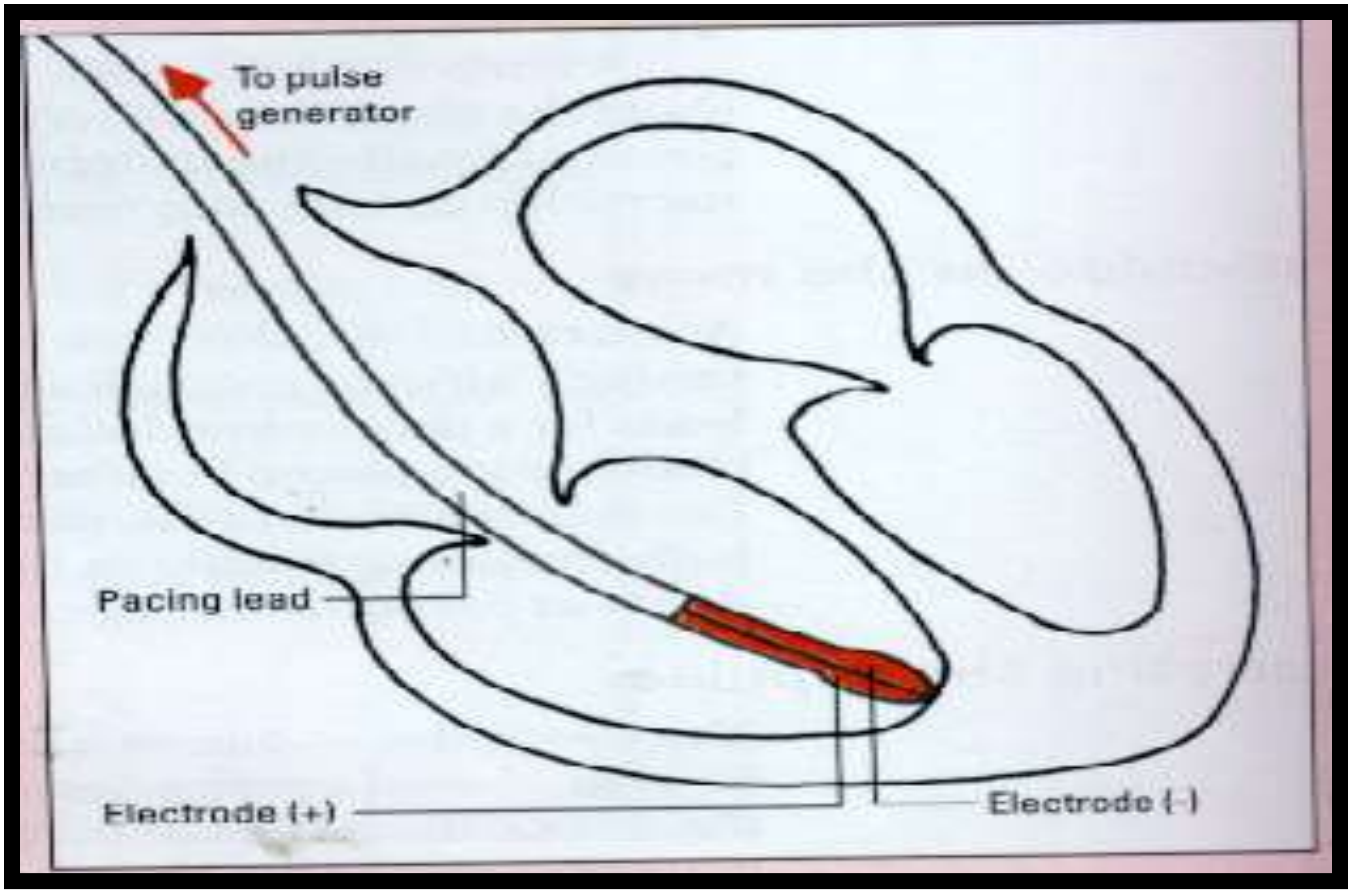
# Unipolar Pacemaker

- **Lead has only one electrode that contacts the heart at its tip (+) pole**
- **The power source is the (-) pole**
- **Patient serves as the grounding source**
- **Patient's body fluids provide the return pathway for the electrical signal**
- **Electromagnetic interference occurs more often in unipolar leads**


Pulse generator (+)
Direction of current flow
Pacing lead
Electrode (-)

# Bipolar Pacemaker

- **If bipolar, there are two wires to the heart or one wire with two electrodes at its tip**
- **Provides a built-in ground lead**
- **Circuit is completed within the heart**
- **Provides more contact with the endocardium; needs lower current to pace**
- **Less chance for cautery interference**


To pulse generator
Pacing lead
Electrode (+)
Electrode (-)

# Indications

1. Sick sinus syndrome (Tachy-brady syndrome)
2. Symptomatic bradycardia
3. Atrial fibrillation
4. Hypersensitive carotid sinus syndrome
5. Second-degree heart block/Mobitz II

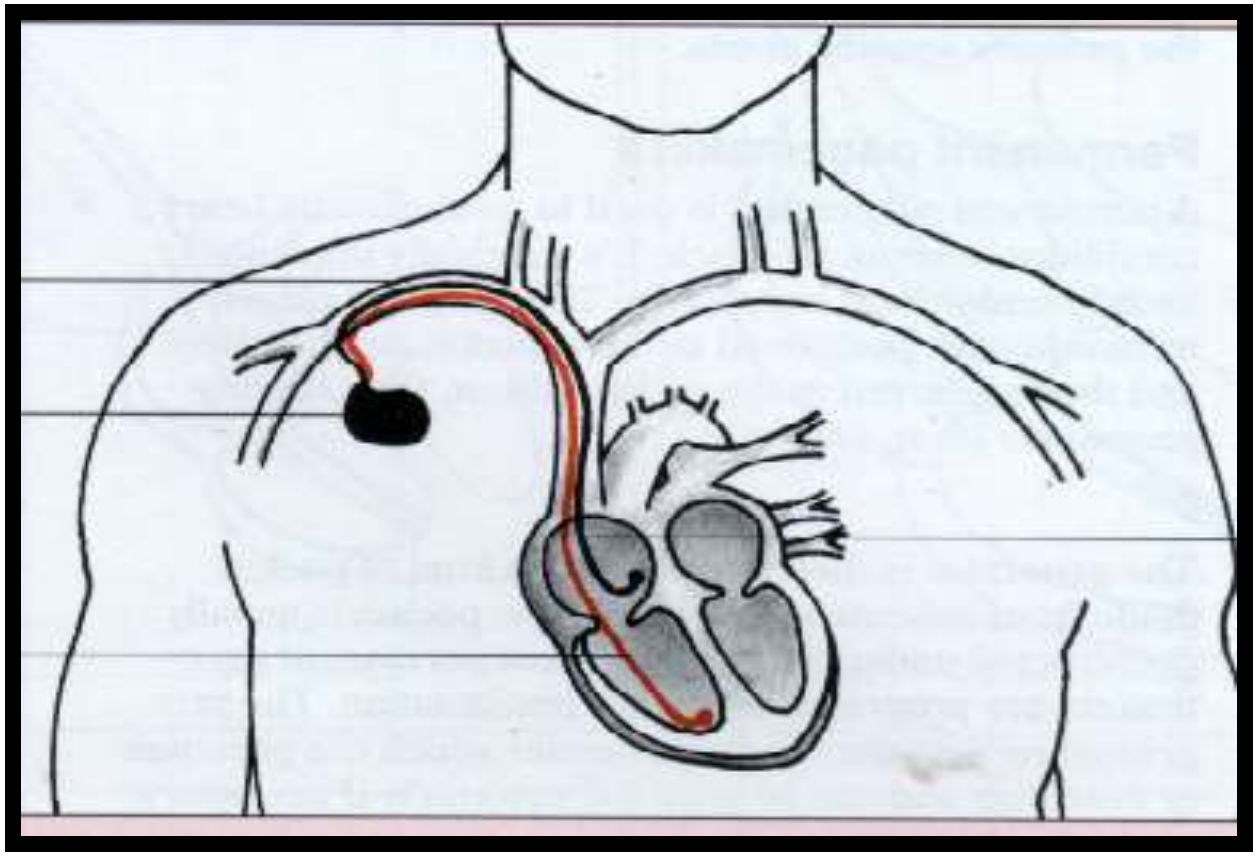
# Indications

6. **Complete heart block**
7. **Sinus arrest/block**
8. **Tachyarrhythmias**

   **Supraventricular, ventricular**

   **To overdrive the arrhythmia**

# Pacemaker Insertion



# Anesthesia for Insertion

**MAC**

- **To provide comfort**
- **To control dysrhythmias**
- **To check for proper function/capture**

**Have external pacer/Isuprel/Atropine ready**

**Continuous ECG and peripheral pulse**

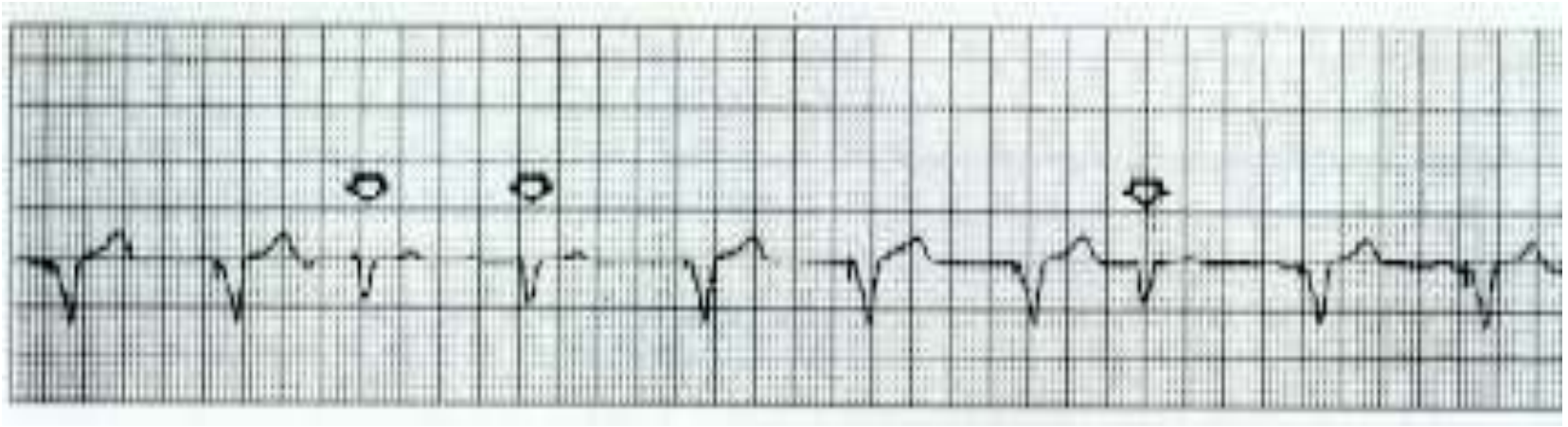
**Pulse ox with plethysmography to see perfusion of each complex**

- **(EKG may become unreadable)**

# Examples of Rhythms

**Sensing**

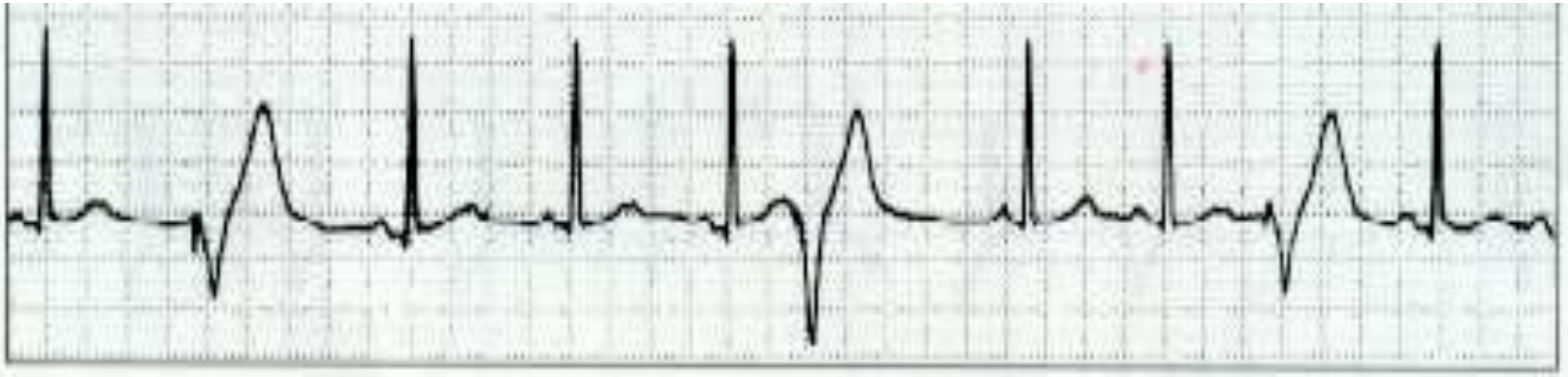
**Patient's own beat is sensed by pacemaker so does not fire**



# Examples of Rhythms

## Undersensing

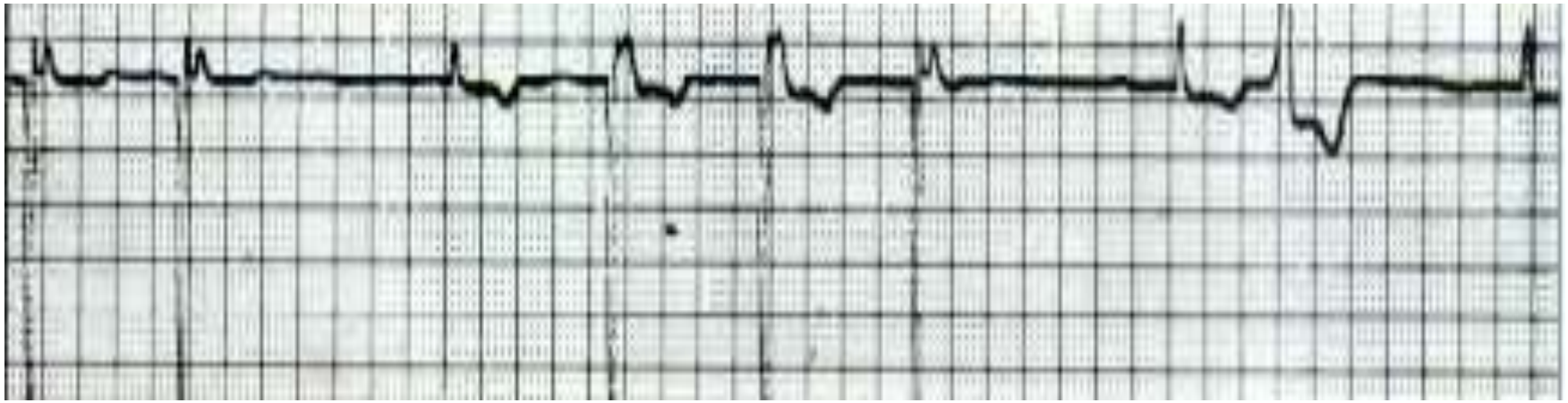
Pacemaker doesn't sense patient's own beat and fires (second last beat)



# Examples of Rhythms

## Oversensing

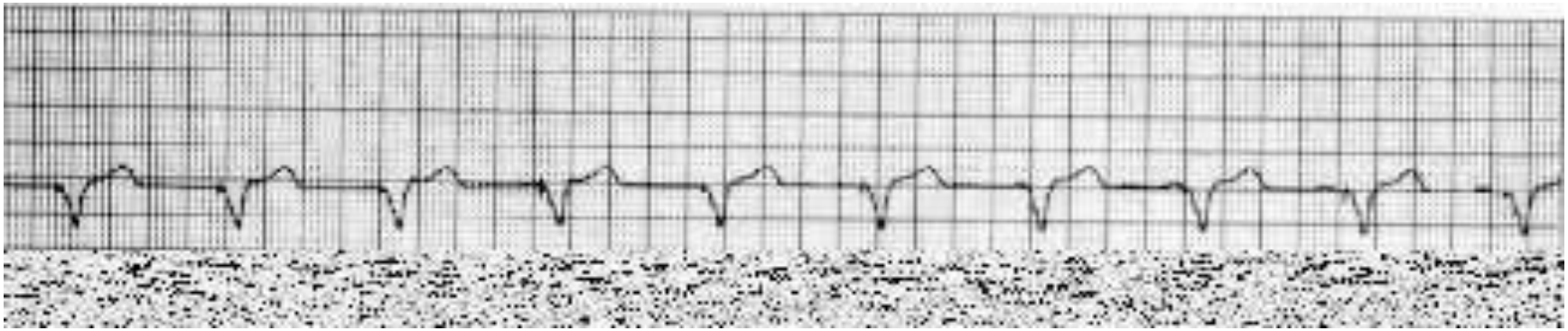
**Pacemaker senses heart beat even though it isn't beating. Note the long pauses.**



# Examples of Rhythms

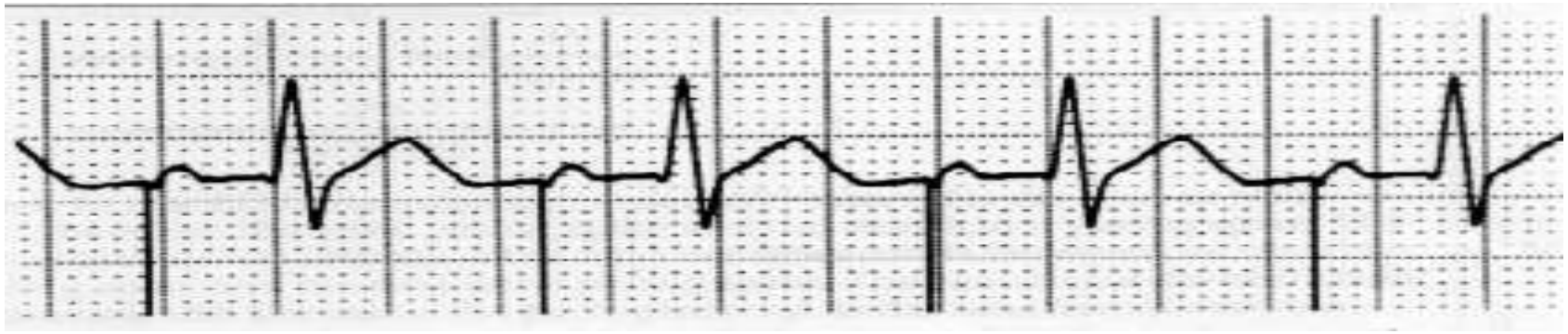
**Capture**

**Pacemaker output (spike) is followed by ventricular polarization (wide QRS).**



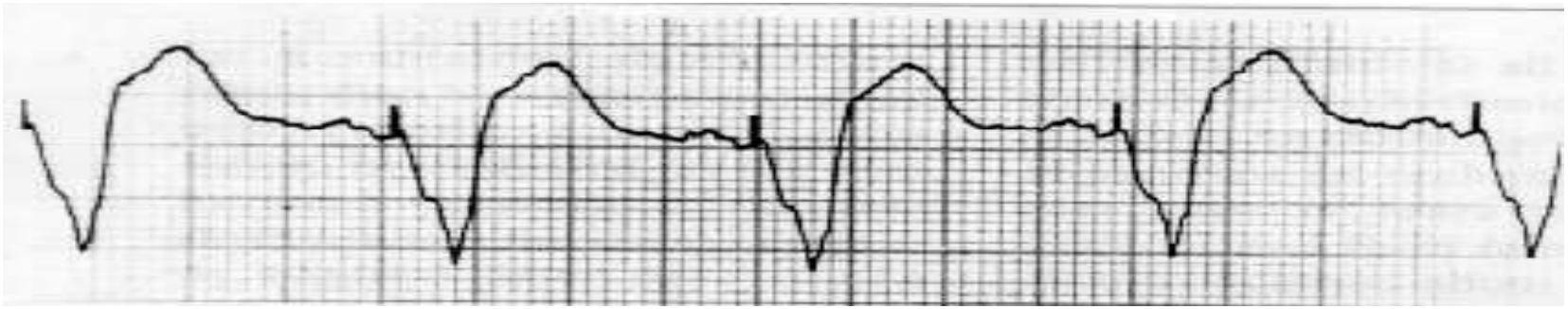
# Examples of Rhythms

**100 % Atrial Paced Rhythm with 100% Capture**



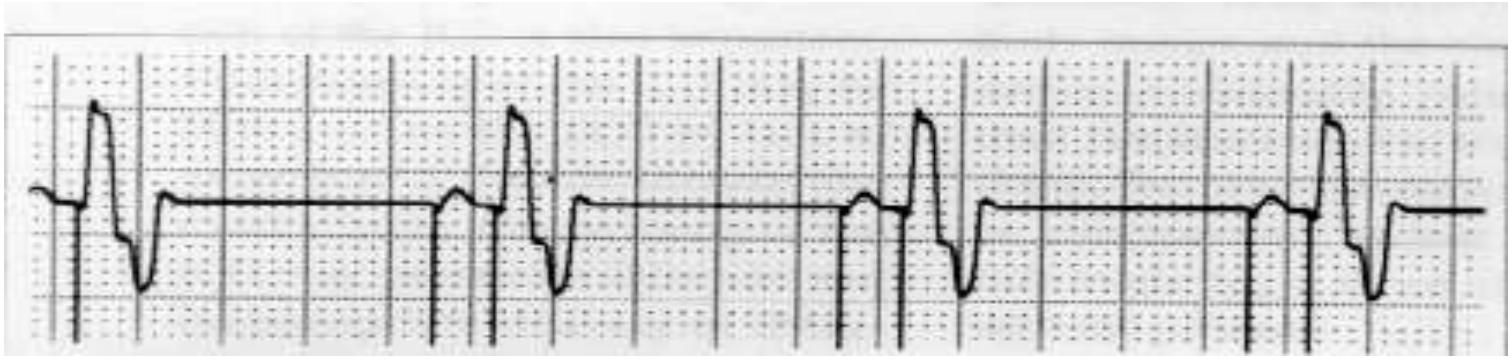
# Examples of Rhythms

**100% Ventricular Paced Rhythm with 100% Capture**



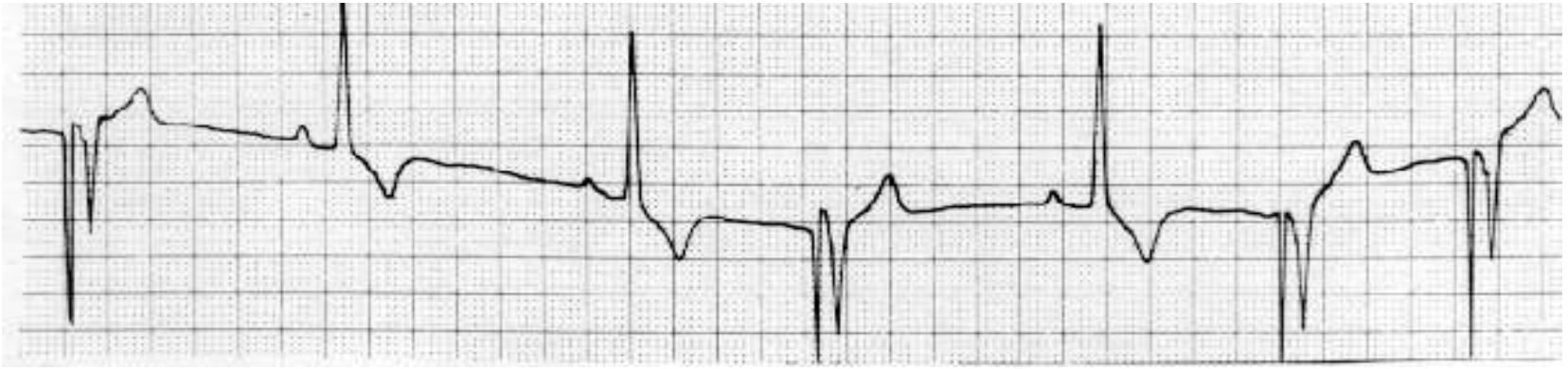
# Examples of Rhythms

## 100% Atrial and 100% Ventricular Paced Rhythm with 100% Capture



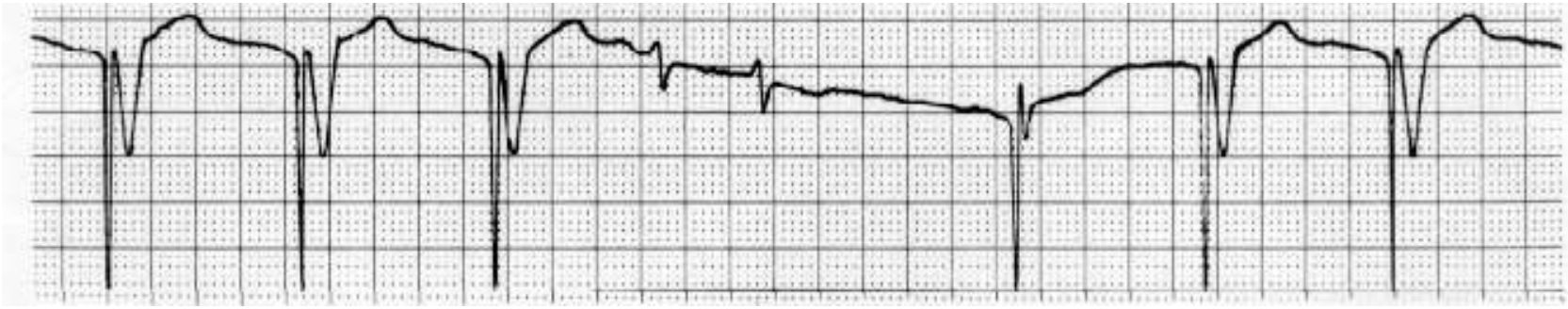
# Examples of Rhythms

**50% Ventricular Paced Rhythm with 100% Capture**



# Examples of Rhythms

**25% Ventricular Paced Rhythm with 100% Capture (Note the sensing that occurs. Pacer senses intrinsic HR and doesn't fire).**



# DEFIBRILLATOR

# Definition

- The *defibrillator* is an electrical device that delivers a pulse of therapeutic current intended to reverse a ventricular fibrillation (VF) or a life-threatening ventricular tachycardia (VT) in the heart of a patient.

- A current applied to the surface of the body in excess of 80 milliamps and less than 1 ampere such that it passes through the heart is apt to cause it to fibrillate.
  - The result is that the cardiac output falls to less than that required to sustain life.
    - This is electrocution.

- However, if the current exceeds 1 ampere, it carries enough energy to cause all of the cardiac muscle fibers to contract simultaneously and cause the heart to stop fibrillating.
  - The current pulse needs to be controlled very carefully.
    - If it is too small, it causes fibrillation, and
    - if it is too large, it can cause burn injuries.

# DEFIBRILLATOR PRINCIPLES

- The early clinical applications of defibrillation in 1956 by P. M. Zoll used an AC current pulse to defibrillate with some success.
  - However, the reliability was significantly improved in 1962 when B. Lown introduced a defibrillator that delivered a short DC pulse of current to the heart through the chest wall.

- Defibrillation occurs because the strong current stimulus causes simultaneous contraction of all of the muscles in the heart.
  - The first region to repolarize after the pulse is the sinoatrial (SA) node.
    - It, therefore, regains control of the pacing of the heart.

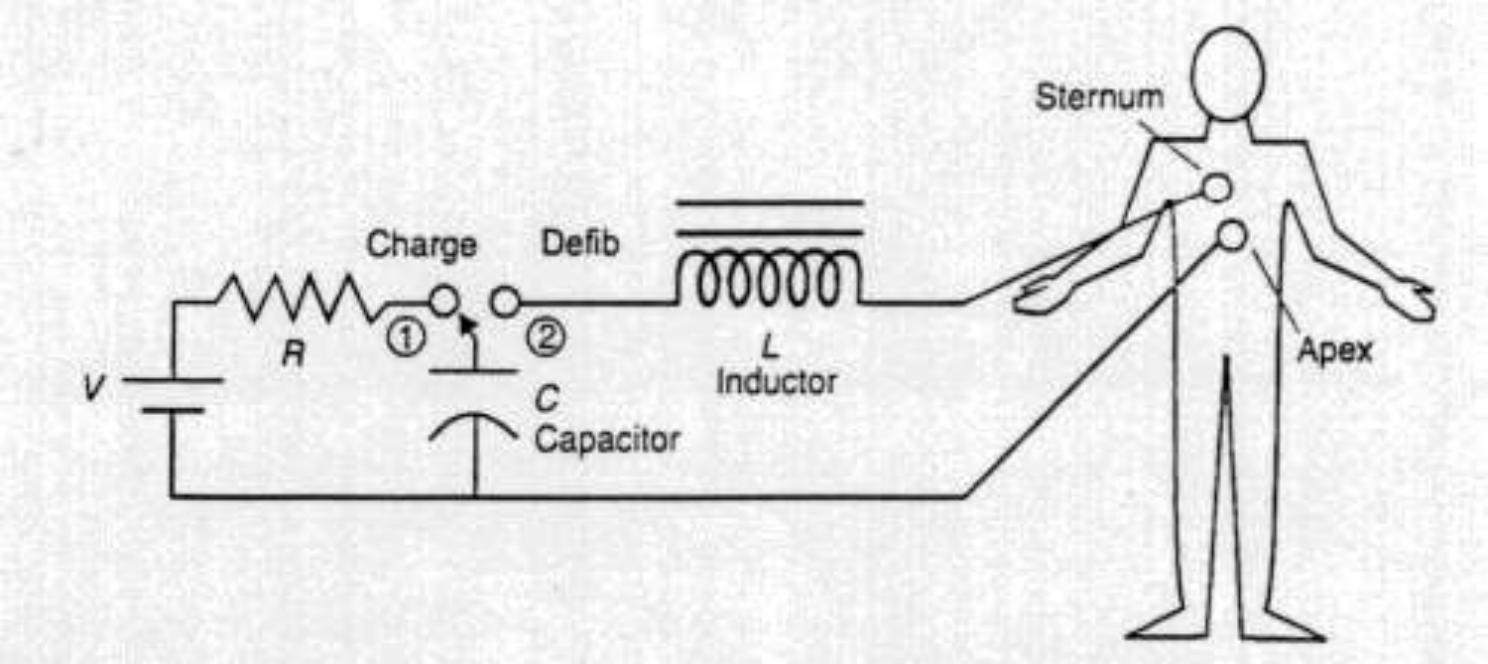
- The effective and safe use of the defibrillator depends upon the proper diagnosis of the symptoms of sudden cardiac death (SCD) and upon quick response.
  - Accurate diagnosis is crucial because the defibrillator pulse can induce fibrillation into a heart that is normally beating.
  - The need for quick response is necessary because the probability of reversing a fibrillation with a defibrillator declines rapidly after only one minute.

- Therefore, the effectiveness of the defibrillator has been improved by making self-diagnostic models available, especially to people with less medical training, such as
  - fire fighters,
  - paramedical professionals, and even
  - laypeople in the home of a cardiac patient.

- These people decrease the response time by their close availability to the victim of SCD who inherently has little or no warning.
  - In addition, implanted defibrillators are available to patients who have survived SCD and are susceptible to further attacks.

# Lown Defibrillator Circuit

- An electrical circuit introduced by Lown to deliver a short, high-current pulse to a patient.



- To prepare the defibrillator for external use, it is necessary to charge the capacitor up to between 1,000 and 6,000 volts.
  - This is done by putting the switch in the charge position, so that the battery voltage, stepped up to these high levels, can be applied to the capacitor.

- The capacitor consists of two pieces of metal separated by an insulating material.
  - If it is made to stand alone, the capacitor will hold its charge for a long time, minutes or even hours in some cases.

- That is, the capacitor stores energy, $W_A$, which develops a voltage, $V$, across its metal plates.
  - The amount of energy in units of joules is given by

$$W_A = C\frac{V^2}{2}$$

    - where $C$ is the value of the capacitance measured in units of farads and $V$ is the voltage across the capacitor.

- The energy stored in the capacitor is proportional to the square of the voltage between its plates.
  - The amount of energy typically stored in the capacitor of a defibrillator, so that it can be later delivered to the patient, ranges from 50 to 400 joules.

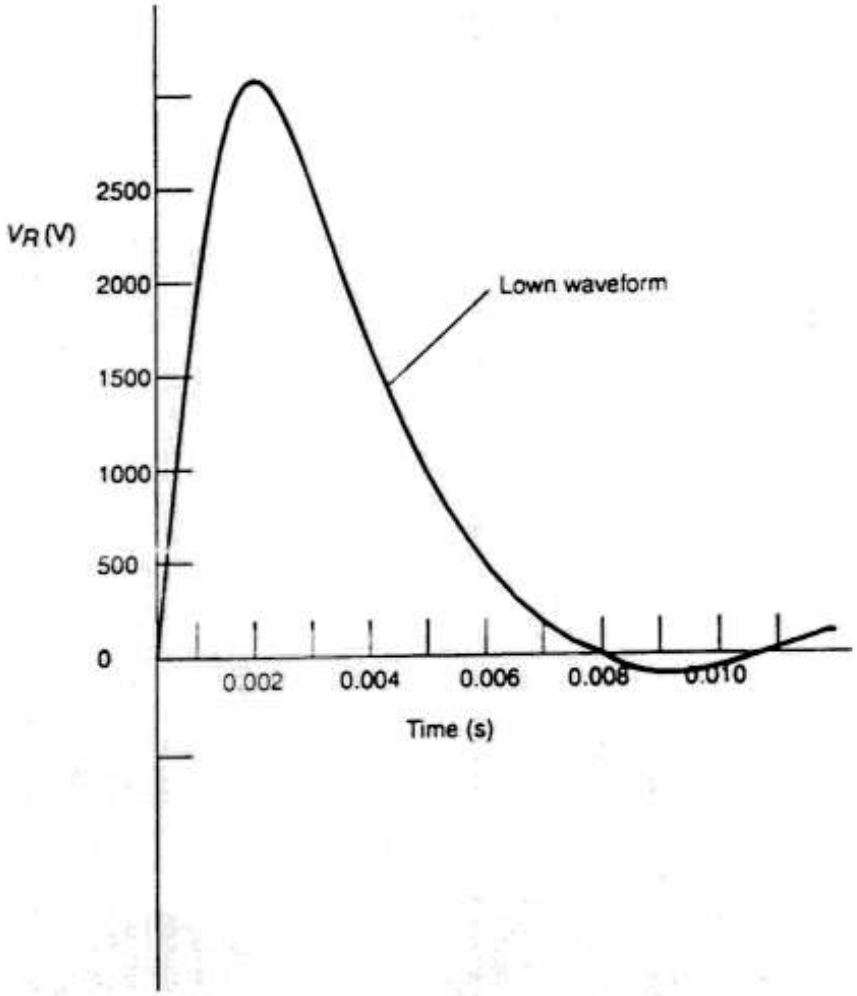
# Defibrillator Pulse Voltage and Energy

- It is important for the defibrillator user to understand the voltage pulse output because its shape is an indicator of proper defibrillator operation.
  - Early defibrillators had an erroneous waveform and were not reliable.

- An understanding of how the energy is distributed among the human—machine interface components determines whether the patient receives the appropriate therapy or whether an injury is inflicted.

- The defibrillator pulse is generated by the basic circuit.
  - After the capacitor has been charged with the switch in position 1, the defibrillator is ready to deliver a voltage pulse to the patient.
  - This delivery is made by putting the switch in the discharge position, 2.

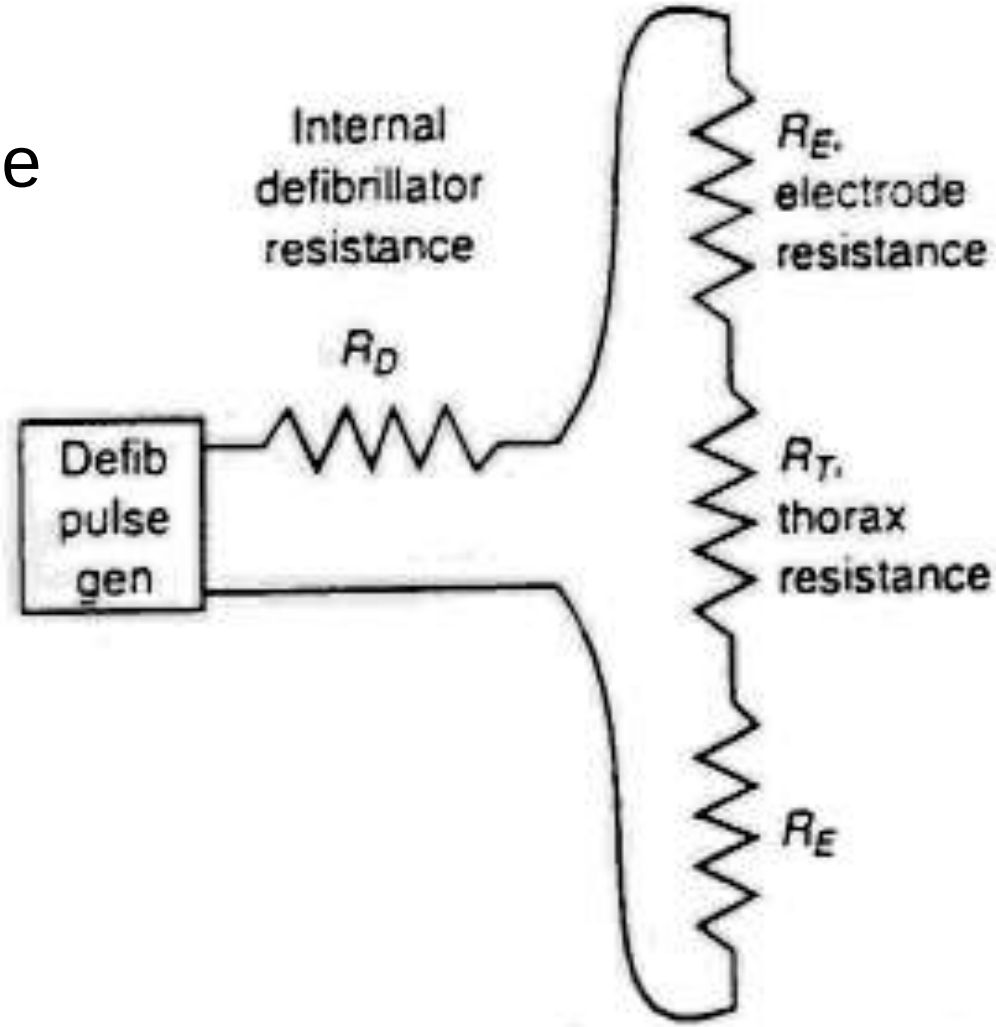
- A voltage waveform across the patient is developed.
  - The current is zero at the instant after the switch is thrown because the energy goes into building up a magnetic field around the inductor, *L.*
  - As that magnetic field builds up, the current, and therefore the voltage, increases in the paddle and patient resistances, causing the initial rise in voltage in the waveform.
  - After the energy stored in the capacitor becomes depleted, the current falls, causing the waveform to peak and then diminish to zero again.



- The oscillation of the energy between the capacitor and inductor after the initial pulse sometimes causes a small ripple to follow, but that should have no significant physiological effect.
  - The inductor and capacitor values are chosen to make a pulse to peak at about 2,600 volts and have a duration of approximately 7 milliseconds.

- All of this energy does not get into the patient.
  - Some is lost in the internal resistance of the defibrillator circuit, $R_D$ and some is wasted in the paddle—skin resistance, $R_E$ .

- To calculate how much of this energy gets to the patient, resistance $R_T$, consider the equivalent circuit.
  - The four resistors in this circuit are in series.



- Therefore, the current in each of them is the same.
  - And the energy absorbed by any one resistor is proportional to the total available energy, according to the voltage division principle.
    - The formula for the energy absorbed by the thorax, $W_T$ is

$$W_T = \frac{R_T}{R_D + 2R_E + R_T} W_D$$

# Diagnostic Defibrillator

- Ventricular fibrillation is a common initial rhythm in sudden cardiac death.
  - Early defibrillation is accepted as the most effective means of improving survival rates in ventricular fibrillation.

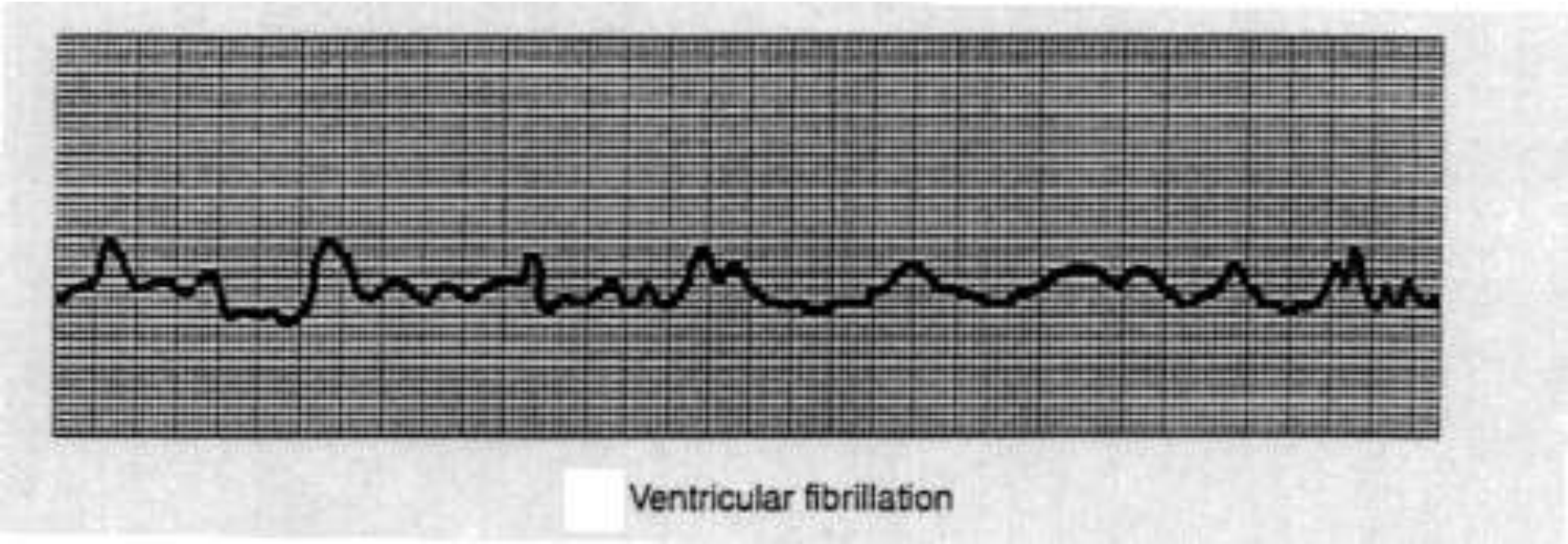
- The greatest impediment to early defibrillation is the fact that many cardiac arrests occur outside the hospital.
  - When communities added early prehospital defibrillation to their Advanced Cardiac Life Support (ACLS) protocols, survival rates improved.
    - Unfortunately, one of the major hazards in using a defibrillator is the misdiagnosis of a fibrillating heart.

- The major symptoms visible without the aid of diagnostic equipment are
  - A loss of consciousness,
  - Dilated pupils,
  - Lack of pulse, and
  - Apnea.

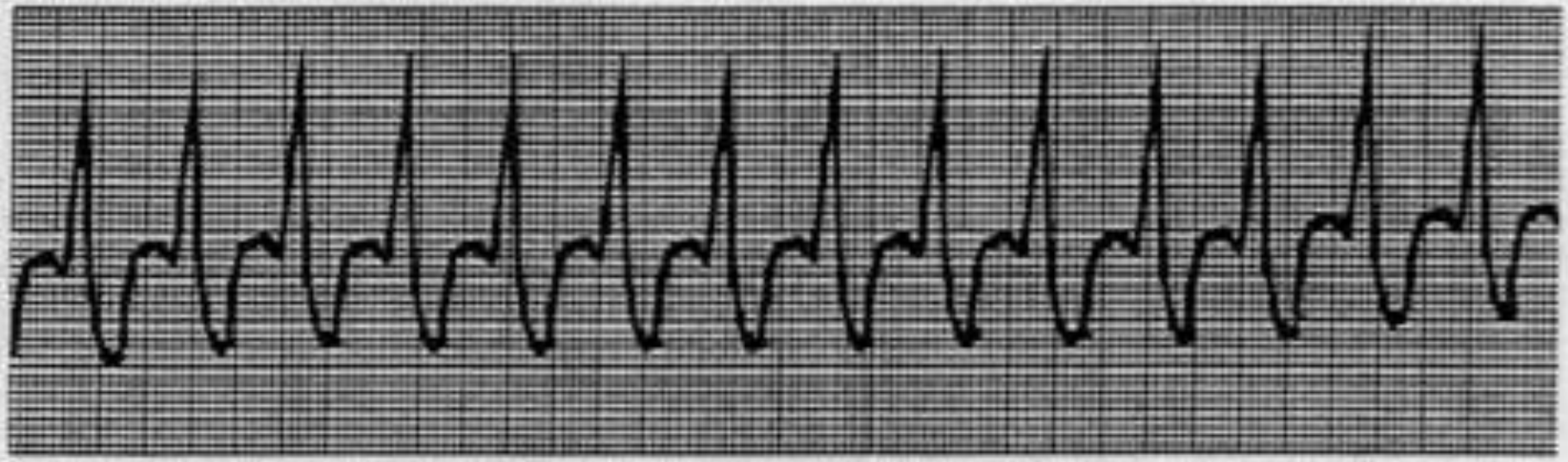
- These symptoms require skill and training to assess and can be misinterpreted.
  - If the defibrillating current is delivered to a normal heart, and if it hits during the *T* wave (when the heart is most vulnerable), it may cause the heart to fibrillate.

- Therefore, it is necessary to have positive evidence that the heart is fibrillating before the defibrillator is used.
  - This may be obtained from the EGG waveform.

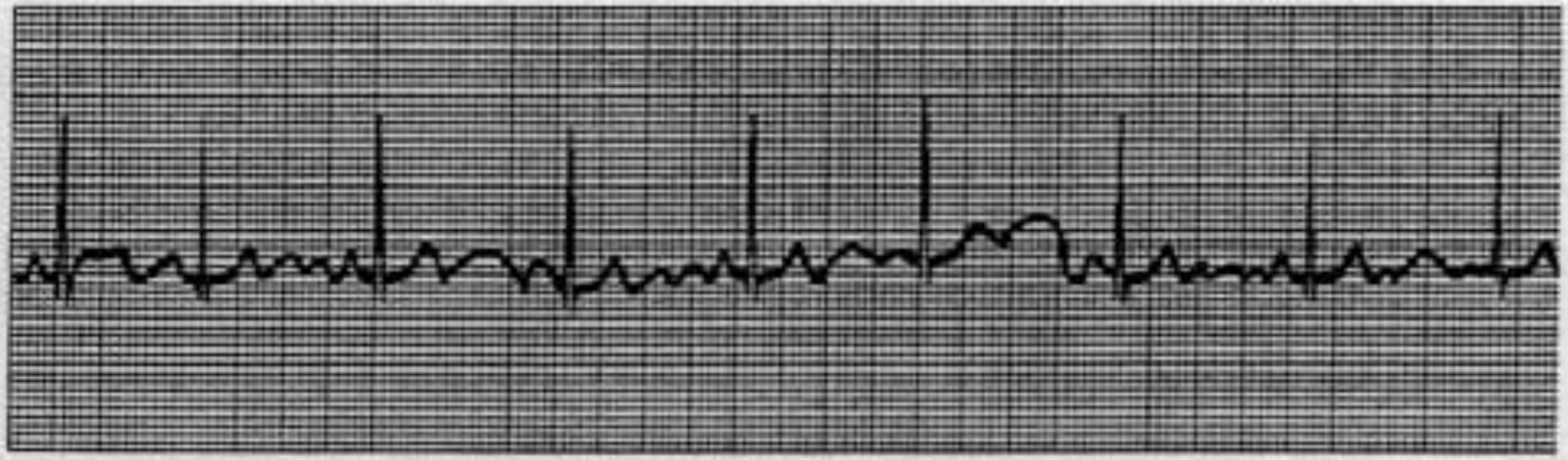
- The fibrillating EGG is characterized by a lack of *QRS* complexes and a visible component of approximately 150-cycle oscillations.



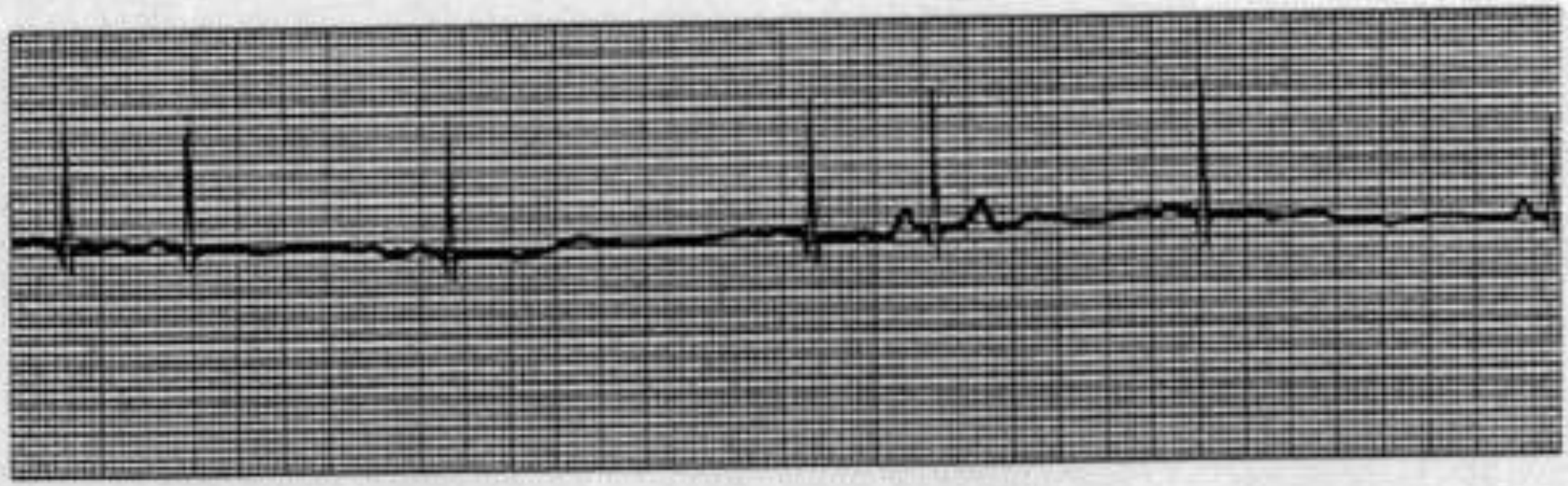
Ventricular fibrillation



Ventricular tachycardia



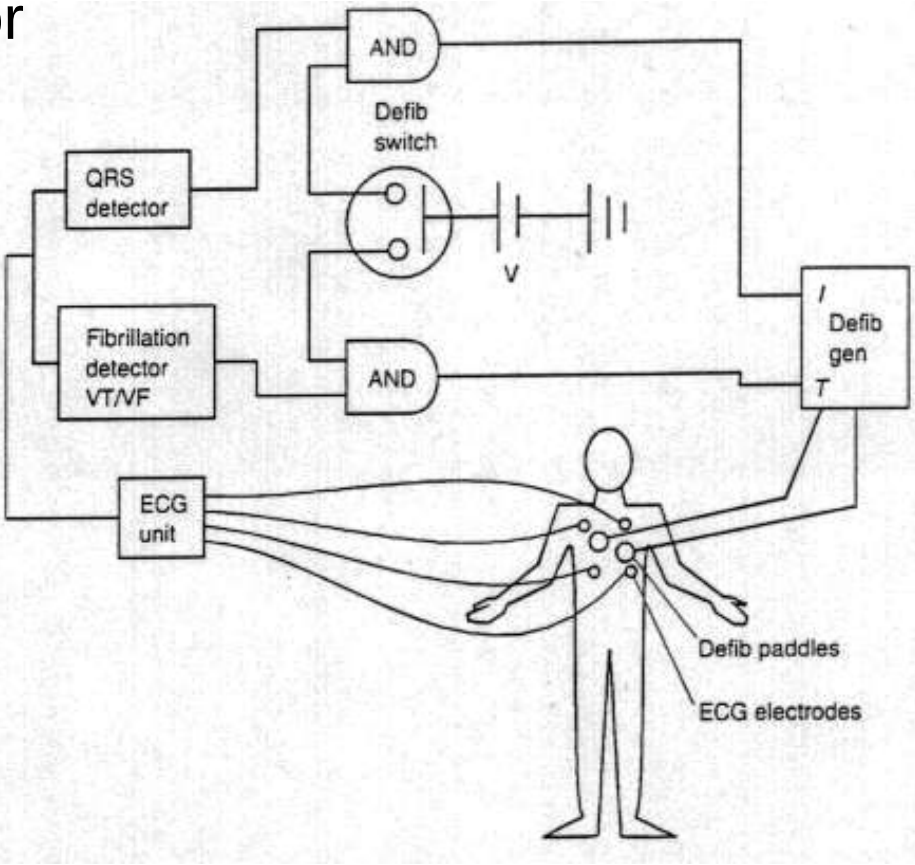
Atrial flutter



Atrial fibrillation

- In an attempt to provide early defibrillation to more of the population, a large number of emergency service people, such as firemen and policemen, who are not used to treating arrhythmias have been trained in the use of the simple automatic external or diagnostic defibrillator.

- The operation of this defibrillator is best explained by beginning with the patient who is wired with four ECG leads placed in the standard position.
  - The EGG waveform information is processed by the EGG unit to the lower left.
  - The output waveform is then applied to the *QRS* detector and the fibrillation detector.



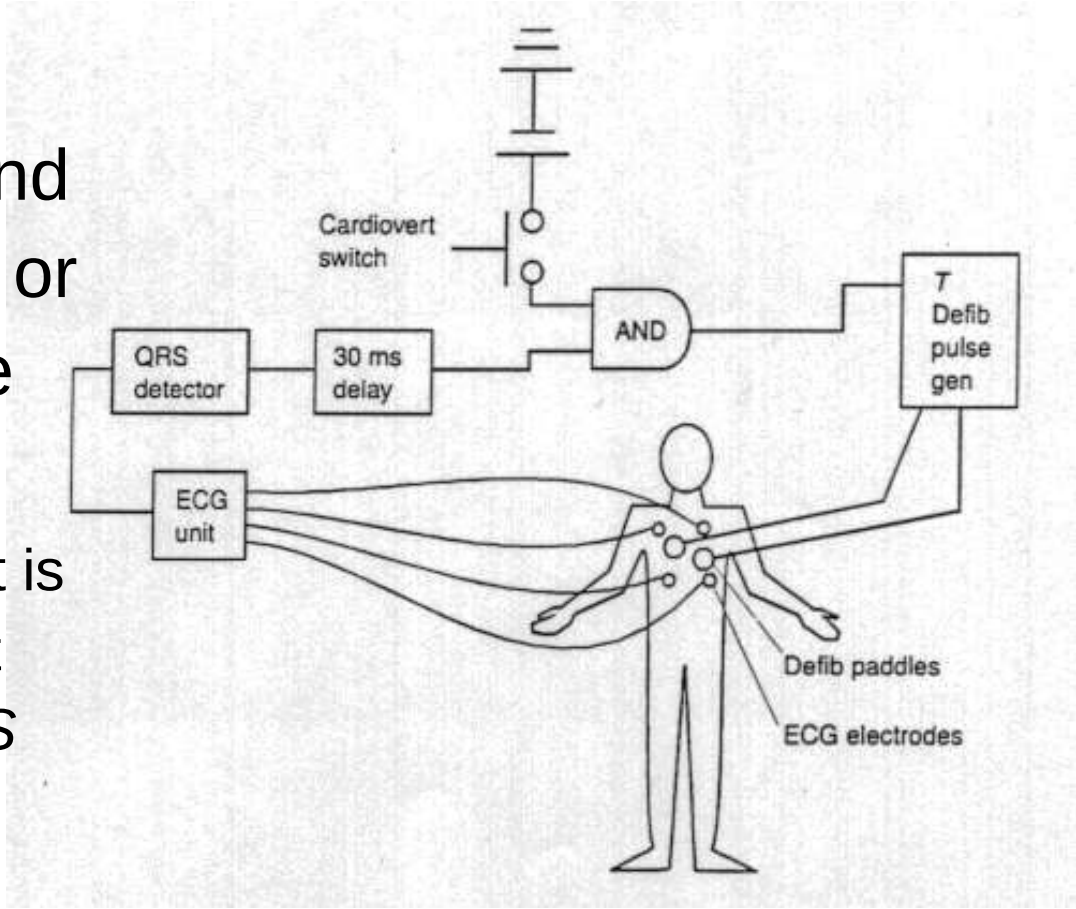
- If the *QRS* is present, a signal will be applied to the upper lead of the upper AND gate.
  - Then if the attendant pushes the *defib* switch, placing a signal on the lower lead also, the AND gate will deliver an inhibiting signal to the defibrillator pulse generator.
    - An AND gate generates an output signal only when stimulus is present on both the upper *and* the lower input terminals.

- If there is no *QRS* and the fibrillation detector delivers a stimulating pulse to the lower lead of the lower AND gate, then when the attendant activates the *defib* switch, a stimulus will be put on both terminals of that gate, and its output will trigger the defibrillator.
  - Thus, the defibrillator will deliver a therapeutic current pulse through the large electrodes on the sternum and apex to the patient's chest.

# Cardioverter

- When a physician diagnoses evidence of an abnormal supraventricular rhythm, such as an atrial flutter or a hemodynamically stable ventricular tachycardia, he or she may prescribe for the patient to be cardioverted.
  - A *cardioverter* delivers a defibrillating pulse to the heart synchronized on the *R* wave so that it does not accidentally cause ventricular fibrillation.

- Here, the leads are placed in the standard position on the chest, and the defibrillator paddles or adhesive electrodes are placed appropriately.
  - The EGG from the patient is amplified by the EGG unit and presented to the *QRS* detector.



- When the *QRS* is present, a signal from the output of the detector is passed through approximately 30 milliseconds of delay and then presented to the AND gate.
  - If the attendant is holding down the cardiovert switch, the AND gate will trigger the defibrillator pulse generator.
    - It then defibrillates the heart approximately 30 milliseconds after the *QRS.*

- This is the point in time that the heart normally depolarizes and delivering the defibrillation pulse at that time should not cause the heart to fibrillate.
  - The timing is important to keep the current pulse from hitting the heart during the *T wave*, when the ventricle may become partially depolarized and cause the heart to fibrillate.

# TELEMETRY

# Definition

**Telemetry : The process of making measurements on an object in the remote area and sending those measurements to a distant location for analysis**

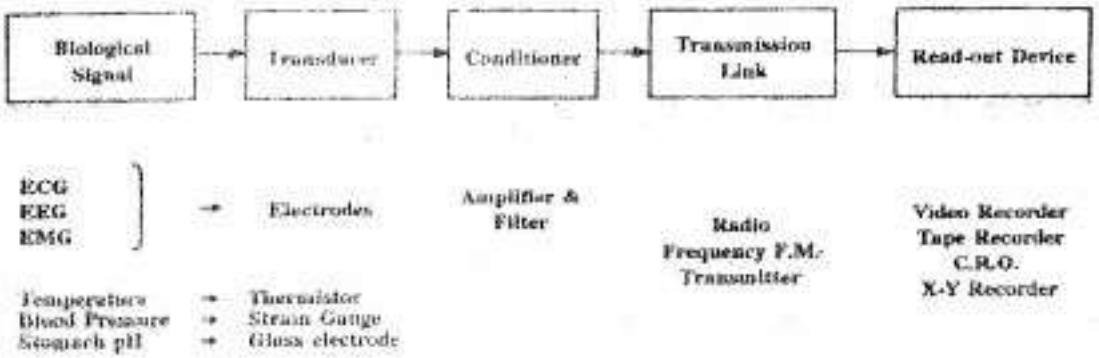
**Bio-Telemetry : The process of acquiring the biological information of a living organism along with their environment and sending those information to a distant location for analysis**

# DIFFERENT TYPES OF BIO TELEMETRY SYSTEM

# ELEMENTS OF BIOTELEMETRY SYSTEM

- The transducer converts the biolog9ical variable in to electrical
- Signal conditioner amplifies and modifies this signal for effective transmission
- Transmission link connects the signal input blocks to the read out devices by wire(or)wireless mean

# Block diagram of a bio-telemetry system



# Design of bio-telemetry system

The telemetry system should be selected to transmit the bio-electric signals with maximum fidelity and simplicity.

The size and weight of the telemetry system should be small.

It should have more stability and reliability

The power consumption should be very small.

# Radio telemetry systems

There are two types

1.single channel telemetry system

2.multichannel telemetry system

Single channel telemetry system:

A miniature battery operated radio transmitter is connected to the electrodes of the patients

Radio receiver which detects the radio signals and recovers the signals for further processing.

Receiving system can even be located in a room separate from the patien

few hundred kHz to about 300mHz

# Block diagram

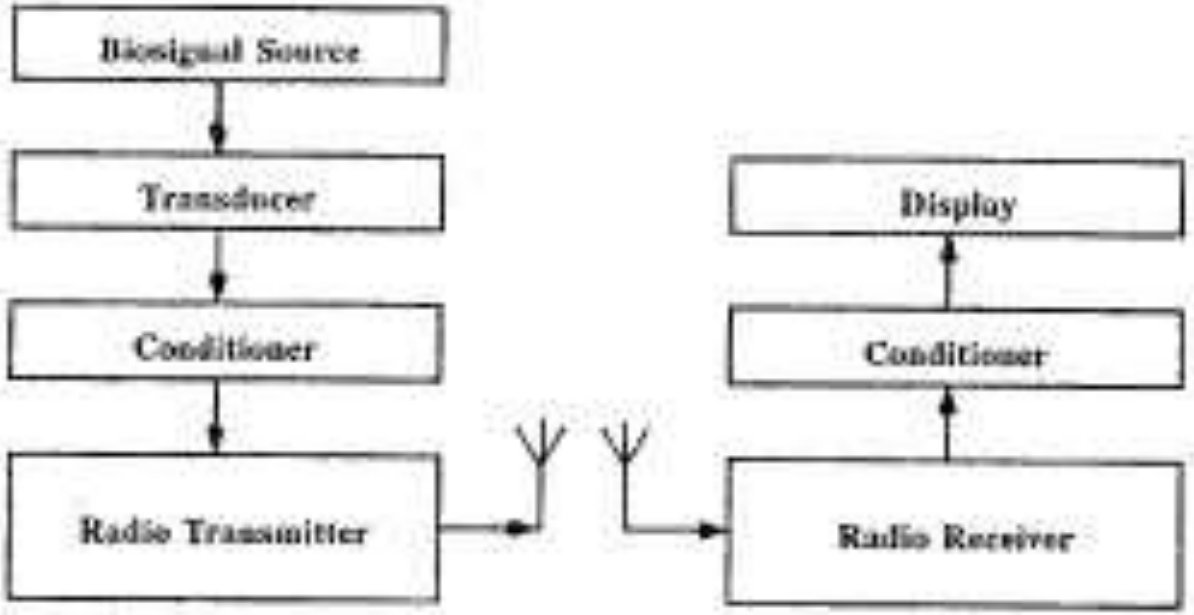



Fig.8.2. Block diagram of a typical single channel radio telemetry system

# Transmission of bio electric variables

- Active measurement:
- bioelectric variables like ECG,EMG and EEG are measured directly with out using any excitation voltage
- Passive measurement:
- Here the physiological variables like blood pressure,temperature,blood flow etc are measured indirectly using transducer and excitation voltage

# Tunnel diode fm transmitter

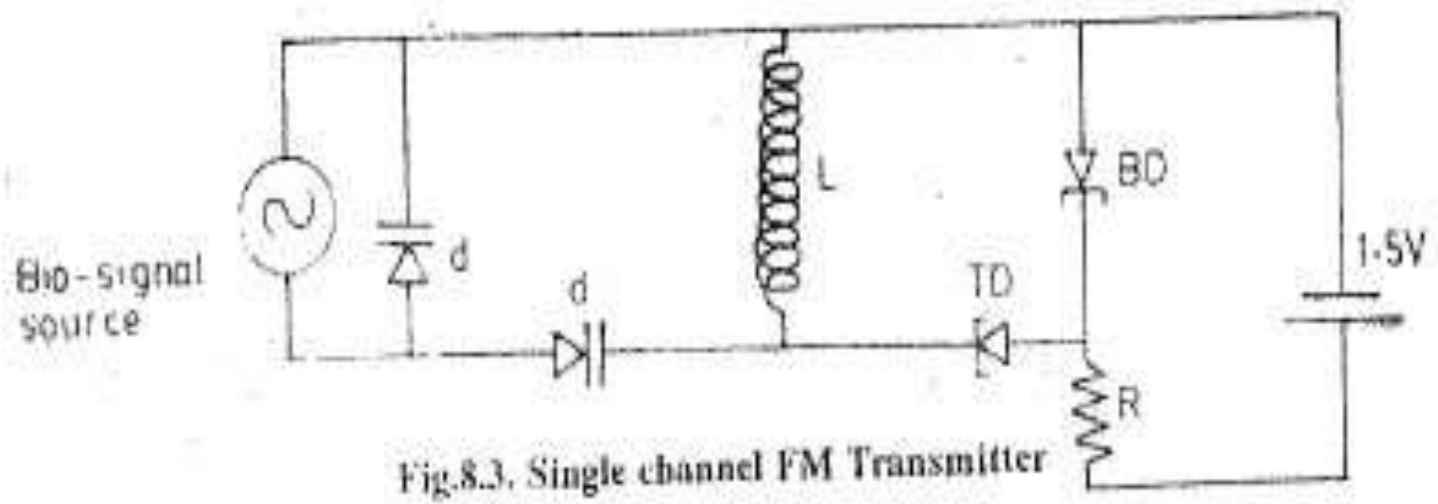



Fig.8.3. Single channel FM Transmitter

This circuit has higher fidelity an sensitivity

Total weight is about 1.44gm with battery

Radio frequency used - 100 to 250mhz

Frequency response - 0.01hz to 20khz

Input impedance - 300kilo ohms to mega ohms

Temperature stability for carrier freq -0.05%/c

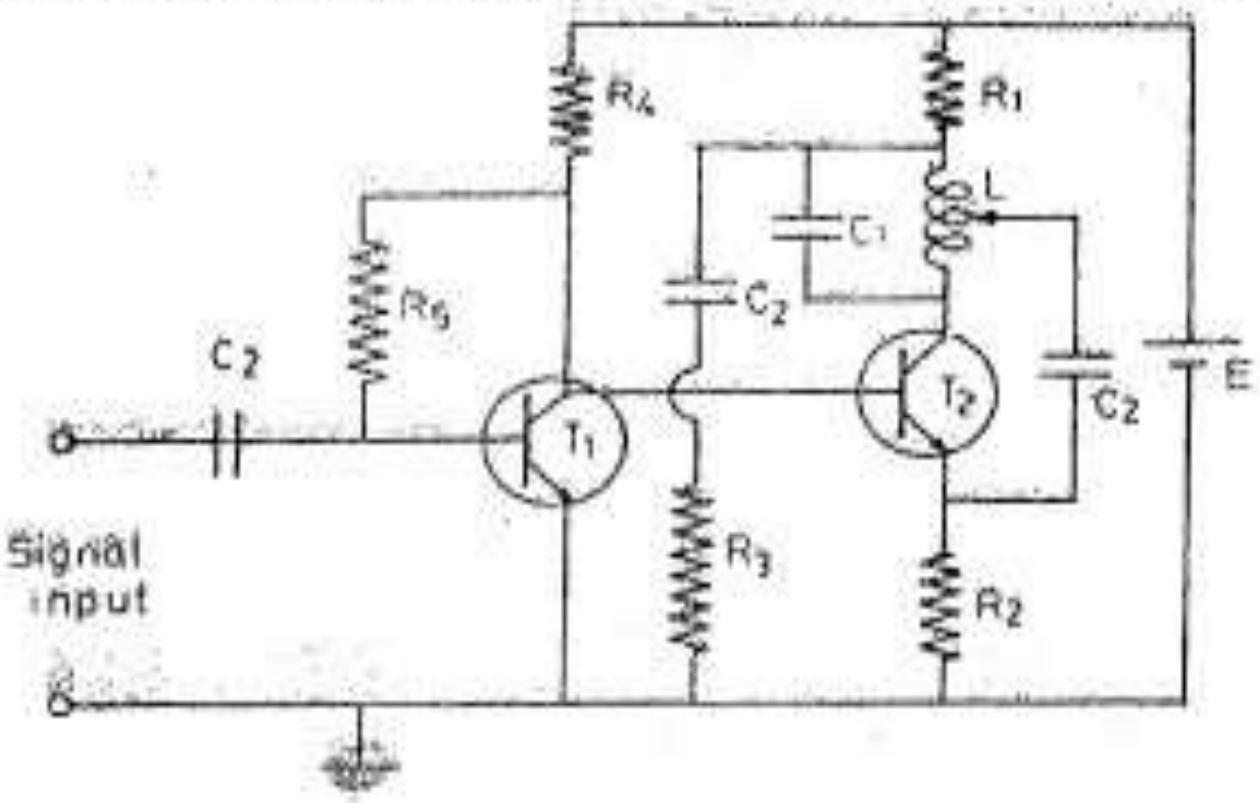
Varactor diodes d which are voltage sensitive semi conductor capacitors are used for freq modulation

The signal is transmitted through the inductor L

# Hartley type F.Mtransmitter

- In this circuit ,the capacitor c1 and inductor l1 form the tank circuit.
- Capacitor  c2 are coupling capacitors
- T1 is the driver amplifier capacitor and T2 is the oscillating transistor.
- Amplitude of i/p signal  varies from 10uv to several millivolts.
- Bandwidth of the signal is from 100hz to 1000hz.

b) Hartley type F.M. Transmitter (for the transmission of ECG, EEG & EMG)



# Radio telemetry with a sub-carrier

When the relative position of transmitter to the body or other conduction object changes,the carrier frequency and amplitude will change.

To avoid this loading effect,the subcarrier system is needed.

The signal is modulated on a subcarrier to convert the signal frequency to the neighbourhood of the subcarrier frequency.

At the receiver end,the receiver detects the R.F. and recovers the subcarrier carrying the signal.

All noise interference and loading effect can be separated by filters

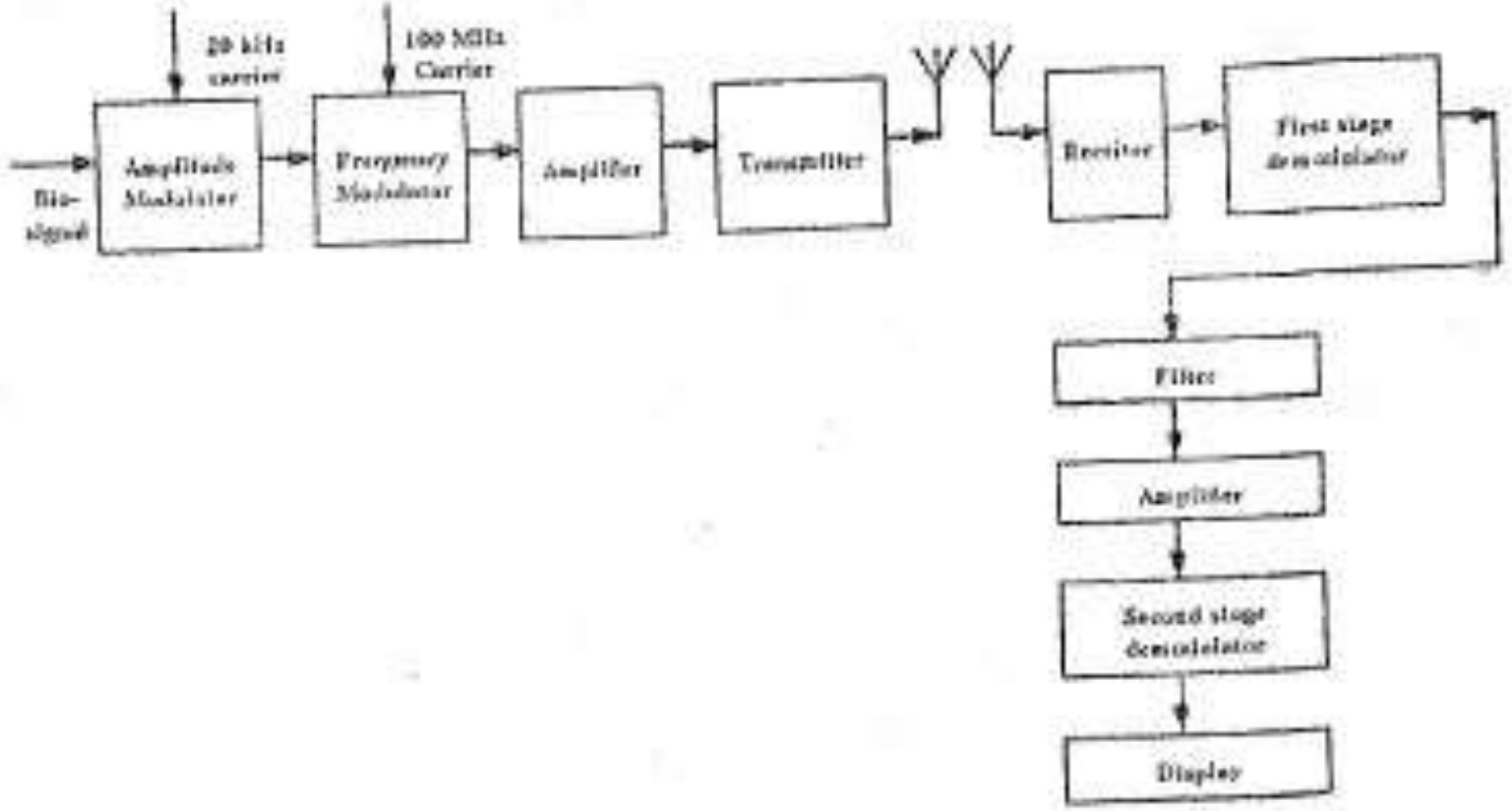



Fig.8.6. Biotelemetry system with a subcarrier

# Multiple channel telemetry system

There are two types :

1. Frequency division multiplex
2. Time division multiplex

## Frequency division multiplex system:

Each signal is frequency modulated on a subcarrier frequency

Then these modulated subcarrier frequencies are combined to modulated the main R.F. carrier.

The frequency of the subcarriers has to be carefully selected to avoid interference

The low pass filters are used to extract the signals without any noise.

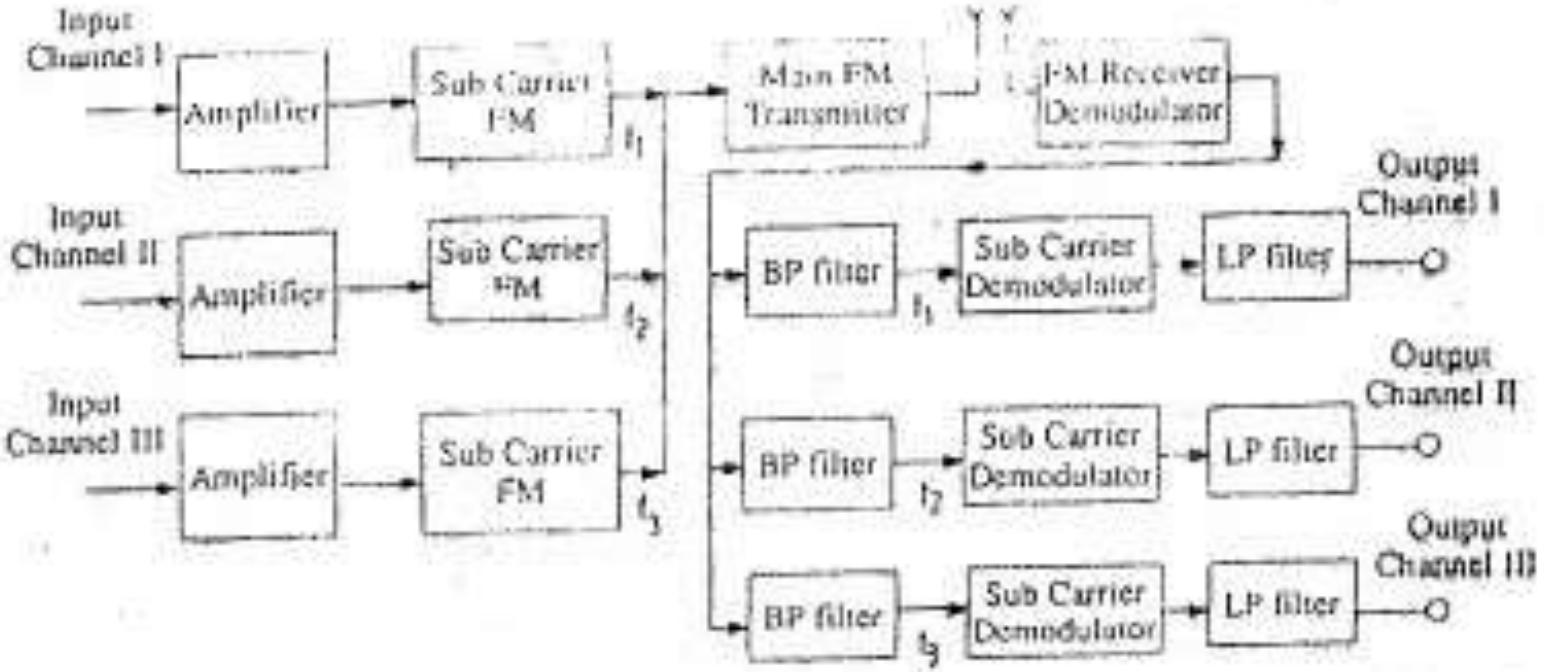



Fig.8.8 Frequency Division Multiplex System

# Time division multiplex telemetry system

- The transmission channel is connected to each signal-channel input for a short time to sample and transmit that signal
- When all the channels have been scanned once a cycle is completed and the next cycle will start
- At the reciever end,the process is reversed
- If the number of scanning cycles per second is large and if the transmitter and the reciever

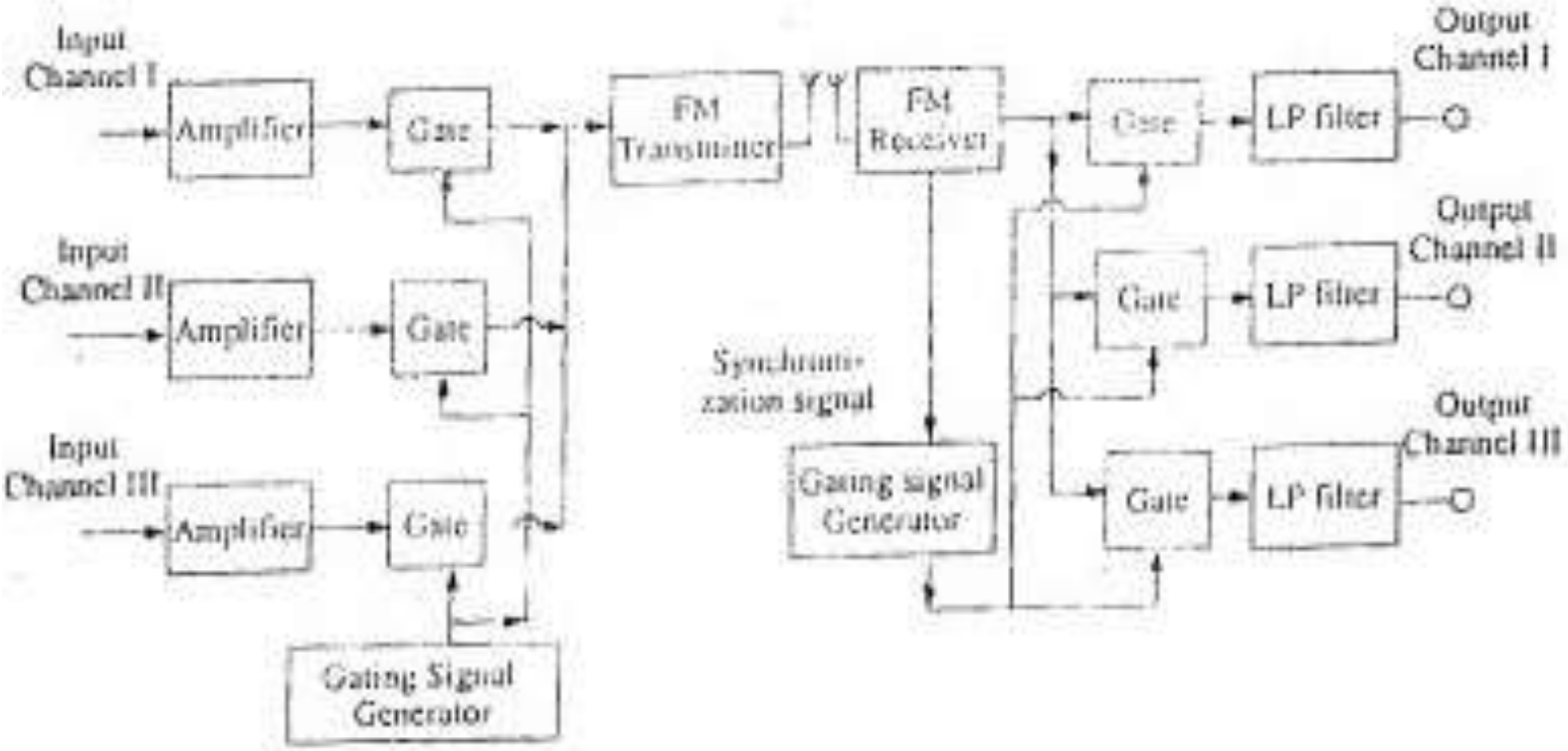



Fig.8.9 Time Division Multiplex System

# RADIO PILL

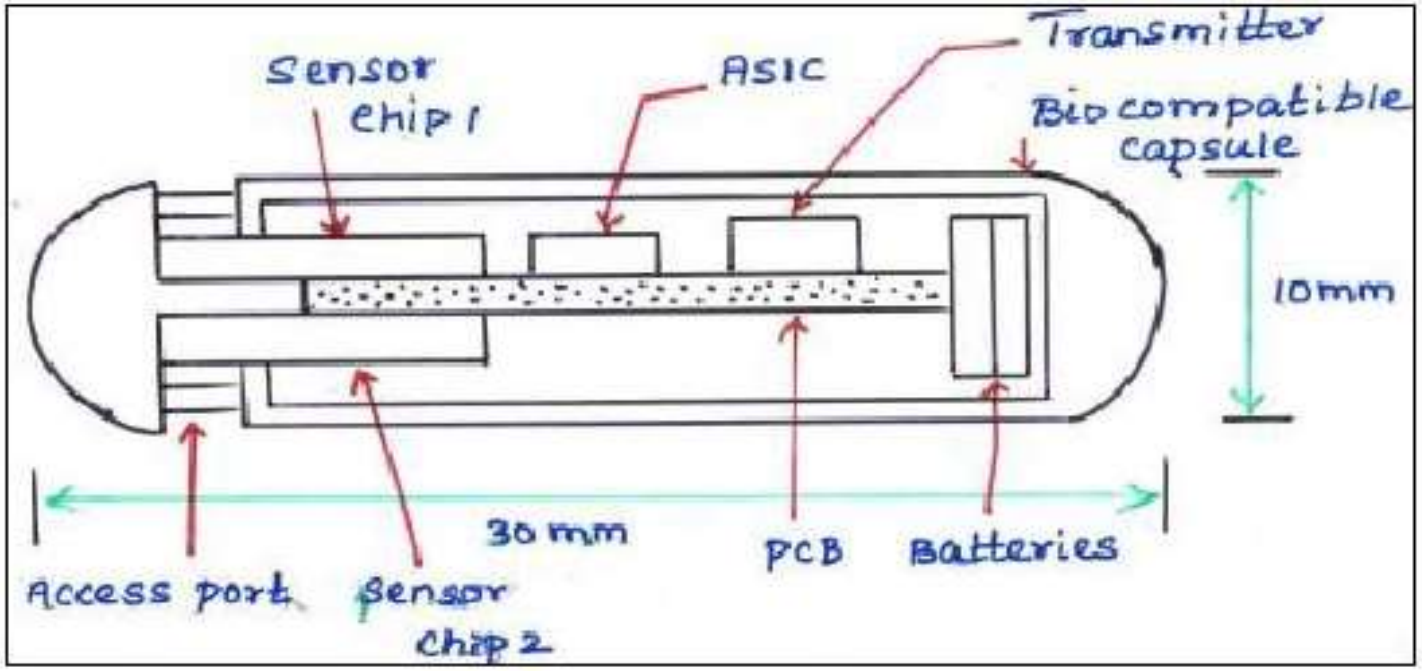
# Radio Pill

- Radio pill when swallowed, will travel the GI tract (Gastrointestinaltract) and simultaneously perform multiparameter in physiological analysis.
- After completing its mission it will come out of the human body by normalbowel movement.

# Radio Pill

- The pill is 10mm in diameter and 30mm long weighing around 5gmand records parameters like temperature, pH, conductivity and dissolved oxygen in real time.
- The pill comprises an outer biocompatible capsule encasing microsensors, a control chip, radio transmitter and two silver-oxide cells.

# Radio Pill


Sensor
Chip 1
ASIC
Transmitter
Bio compatible
capsule
10mm
30 mm
Access port
Sensor
Chip 2
PCB
Batteries

# Radio Pill

- The outer casing of the pill is made by machining chemically resistant polyetheterketone, which is biocompatible. It is made up of two halves, which are joined together by screwing.
- The pill houses a PCB chip carrier that acts as a common platform for attachment of sensors, application- specific integrated circuit (ASIC), radio transmitter and batteries

# TELESTIMULATION

- Telestimulation systems are described for chronic indirect muscle stimulation in caged rabbits and mice.
- Both systems use a 5 MHz carrier frequency transmission and consist of a transmitter and a receiver.
- The latter is fixed to the back of the animal.

# TELESTIMULATION

- The system for rabbits uses pulse width modulation for transmitting stimulation frequency and amplitude.
- Duration of the stimulation impulse is generated in the receiver.
- Clock batteries in the receiver generate impulse energy.

# TELESTIMULATION

- The impulse amplitude varies by only 1%.
- In the system used for mice, impulse energy is transmitted together with the stimulation frequency.
- This is achieved by a receiver containing two separate coils which are opposed to each other in an angle of 80 degrees C.

# TELESTIMULATION

- In contrast to the rabbit system, the duration of the stimulation impulse is generated by the impulse width of the 5 MHz carrier.
- The amplitude of the stimulation impulse depends on the amplitude of the carrier.
- Due to the geometry of induction coil and receiver, impulse intensity varies at maximum by only 10%.

# UNIT 4

# Definition of Radiation

- “Radiation is an energy in the form of electro-magnetic waves or particulate matter, traveling in the air.”

# Types of Radiation

- Radiation is classified into:
  - Ionizing radiation
  - Non-ionizing radiation

# Ionizing Versus Non-ionizing Radiation

- **Ionizing Radiation**
  - **Higher energy electromagnetic waves (gamma) or heavy particles (beta and alpha).**
  - **High enough energy to pull electron from orbit.**

- **Non-ionizing Radiation**
  - **Lower energy electromagnetic waves.**
  - **Not enough energy to pull electron from orbit, but can excite the electron.**

# Ionizing Radiation

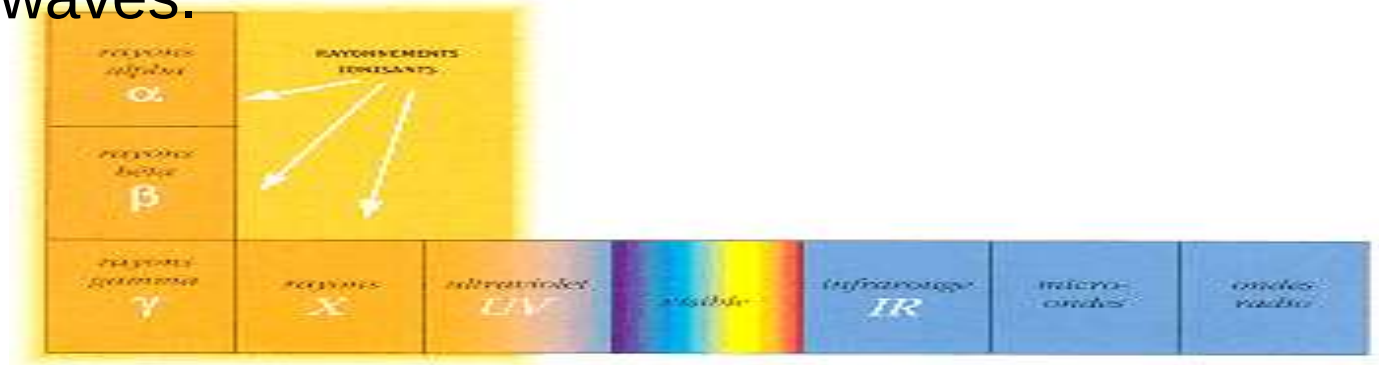
- Definition:

  “ It is a type of radiation that is able to disrupt atoms and molecules on which they pass through, giving rise to ions and free radicals”.

# Another Definition

## Ionizing radiation

A radiation is said to be ionizing when it has enough energy to eject one or more electrons from the atoms or molecules in the irradiated medium. This is the case of a and b radiations, as well as of electromagnetic radiations such as gamma radiations, X-rays and some ultra-violet rays. Visible or infrared light are not, nor are microwaves or radio waves.



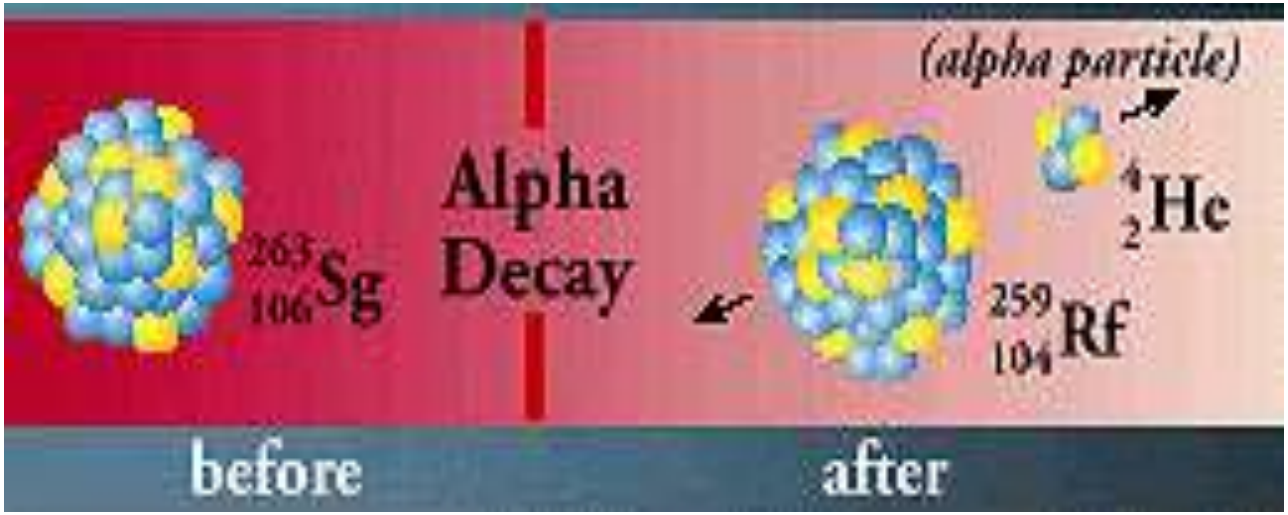
# Primary Types of Ionizing Radiation

- Alpha particles
- Beta particles
- Gamma rays (or photons)
- X-Rays (or photons)
- Neutrons

# Types and Characteristics of Ionizing Radiation

## Alpha Particles

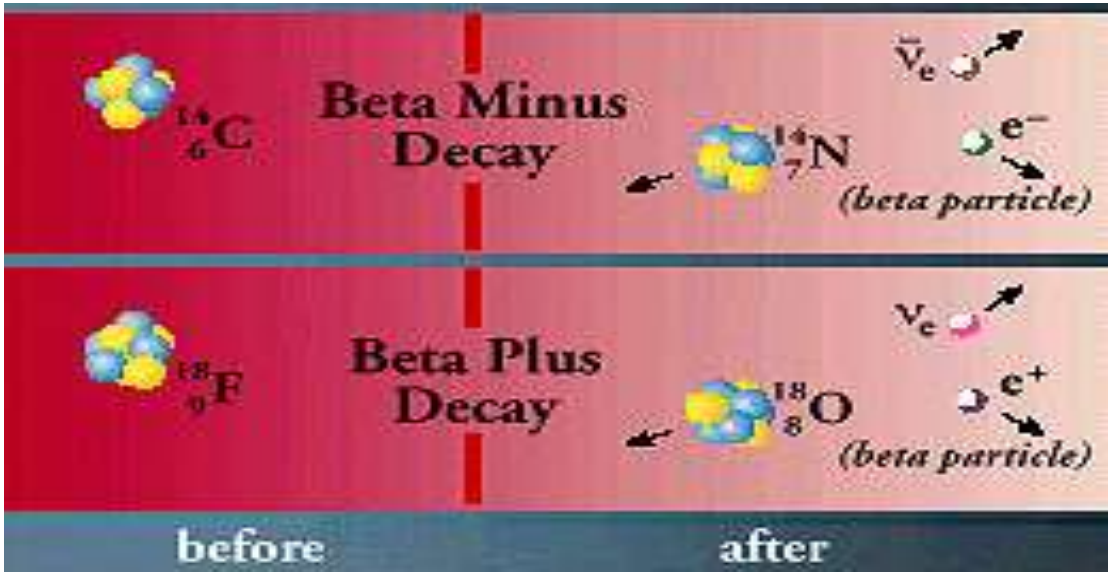
Alpha Particles: 2 neutrons and 2 protons
They travel short distances, have large mass
Only a hazard when inhaled



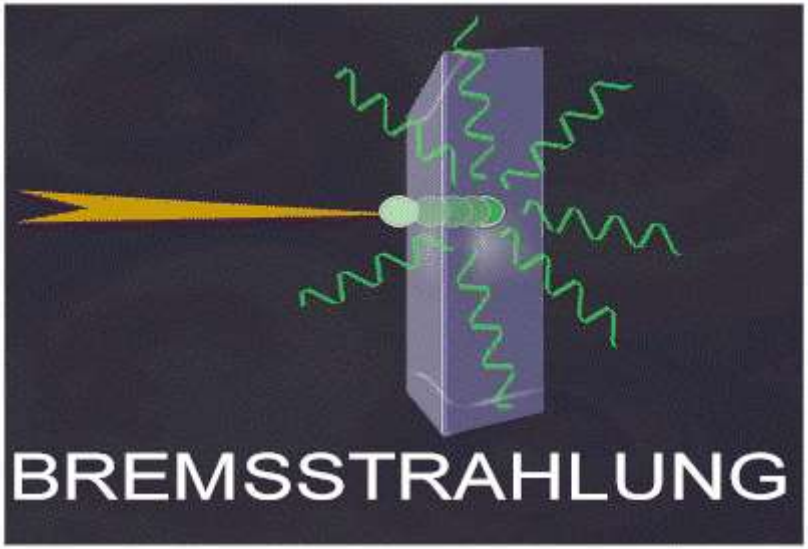
- ***Alpha Particles*** *(or Alpha Radiation)*: **Helium nucleus** (2 neutrons and 2 protons); +2 charge; heavy (4 AMU). Typical Energy = 4-8 MeV; **Limited range** (<10cm in air; 60µm in tissue); High LET (**QF=20**) causing **heavy damage** (4K-9K ion pairs/µm in tissue). **Easily shielded** (e.g., paper, skin) so an **internal radiation** hazard. Eventually lose too much energy to ionize; become He.

# Beta Particles

Beta Particles: Electrons or positrons having small mass and variable energy. Electrons form when a neutron transforms into a proton and an electron or:

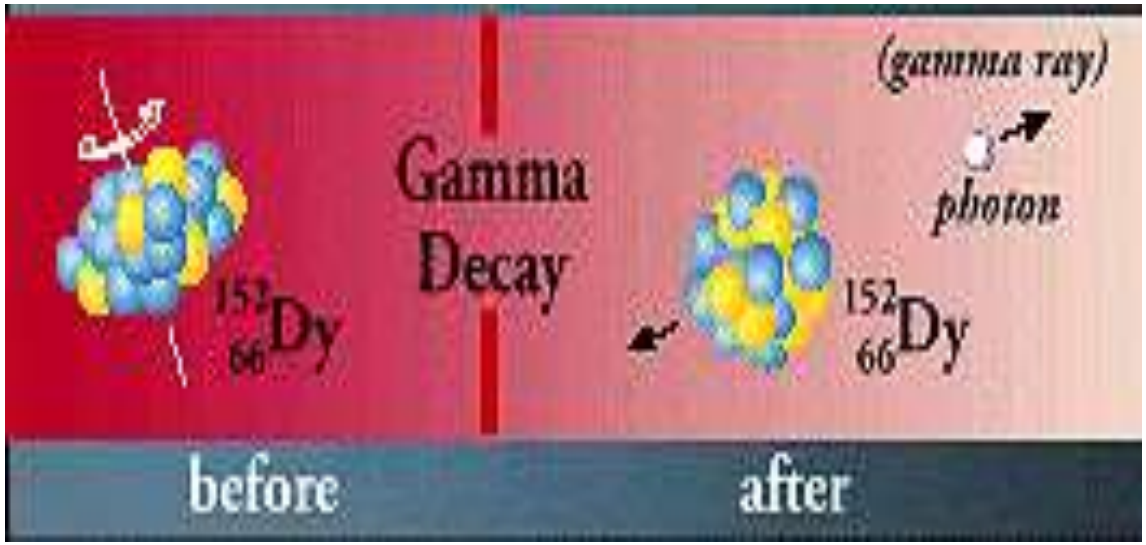


- ***Beta Particles***: High speed **electron ejected from nucleus**; -1 charge, light 0.00055 AMU; Typical Energy = several KeV to 5 MeV; Range approx. 12'/MeV in air, a few mm in tissue; Low LET (**QF=1**) causing **light damage** (6-8 ion pairs/μm in tissue). Primarily an internal hazard, but high beta can be an external hazard to skin. In addition, the high speed electrons may lose energy in the form of X-rays when they quickly decelerate upon striking a heavy material. This is called **Bremsstralung** (or Breaking) **Radiation.** Aluminum and other light (<14) materials are used for shielding.


BREMSSTRAHLUNG

# Gamma Rays

**Gamma Rays (or photons): Result when the nucleus releases energy, usually after an alpha, beta or positron transition**



# X-Rays

X-Rays:  Occur whenever an inner shell orbital electron is removed and rearrangement  of the atomic electrons results with the release of the elements characteristic X-Ray energy

- ***X-*** *and* ***Gamma Rays***: **X-rays** are photons (Electromagnetic radiations) emitted **from electron orbits**. **Gamma rays** are photons emitted **from the nucleus**, often as part of radioactive decay. Gamma rays typically have higher energy (Mev's) than X-rays (KeV's), but both are unlimited.

# Neutrons

Neutrons:  Have the same mass as protons but are uncharged

# Non-ionizing Radiation

- Definition:

“ They are electromagnetic waves incapable of producing ions while passing through matter, due to their lower energy.”

- All earth surface system components emit radiation---the sun and the earth are the components we are most interested in

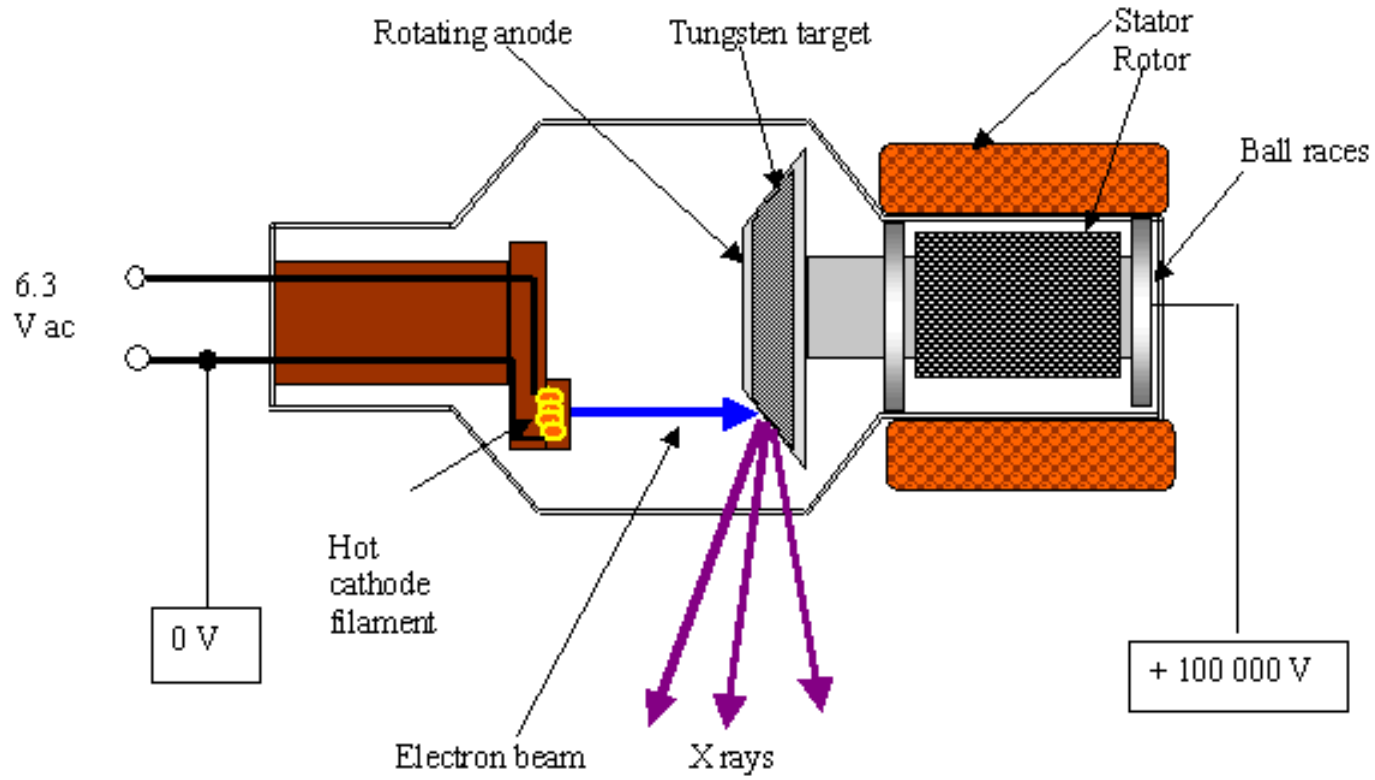
- The sun emits radiation composed of high energy infrared radiation, visible light, and ultraviolet radiation collectively known as shortwave radiation (SW)

- The earth emits radiation composed of lower energy infrared radiation collectively known as long-wave radiation (LW)

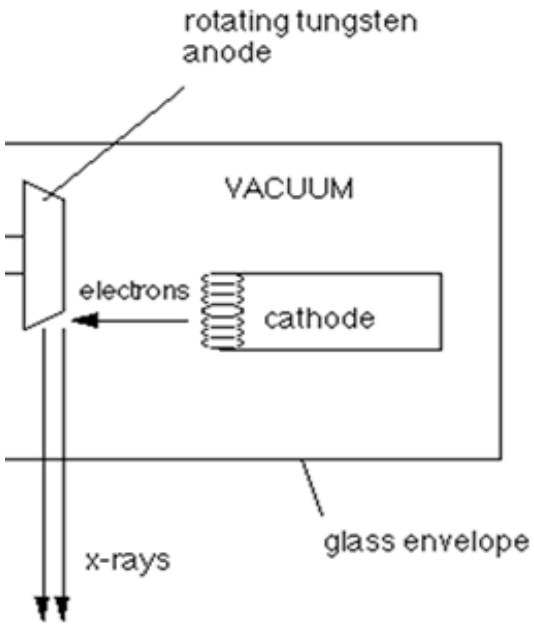
# Examples on Non-ionizing Radiation Sources

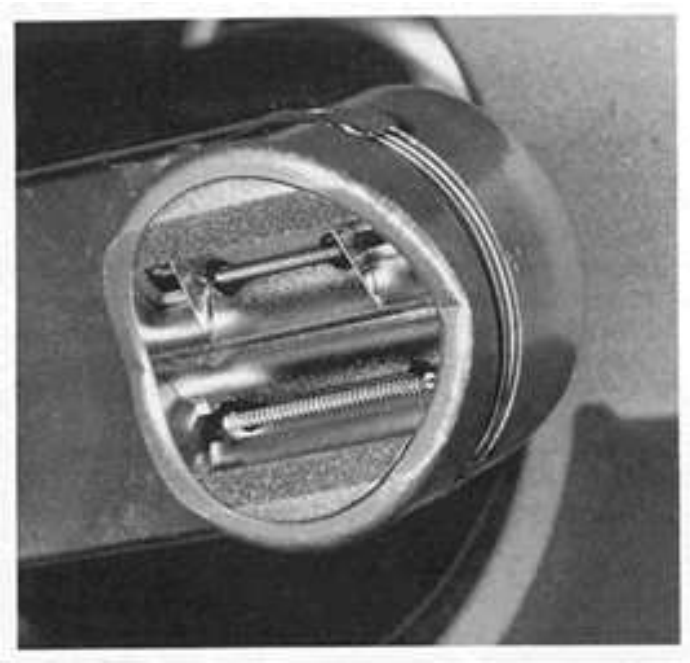
- Visible light
- Microwaves
- Radios
- Video Display Terminals
- Power lines
- Radiofrequency Diathermy (Physical Therapy)
- Lasers

# X-ray Production


Rotating anode
Tungsten target
Stator
Rotor
Ball races
6.3
V ac
Hot
cathode
filament
0 V
+ 100 000 V
Electron beam
X rays

# CATHODE



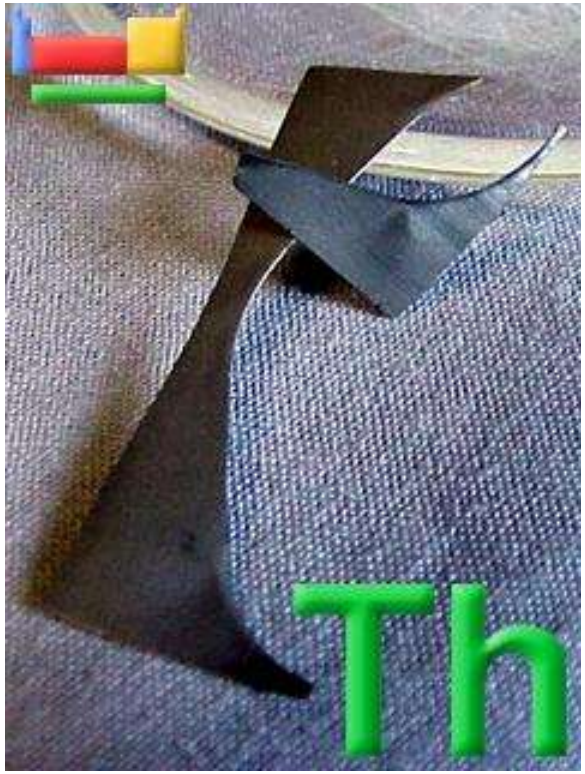



MADE OF TUNGSTEN + 1%-3% THORIUM

# TUNGSTEN

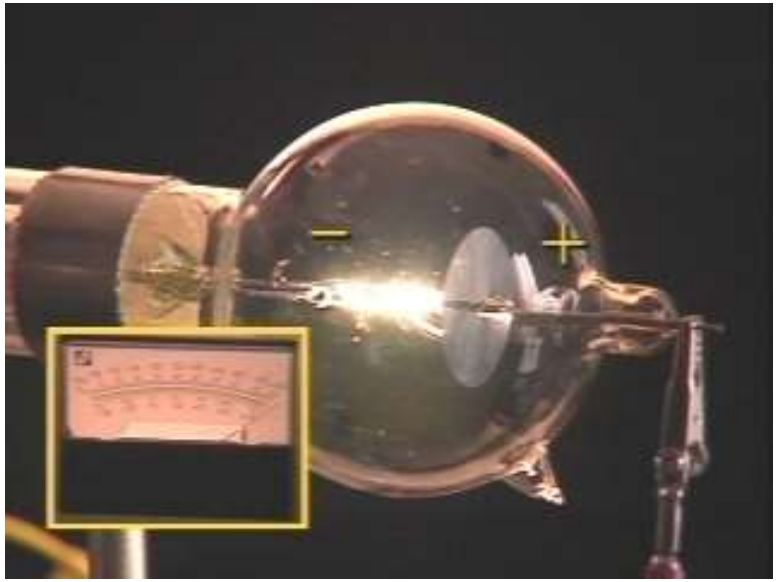

MELTING POINT- 3,410 DEG. CELSIUS

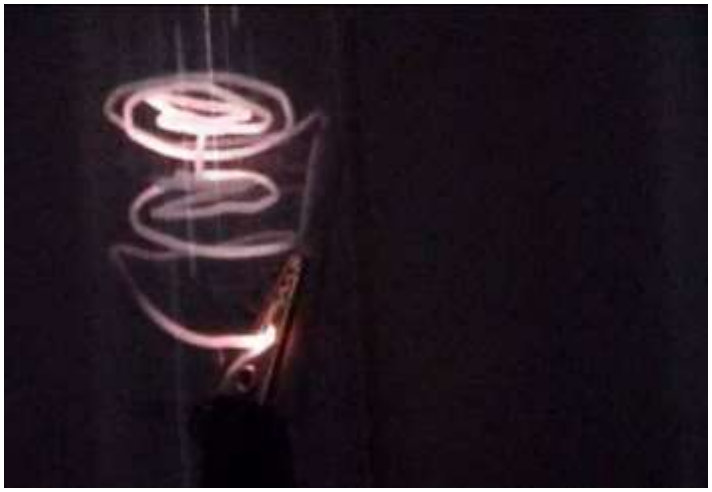
# THORIUM




Z # 90

# THERMIONIC EMISSION



CATHODE HEATED UP TO AT LEAST 2,200 DEG. CELSIUS

# ANODE +++++

TUNGSTEN TARGET

# TUNGTEN AS TARGET

HIGH Z# - 74------EFFICIENCY OF X-RAY PRODUCTION 

HIGH MELTING POINT –3,410 ° C– TARGET HEATED TO 2,000 ° C

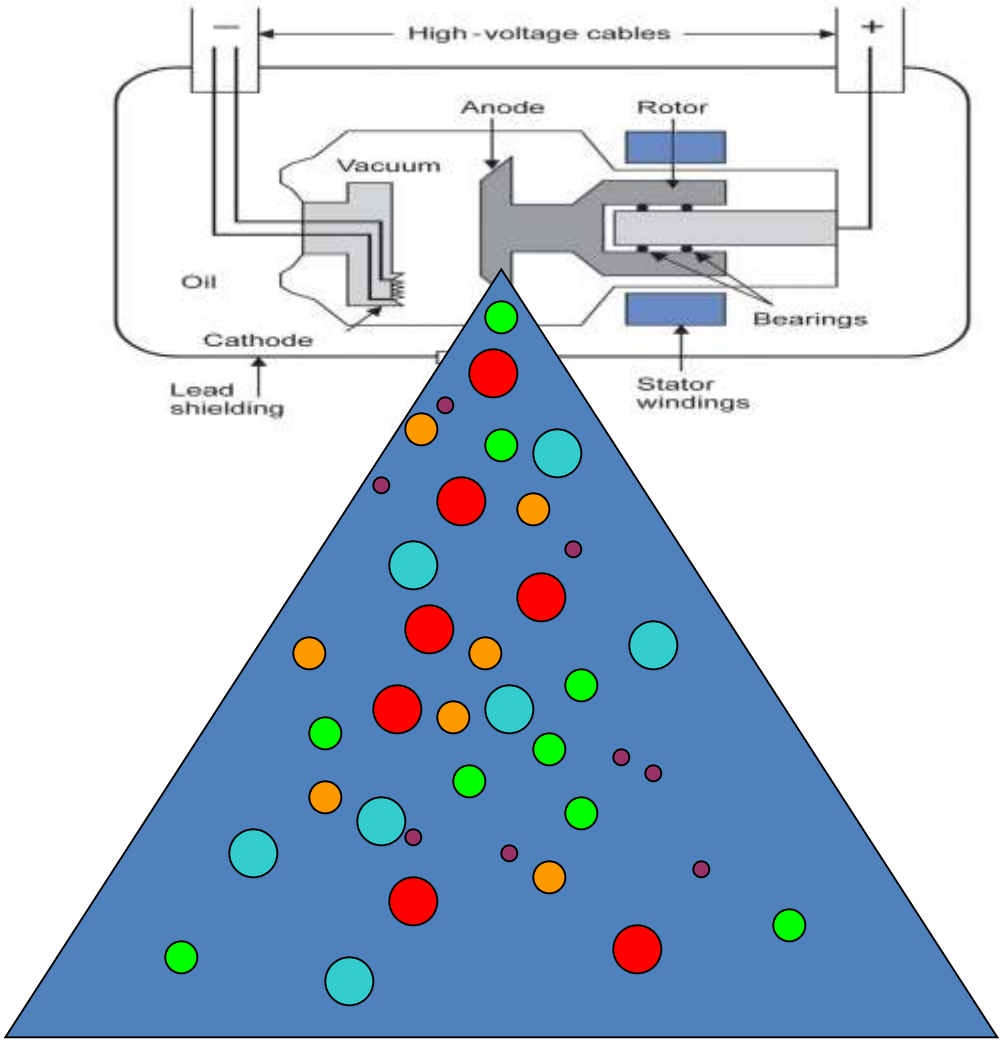
# X-RAY PRODUCTION

- BREMSSTRAHLUNG RADIATION
- CHARACTERISTIC RADIATION

# BREMSSTRAHLUNG RADIATION

If an incoming free electron gets close to the nucleus of a target atom, the strong electric field of the nucleus will attract the electron, thus changing direction and speed of the electron. The Electron  looses energy which will be emitted as an X-ray photon. The energy of this photon will depend on the degree of interaction between nucleus and electron, i.e. the passing distance. Several subsequent interactions between one and the same electron and different nuclei are possible. X-rays originating from this process are called bremsstrahlung. Bemsstrahlung is a German word directly describing the process: "Strahlung" means "radiation", and "Bremse" means "brake

# BREMS EMISSION-CONTINUOUS

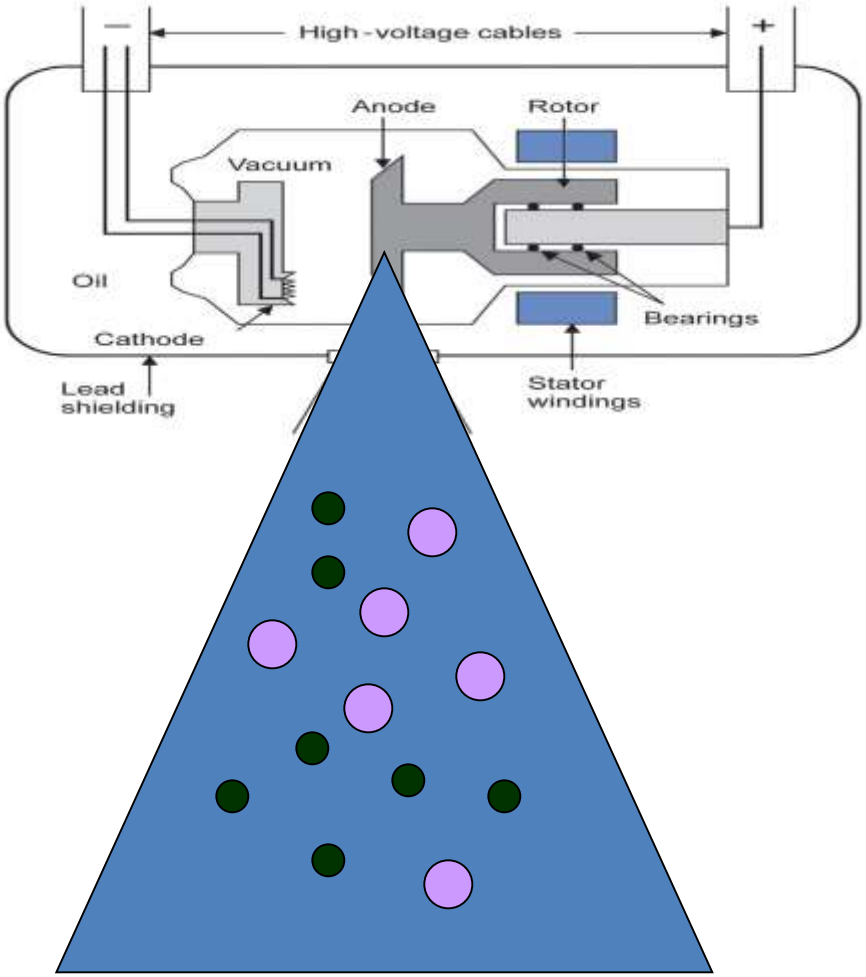


# Characteristic X-rays

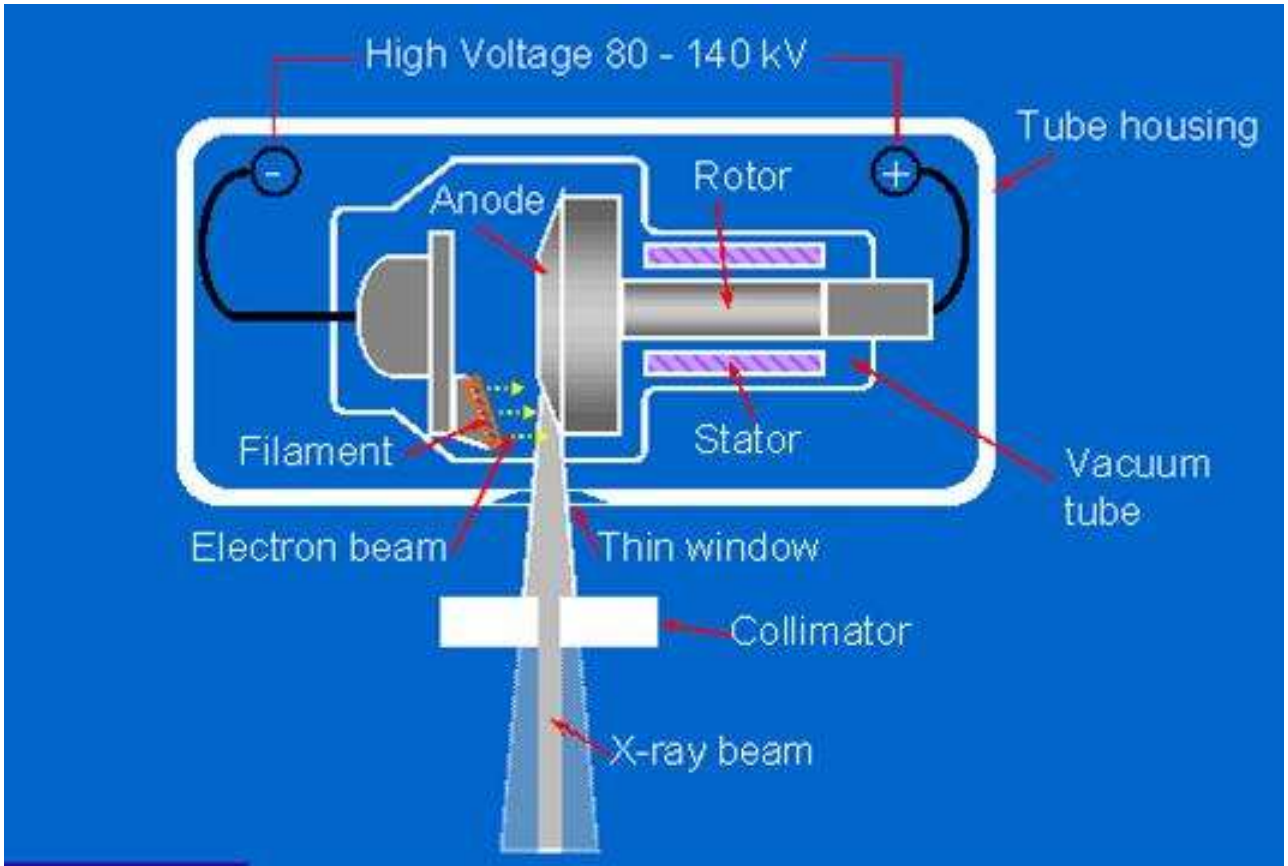
The high energy electron can also cause an electron close to the nucleus in a metal atom to be knocked out from its place. This vacancy is filled by an electron further out from the nucleus. The well defined difference in binding energy, characteristic of the material, is emitted as a monoenergetic photon. When detected this X-ray photon gives rise to a characteristic X-ray line in the energy spectrum.

# CHARACTERISTIC EMISSION-

# LESS POLYENERGETIC!

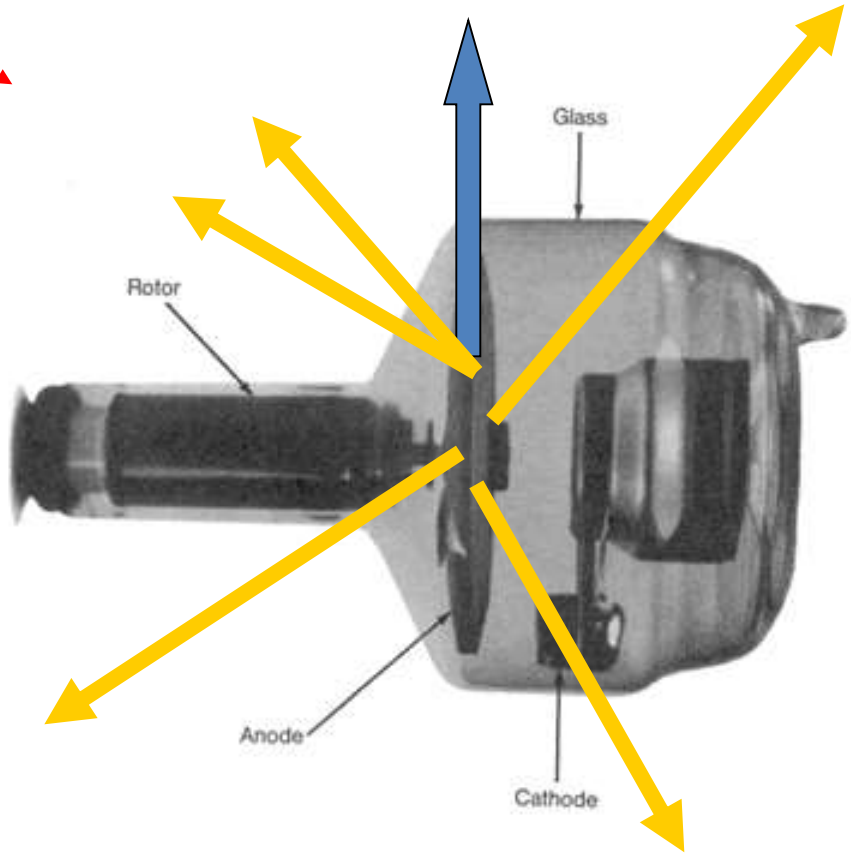


# USEFUL RADIATION – PROJECTED TOWARD THE PATIENT

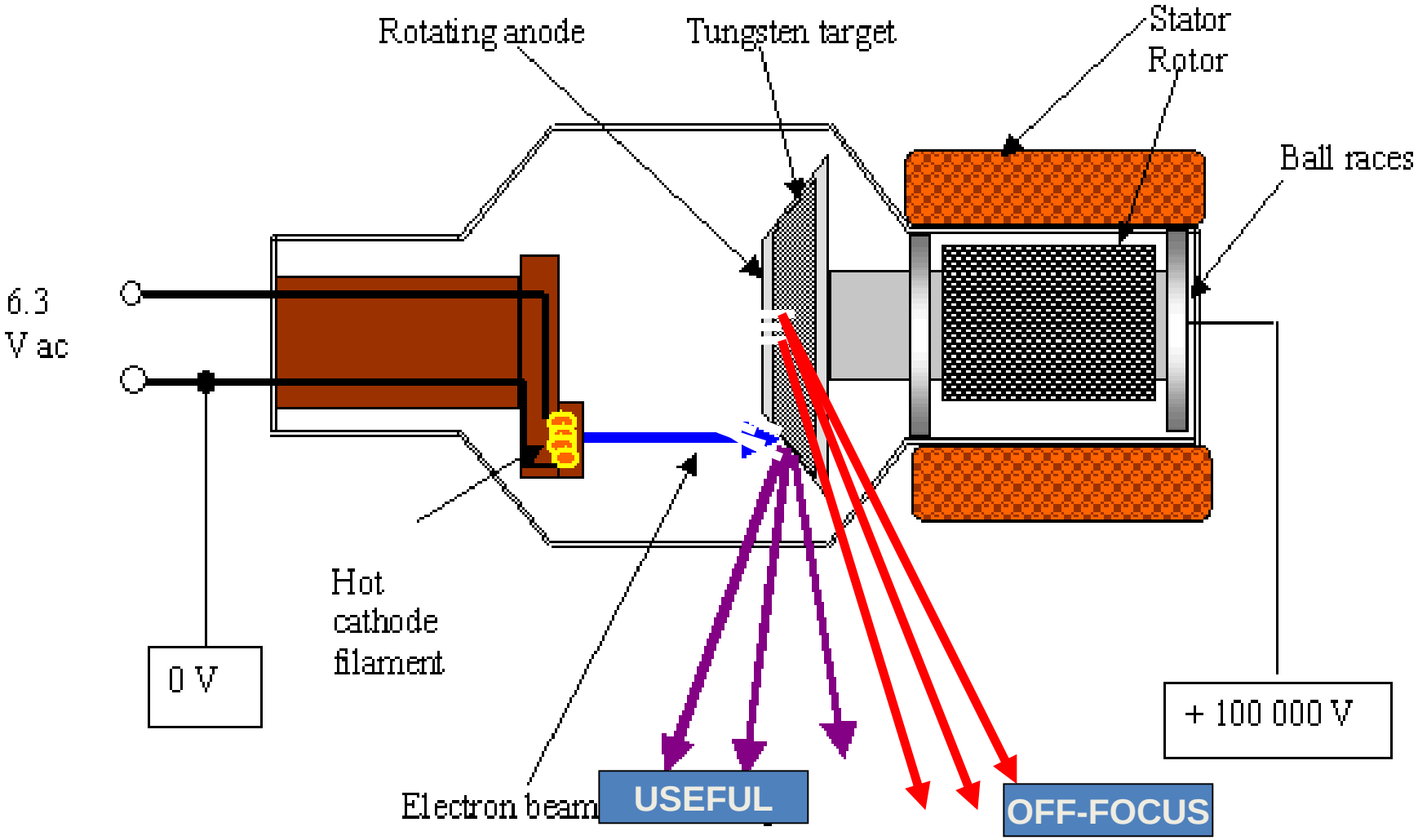


# LEAKAGE RADIATION

HOUSING



# OFF-FOCUS RADIATION



# USE OF RADIOISOTOPES IN MEDICINE

# Use Of Radioisotopes In Medicine

- Reactor Radioisotopes (half-life indicated)
- Molybdenum-99 (66 h): Used as the 'parent' in a generator to produce technetium-99m.
- Technetium-99m (6 h): Used in to image the skeleton and heart muscle in particular, but also for brain, thyroid, lungs (perfusion and ventilation), liver, spleen, kidney (structure and filtration rate), gall bladder, bone marrow, salivary and lacrimal glands, heart blood pool, infection and numerous specialised medical studies.

# Use Of Radioisotopes In Medicine

- Bismuth-213 (46 min): Used for TAT.
- Chromium-51 (28 d): Used to label red blood cells and quantify gastro- intestinal protein loss.
- Cobalt-60 (10.5 mth): Formerly used for external beam radiotherapy.
- Copper-64 (13 h): Used to study genetic diseases affecting copper metabolism, such as Wilson's and Menke's diseases.

# Use Of Radioisotopes In Medicine

- Dysprosium-165 (2 h): Used as an aggregated hydroxide for synovectomy treatment of arthritis.
- Erbium-169 (9.4 d): Use for relieving arthritis pain in synovial joints.
- Holmium-166 (26 h): Being developed for diagnosis and treatment of liver tumours.

# Use Of Radioisotopes In Medicine

- Iodine-125 (60 d): Used in cancer brachytherapy (prostate and brain), also diagnostically to evaluate the filtration rate of kidneys and to diagnose deep vein thrombosis in the leg. It is also widely used in radioimmuno- assays to show the presence of hormones in tiny quantities.
- Iodine-131 (8 d): Widely used in treating thyroid cancer and in imaging the thyroid; also in diagnosis of abnormal liver function, renal (kidney) blood flow and urinary tract obstruction. A strong gamma emitter, but used for beta therapy.

# Use Of Radioisotopes In Medicine

- Iridium-192 (74 d): Supplied in wire form for use as an internal radiotherapy source for cancer treatment (used then removed).
- Iron-59 (46 d): Used in studies of iron metabolism in the spleen.
- Lutetium-177 (6.7 d): Lu-177 is increasingly important as it emits just enough gamma for imaging while the beta radiation does the therapy on small (eg endocrine) tumours. Its half-life is long enough to allow sophisticated preparation for use.

# Use Of Radioisotopes In Medicine

- Palladium-103 (17 d): Used to make brachytherapy permanent implant seeds for early stage prostate cancer.
- Phosphorus-32 (14 d): Used in the treatment of polycythemia vera (excess red blood cells). Beta emitter.
- Potassium-42 (12 h): Used for the determination of exchangeable potassium in coronary blood flow.
- Rhenium-186 (3.8 d): Used for pain relief in bone cancer. Beta emitter with weak gamma for imaging.

# Use Of Radioisotopes In Medicine

- Rhenium-188 (17 h): Used to beta irradiate coronary arteries from an angioplasty balloon.
- Samarium-153 (47 h): Sm-153 is very effective in relieving the pain of secondary cancers lodged in the bone, sold as Quadramet. Also very effective for prostate and breast cancer. Beta emitter.
- Selenium-75 (120 d): Used in the form of seleno-methionine to study the production of digestive enzymes.
- Sodium-24 (15 h): For studies of electrolytes within the body.

# Use Of Radioisotopes In Medicine

- Strontium-89 (50 d): Very effective in reducing the pain of prostate and bone cancer. Beta emitter.
- Xenon-133 (5 d): Used for pulmonary (lung) ventilation studies.
- Ytterbium-169 (32 d): Used for cerebrospinal fluid studies in the brain.
- Yttrium-90 (64 h): Used for cancer brachytherapy and as silicate colloid for the relieving the pain of arthritis in larger synovial joints. Pure beta emitter.
- Radioisotopes of caesium, gold and ruthenium are also used in brachytherapy.

# Use Of Radioisotopes In Medicine

- Cyclotron Radioisotopes
- Carbon-11, Nitrogen-13, Oxygen-15, Fluorine-18: These are positron emitters used in PET for studying brain physiology and pathology, in particular for localising epileptic focus, and in dementia, psychiatry and neuropharmacology studies. They also have a significant role in cardiology. F-18 in FDG has become very important in detection of cancers and the monitoring of progress in their treatment, using PET.
- Cobalt-57 (272 d): Used as a marker to estimate organ size and for in-vitro diagnostic kits.

# Use Of Radioisotopes In Medicine

- Gallium-67 (78 h): Used for tumour imaging and localisation of inflammatory lesions (infections).
- Indium-111 (2.8 d): Used for specialist diagnostic studies, eg brain studies, infection and colon transit studies.
- Iodine-123 (13 h): Increasingly used for diagnosis of thyroid function, it is a gamma emitter without the beta radiation of I-131.

# Use Of Radioisotopes In Medicine

- Krypton-81m (13 sec) from Rubidium-81 (4.6 h): Kr-81m gas can yield functional images of pulmonary ventilation, e.g. in asthmatic patients, and for the early diagnosis of lung diseases and function.
- Rubidium-82 (65 h): Convenient PET agent in myocardial perfusion imaging.
- Strontium-92 (25 d): Used as the 'parent' in a generator to produce Rb-82.
- Thallium-201 (73 h): Used for diagnosis of coronary artery disease other heart conditions such as heart muscle death and for location of low-grade lymphomas.

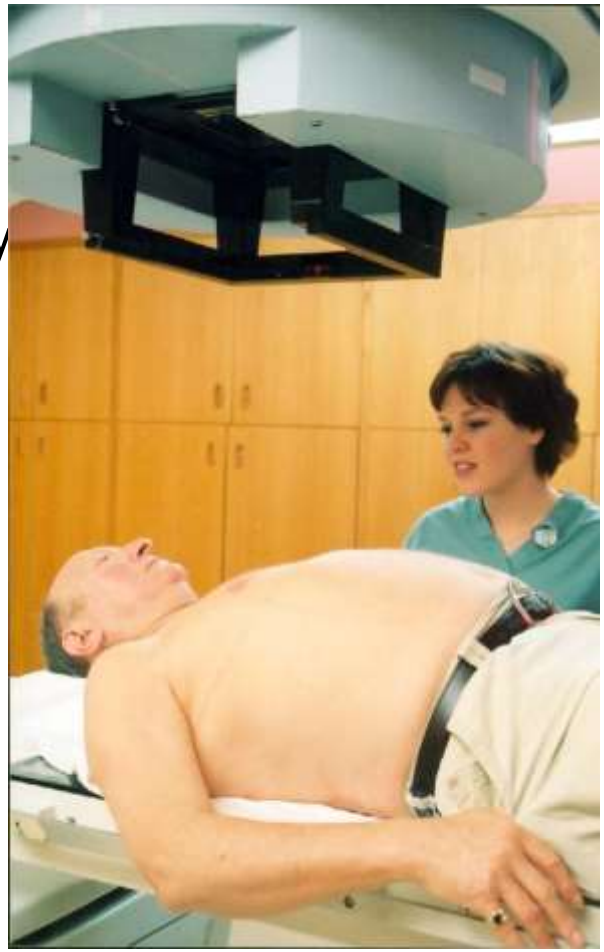
# Understanding Radiation Therapy

# Introduction to Radiation Oncology

- Radiation has been an effective tool for treating cancer for more than 100 years.
- Radiation oncologists are doctors trained to use radiation to eradicate cancer.
- About two-thirds of all cancer patients will receive radiation therapy as part of their treatment.

# What Is Radiation Therapy?

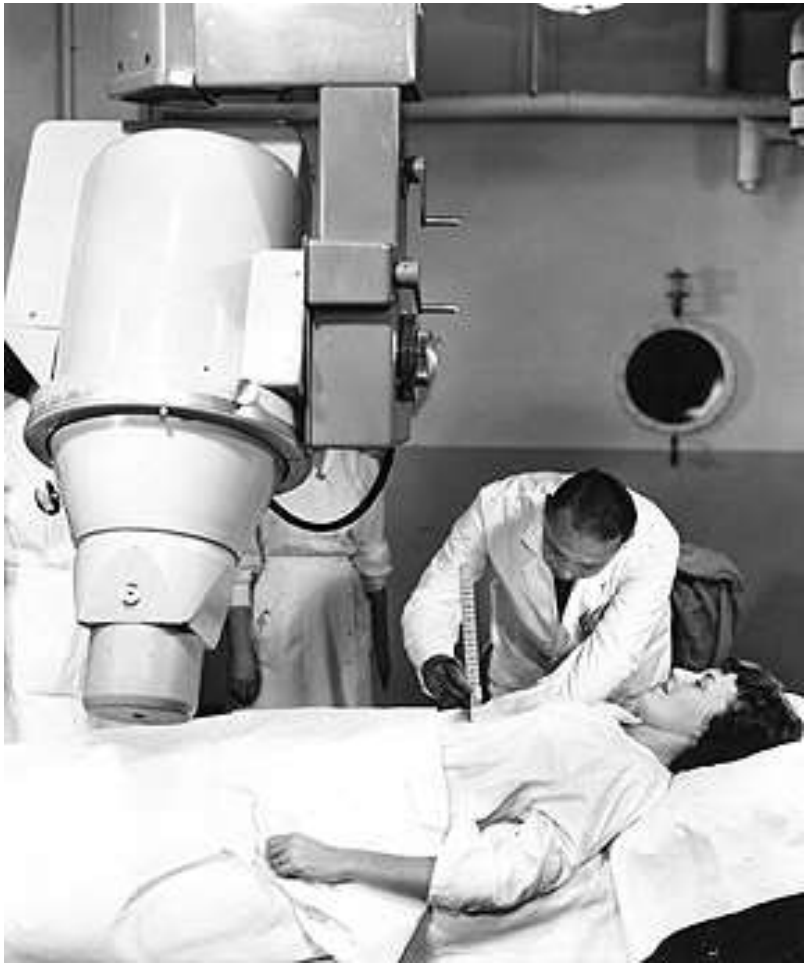
- Radiation therapy works by damaging the DNA within cancer cells and destroying their ability to reproduce.
- When the damaged cancer cells are destroyed by radiation, the body naturally eliminates them.
- Normal cells can be affected by radiation, but they are able to repair themselves.
- Sometimes radiation therapy is the only treatment a patient needs.
- Other times, it is combined with other treatments, like surgery and chemotherapy.



# Brief History of Radiation Therapy

- The first patient was treated with radiation in 1896, two months after the discovery of the X-ray.
- Back then, both doctors and non-physicians treated cancer patients with radiation.
- Rapid technology advances began in the early 1950s with cobalt units followed by linear accelerators a few years later.
- Recent technology advances have made radiation more effective and precise.

# Methods of Delivering Radiation Therapy



Early 1950s

Today

# How Is Radiation Therapy Used?

Radiation therapy is used two different ways.

- To cure cancer:
  - Destroy tumors that have not spread to other body parts.
  - Reduce the risk that cancer will return after surgery or chemotherapy.
- To reduce symptoms:
  - Shrink tumors affecting quality of life, like a lung tumor that is causing shortness of breath.
  - Alleviate pain by reducing the size of a tumor.

# Meet the Radiation Oncology Team

- **Radiation Oncologist**
  - The doctor who oversees the radiation therapy treatments.
- **Medical Radiation Physicist**
  - Ensures that complex treatment plans are properly tailored for each patient.
- **Dosimetrist**
  - Works with the radiation oncologist and medical physicist to calculate the proper dose of radiation given to the tumor.
- **Radiation Therapist**
  - Administers the daily radiation under the doctor's prescription and supervision.
- **Radiation Oncology Nurse**
  - Cares for the patient and family by providing education, emotional support and tips for managing side effects.

# Types of Radiation Therapy

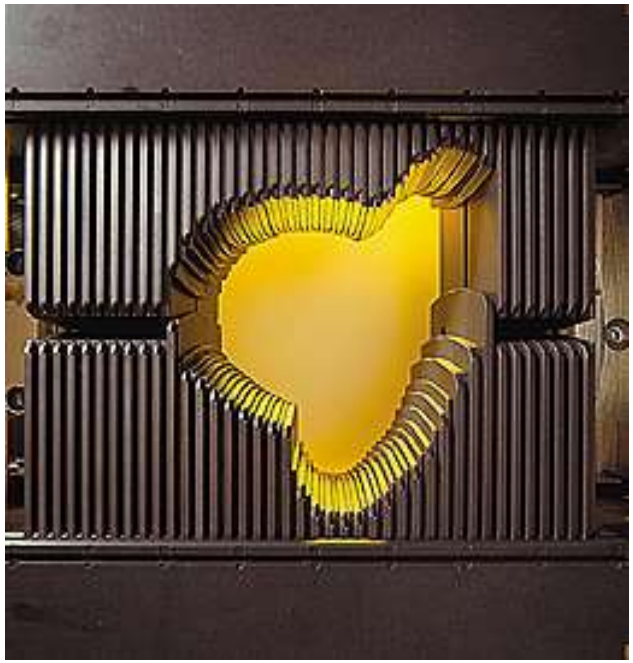
- Radiation therapy can be delivered two ways – externally and internally.
  - External beam radiation therapy delivers radiation using a linear accelerator.
  - Internal radiation therapy, called brachytherapy or seed implants, involves placing radioactive sources inside the patient.
- The type of treatment used will depend on the location, size and type of cancer.

# Planning Radiation Therapy - Simulation

- Each treatment is mapped out in detail using treatment planning software.
- Radiation therapy must be aimed at the same target every time. Doctors use several devices to do this:
  - Skin markings or tattoos.
  - Immobilization devices – casts, molds, headrests.

# External Radiation Therapy

- Specialized types of external beam radiation therapy
  - **Three-dimensional conformal radiation therapy (3D-CRT)**
    - Uses CT or MRI scans to create a 3-D picture of the tumor.
    - Beams are precisely directed to avoid radiating normal tissue.
  - **Intensity modulated radiation therapy (IMRT)**
    - A specialized form of 3D-CRT.
    - Radiation is broken into many “beamlets” and the intensity of each can be adjusted individually.



# External Radiation Therapy

- Proton Beam Therapy
  - Uses protons rather than X-rays to treat certain types of cancer.
  - Allows doctors to better focus the dose on the tumor with the potential to reduce the dose to nearby healthy tissue.
- Neutron Beam Therapy
  - A specialized form of radiation therapy that can be used to treat certain tumors that are very difficult to kill using conventional radiation therapy.
- Stereotactic Radiotherapy
  - Sometimes called stereotactic radiosurgery, this technique allows the radiation oncologist to precisely focus beams of radiation to destroy certain tumors, sometimes in only one treatment.

# Internal Radiation Therapy

- Places radioactive material into tumor or surrounding tissue.
  - Also called brachytherapy – brachy Greek for “short distance.”
  - Radiation sources placed close to the tumor so large doses can hit the cancer cells.
  - Allows minimal radiation exposure to normal tissue.
  - Radioactive sources used are thin wires, ribbons, capsules or seeds.
  - These can be either permanently or temporarily placed in the body.

# Side Effects of Radiation Therapy

- Side effects, like skin tenderness, are generally limited to the area receiving radiation.
- Unlike chemotherapy, radiation usually doesn't cause hair loss or nausea.
- Most side effects begin during the second or third week of treatment.
- Side effects may last for several weeks after the final treatment.

# Is Radiation Therapy Safe?

- Many advances have been made in the field to ensure it remains safe and effective.
- Multiple healthcare professionals develop and review the treatment plan to ensure that the target area is receiving the dose of radiation needed.
- The treatment plan and equipment are constantly checked to ensure proper treatment is being given.

# UNIT 5

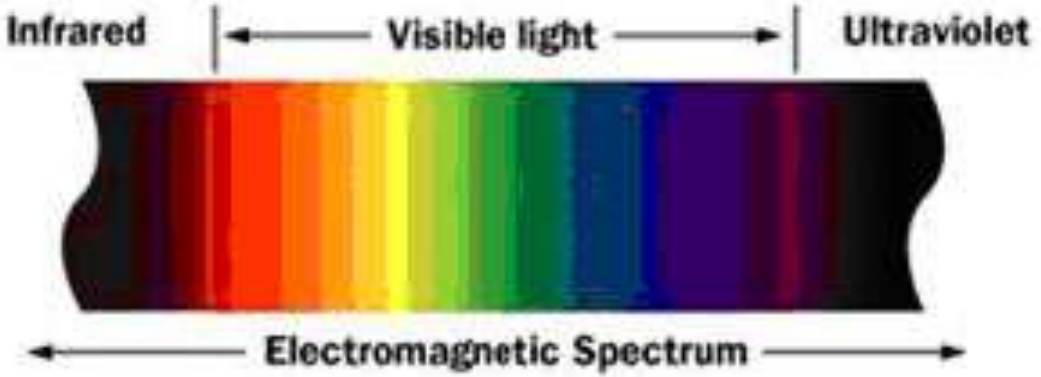
# THERMOGRAPHY

# Infrared Energy & Radiation

- Part of electro magnetic spectrum
- It travels through space at the speed of light.
- The thermal energy emitted from the surface of a material is called IR radiation.
- Temperature of an object=IR radiation emitted from it.
- Eg: x-ray, ultra violet, radio waves.

# Electromagnetic Spectrum

- Infrared radiation, visible light & ultra violet light form energy in spectrum.
- Categorized by wave length & frequency.
- Human eye can see narrow range of wavelength.(0.4-0.75 micron)



# Thermography

- It’s a - infrared imaging science.
  - cost effective method.
  - non invasive method.
  - non contact method.
- Applications include building diagnostics, plant maintenance, research, etc.

# Definition

- IRT is the technique that used for producing a visible image of invisible IR energy emitted by objects.
- Since wavelength is too long for the sensors in our eyes, IR cameras are used.

- It can be applied in any situation where a problem or condition can display itself by means of a “thermal difference”.
- For example, firefighters use it to see through smoke, find persons, and localize hotspots of fires. Cooled IR cameras can also be found at most major astronomy research telescopes.

- Its non contact.

  -uses remote sensing, keeps the user out of danger.

- It is two dimensional.

  -thermal patterns can be analyzed, comparison between areas of target is possible.

- It is real time.

  -fast scanning of stationary targets, capture of fast moving targets & fast changing thermal patterns.

# Principle

- Black body radiation-Black body is that which absorbs completely all the radiations falling on it.

- The law is associated with “Thermodynamics”.

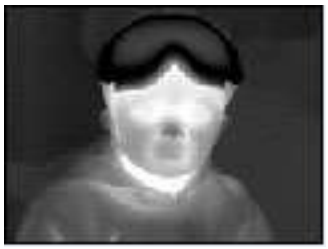
- Every object whose surface temperature is above absolute zero (-273 °C) radiates energy at a wavelength corresponding to its surface temperature.

# Thermographic Camera

- Produces a live TV image of heat radiation.
- It converts invisible IR energy into a 2d visual image & displays on std. TV monitor.
- Thermal image produced is called thermogram.
- It allows us to see what our eyes can't.
- It resembles a std. camcorder.

# How camera see heat?

- It can image temperatures from -20 to 500 degree Celsius & can be extended down to -40 & up to 2000 degree Celsius.
- It converts invisible IR energy to 2d visual image.
- Then displays on a TV monitor.



# Types of Thermographic Cameras

2 types:

- Cooled cameras-They are contained in a vacuum sealed case & cryogenically cooled. Drawbacks- expensive to produce & run, several minutes to cool down before it begin working.
- Uncooled cameras-Use sensors that work by change of resistance, volume & current when heated. It is smaller & less costly.
- Cooled cameras provide superior image quality than uncooled.

# Process

- IR camera creates an image.

  -convert radiant heat energy into a signal.

- Colorizing IR images.

  -camera assigns black to coolest area & white to hottest area.

- Adjusting images for clarity.

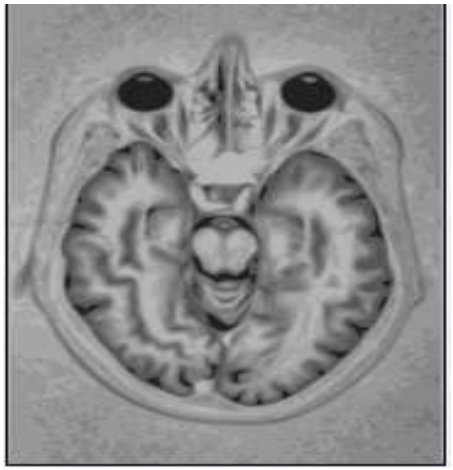
  -upper & lower temperature limits are adjusted to get the clearest picture.

# Applications

- Medical imaging
- Night vision
- Non destructive testing
- Medical field
- Condition monitoring

# Medical Imaging

- The technique used to create images of human body for clinical purposes or medical science.
- Imaging technology:
  - Electron microscope.
  - Fluoroscopy.
  - Magnetic Resonance Imaging (MRI).
  - Positron Emission Tomography (PET).



# Night Vision

- Ability to see in a dark enviornment.
- Possible by 2 approaches: spectral range, intensity range.
- NVD used in military forces.
- Absence of Tapetum lucidum is the reason for poor night vision in humans.
- Thermal imaging cameras helps in seei rain and smoke.

# Non-Destructive Testing (NDT)

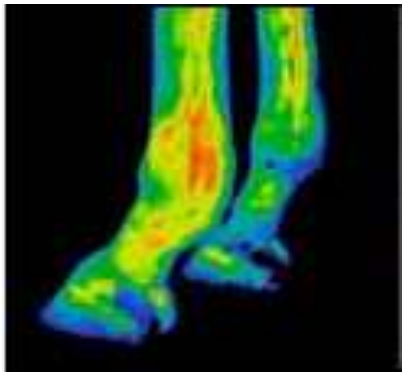
- It is the testing that does not destroy the test object.
- Aimed mainly at industrial NDT.
- Destructive testing is not possible for forensic investigation.
- Eg:-Aircraft skins need regular checking to detect cracks.

  Underground pipelines are subject to corrosion & stress corrosion cracking.

# Medical Thermography

It can be done in 2 fields

-Vetinary Minor injuries to muscle tissue may go unnoticed until the problem is more severe.IR imaging aids expert trainer in caring for the horse.



# Medical Thermography

-Human beings

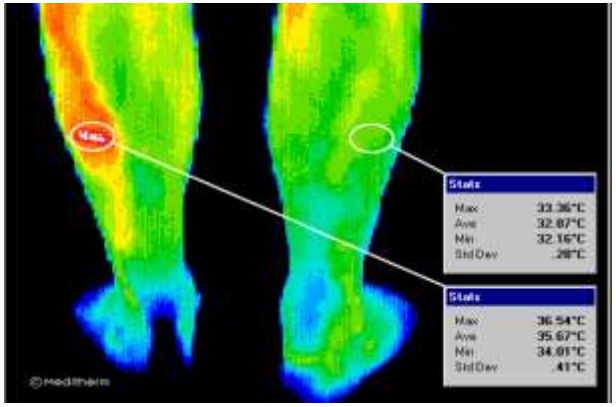
- Respiratory dysfunctions-asthma,bronchitis
- Digestive disorders-hyper &hypo gastric secretions.
- Urinary diseases-urinary tract inspections.
- Cardiovascular & circulatory

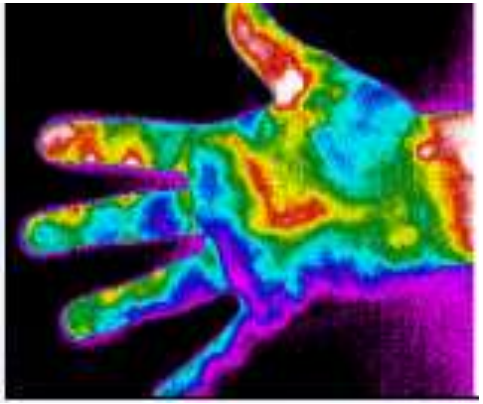
  disorders-heart disease, varicose vein.
- Nervous dysfunctions-brain, spinal cord, nerves.

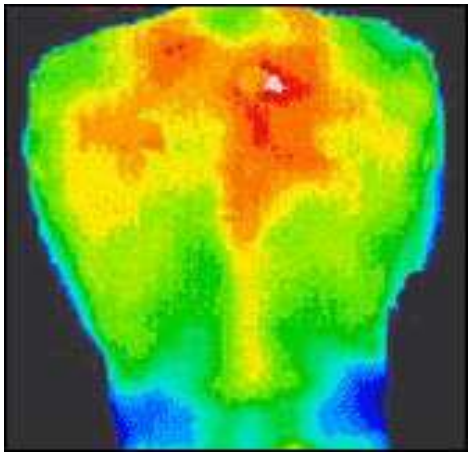
# Medical Thermography

- Locomotors disorders-arthritis, disk injury.
- Surgical assistance-tumours size, surgical area.
- Skin problems-skin cancer & tumours.
- Dentistry-inflammation in oral cavity.
- Endocrine disorders-hypo & hyperthyroidism.
- Ear, Nose & Throat dysfunctions-tonsillitis, sinusitis.

# Some Examples





# Condition Monitoring

- Monitoring a parameter of condition in machinery, such that a significant change is indicative of a developing faliure.
- Major component of predictive maintenance.
- Cost effective than allowing the machinery to fail.
- Serviceable machinery-rotating machines & stationary plant like boilers, heat exchangers.

# Condition Monitoring

- Electrical maintenance-camera can see the difference in the heat of defected & normal components.
- Buildings-monitors the heat loss & air leakage.
- Furnace & boilers-finds incipient defects in power plant equipments.
- Tanks & vessels-inspects for tank leaks & to verify tank level.

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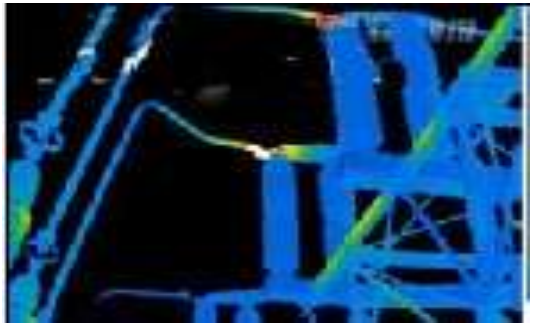
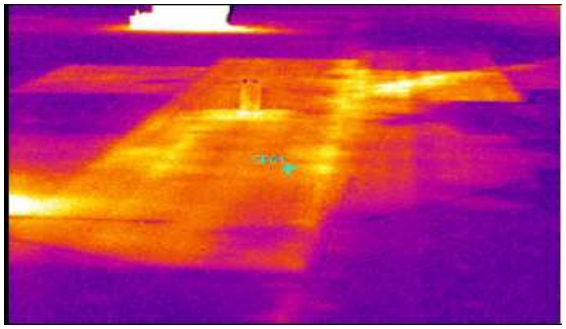
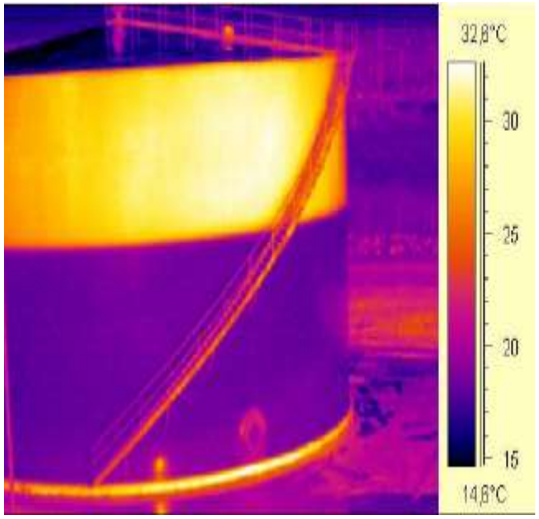






# Active & Passive Thermography

- In passive thermography, inspected parts are naturally at a higher or lower temperature than the background.
- In active thermography, an energy source is required to produce a thermal contrast.
- The defects can be either detected as hot (active) or cold spots (passive) on the surface.

# Advantages

- Non-destructive test method.
- Capable of catching moving targets in real time.
- Find defects in shafts and other metal parts.
- Measurement in areas inaccessible or hazardous for other methods.
- Condition monitoring.
- Help to compare temperatures over a large area .

# Limitations

- Training and staying proficient in IR scanning is time consuming.
- Images is hard to interpret accurately even with experience.
- Quality cameras have a high price range.
- Cameras have worse accuracy.

# Conclusion

- Thermography enables us to see and measure heat.
- It is a method that utilizes a thermal image to detect, display and record thermal patterns and temperatures across the surface of an object.
- It is the future in water damage and mold claims adjudication for the insurance industry.

# ENDOSCOPY

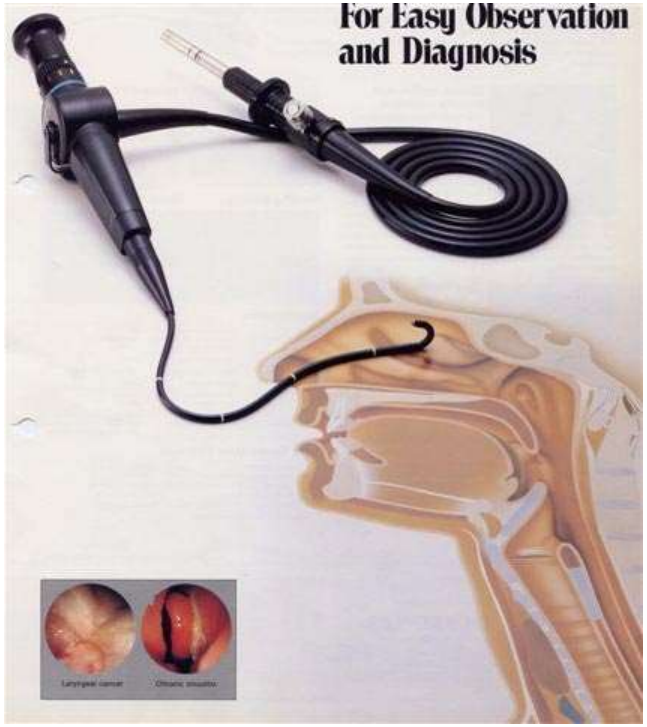
# ENDOSCOPY

Endoscopy, is the examination of internal body cavities using a specialized medical instrument called an endoscope.

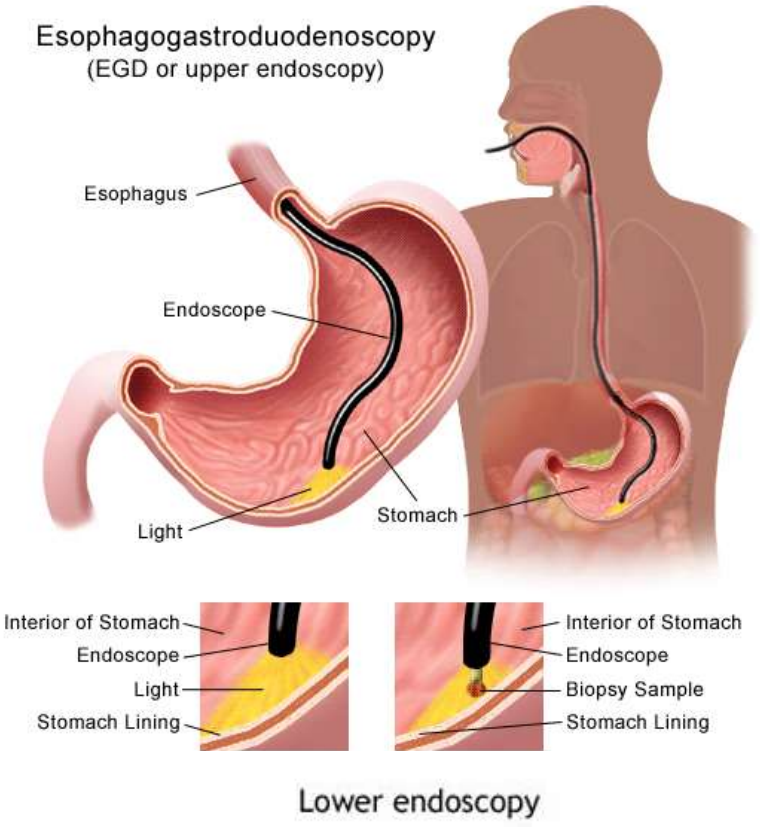
Physicians use endoscopy to diagnose, monitor, and surgically treat various medical problems.

# ENDOSC

- An endoscope is a slender, flexible tube equipped with lenses and a light source. Illumination is done by the help of a number of optical fibres.
- Reflected light rays are collected by CCD( Charge coupled device) and electrical signals are produced, which are fed to the video monitor to get image.
- Thorough one channel of endoscope water and air is conducted to wash and dry the surgical site.

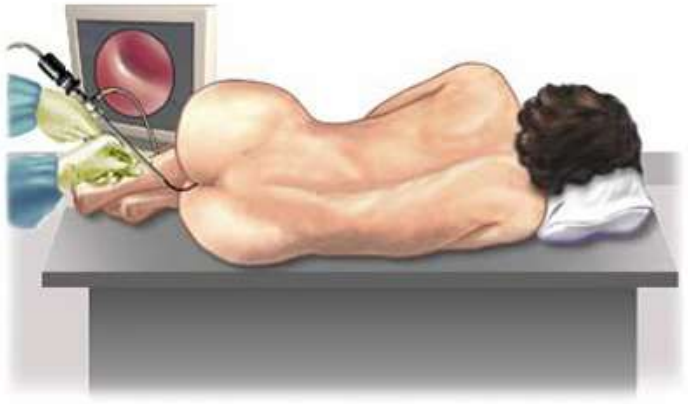


# ENDOSC(

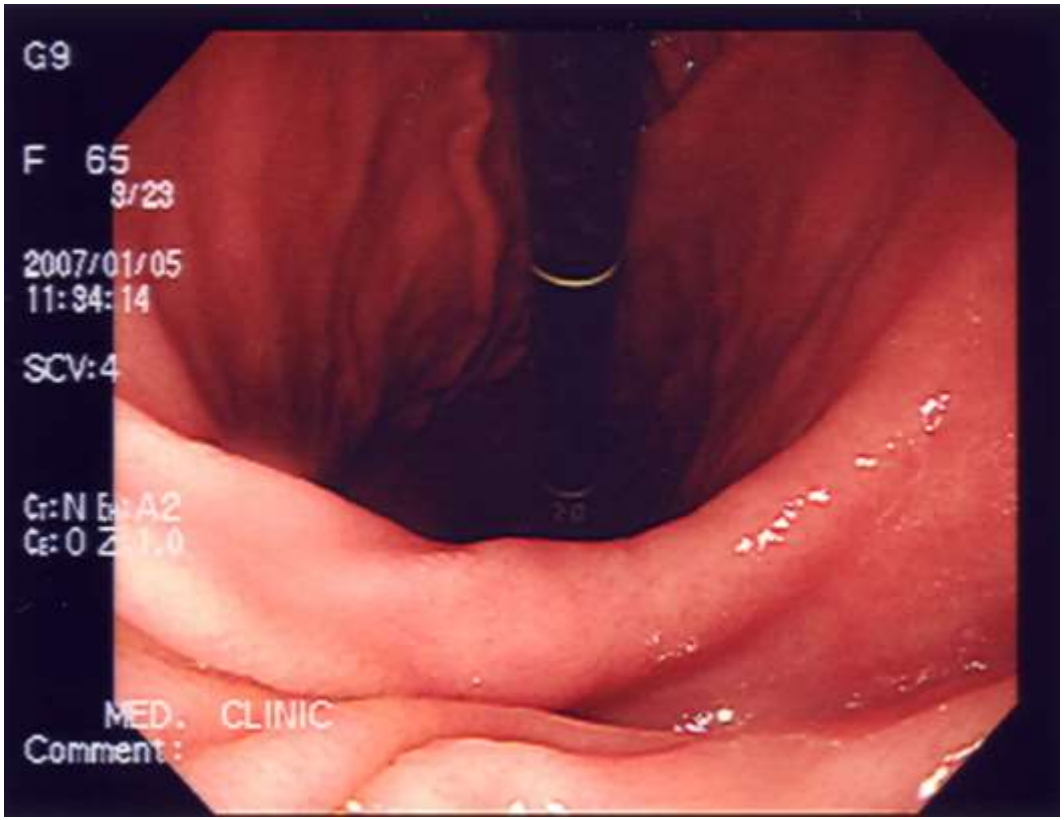



- The endoscope also has a channel through which surgeons can manipulate tiny instruments, such as forceps, surgical scissors, and suction devices.
- A variety of instruments can be fitted to the endoscope for different purposes.

- A surgeon introduces the endoscope into the body either through a body opening, such as the mouth or the anus, or through a small incision in the skin.



# ENDOSCOPY




- The endoscope gives visual evidence of the problem, such as ulceration or inflammation
- It can be used to collect a sample of tissue; remove problematic tissue, such as polyps
- It is used to take photograph of the hollow internal organs

# ENDOSCOPY

- Depending on the body part, each type of endoscopy has its own special term, such as

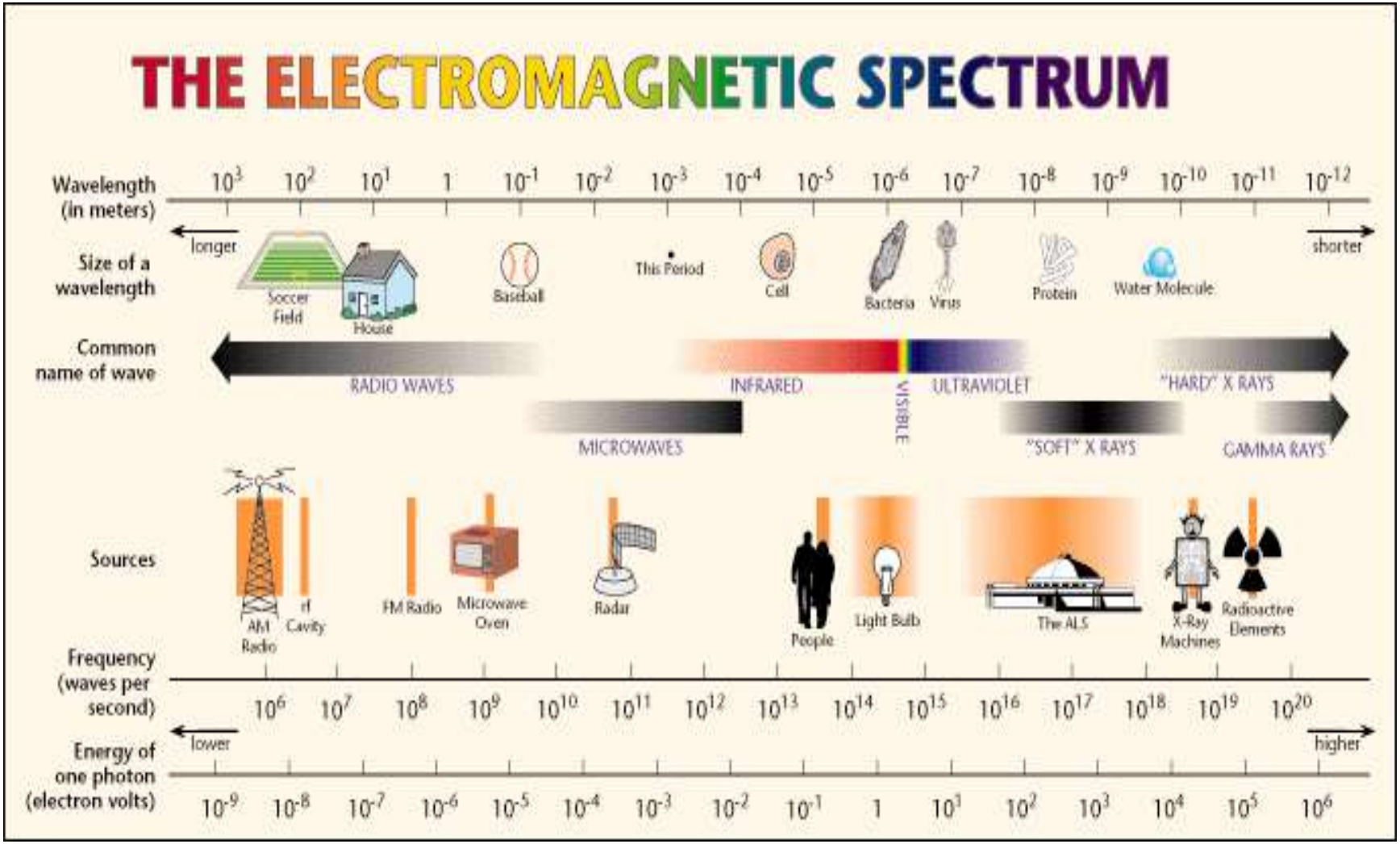
  laparoscopy (abdomen, uterus, fallopian tube),
  laryngoscopy (vocal cords),
  bronchoscopy (lungs),
  colonoscopy (colon),
  arthroscopy (joint) and
  Gastroscopy (Stomach).

# Laser Therapy

# Laser Therapy

- Light Amplification by the Stimulated Emission of Radiation

- Compressed light of a wavelength from the cold, red part of the spectrum of electromagnetic radiation
  - Monochromatic - single wavelength, single color
  - Coherent - travels in straight line
  - Polarized - concentrates its beam in a defined location/spot


THE ELECTROMAGNETIC SPECTRUM
Wavelength (in meters)
$10^{3}$ $10^{2}$ $10^{1}$ 1 $10^{-1}$ $10^{-2}$ $10^{-3}$ $10^{-4}$ $10^{-5}$ $10^{-6}$ $10^{-7}$ $10^{-8}$ $10^{-9}$ $10^{-10}$ $10^{-11}$ $10^{-12}$
longer
shorter
Size of a wavelength
Soccer Field
House
Baseball
This Period
Cell
Bacteria
Virus
Protein
Water Molecule
Common name of wave
RADIO WAVES
INFRARED
VISIBLE
ULTRAVIOLET
"HARD" X RAYS
MICROWAVES
"SOFT" X RAYS
GAMMA RAYS
Sources
AM Radio
rf Cavity
FM Radio
Microwave Oven
Radar
People
Light Bulb
The ALS
X-Ray Machines
Radioactive Elements
Frequency (waves per second)
$10^{6}$ $10^{7}$ $10^{8}$ $10^{9}$ $10^{10}$ $10^{11}$ $10^{12}$ $10^{13}$ $10^{14}$ $10^{15}$ $10^{16}$ $10^{17}$ $10^{18}$ $10^{19}$ $10^{20}$
Energy of one photon (electron volts)
lower
higher
$10^{-9}$ $10^{-8}$ $10^{-7}$ $10^{-6}$ $10^{-5}$ $10^{-4}$ $10^{-3}$ $10^{-2}$ $10^{-1}$ 1 $10^{1}$ $10^{2}$ $10^{3}$ $10^{4}$ $10^{5}$ $10^{6}$

- Albert Einstein – 1st described this theory that was transformed in to laser therapy
- By the end of the 60's, Endre Mester (Hungary) -
  - was reporting on wound healing through laser therapy
- In early 1960's, the 1st low level laser was developed.
- In Feb. 2002, the MicroLight 830 (ML830) received FDA approval for Carpal Tunnel Syndrome Treatment (research treatment)
- Laser therapy – has been studied in Europe for past 25-30 years; US 15-20 years

# Types of LASER

- Therapeutic Laser
- Low Level Laser Therapy
- Low Power Laser Therapy
- Low Level Laser
- Low Power Laser
- Low-energy Laser
- Soft Laser
- Low-reactive-level Laser

# Types of LASER

- Low-intensity-level Laser
- Photobiostimulation Laser
- Photobiomodulation Laser
- Mid-Laser
- Medical Laser
- Biostimulating Laser
- Bioregulating Laser

# Working of LASER

- Laser light waves penetrate the skin with no heating effect, no damage to skin & no side effects.

- **Laser light directs biostimulative light energy to the body's cells which convert into chemical energy to promote natural healing & pain relief.

- Optimizes the immune responses of blood & has anti-inflammatory & immunosuppressive effects.

# Physiological Effects

- Biostimulation – improved metabolism, increase of cell metabolism
  - Increases speed, quality & tensile strength of tissue repair
- Improved blood circulation & vasodilation
  - Increases blood supply
- Increases ATP production
- Analgesic effect
  - Relieves acute/chronic pain
- Anti-inflammatory & anti-edematous effects
  - Reduces inflammation

# Physiological Effects

- Stimulation of wound healing
  - Promotes faster wound healing/clot formation
  - Helps generate new & healthy cells & tissue
- Increase collagen production
  - Develops collagen & muscle tissue
- Increase macrophage activity
  - Stimulates immune system
- Alter nerve conduction velocity
  - Stimulates nerve function

# Tissue & Cellular Response

- Red light affects all cell types
  - Absorbed by the mitochondrial present in all cells
  - Cytochromes (respiratory chain enzymes) within the mitochondria have been identified as the primary biostimulation chromophores (*primary light-absorbing molecules*).
  - Since enzymes are catalysts with the capability of processing thousands of substrate molecules, they provide amplification of initiation of a biological response with light.

- Infrared light is more selective absorbed by specific proteins in the cell membrane & affects permeability directly

# Laser Generators

- Components of a generator:
  - Power supply – electrical power supply that can deliver up to 10,000 volts & 100's amps
  - Lasing medium – gas, solid, liquid
  - Pumping device –
    - high voltage, photoflash lamps, radio-frequency oscillators or other lasers (pumping is used to describe the process of elevating an orbiting electron to a higher, excited energy level)
  - Optical resonant cavity – contains lasing medium

# Types of Lasers

- **4 categories of lasers**
  - Crystal & Glass (*solid* - rod)
    - Synthetic ruby & others (synthetic ensures purity)
  - Gas (*chamber*) – 1961
    - HeNe, argon, $CO_2$, & others (HeNe under investigation)
  - Semiconductor (*diode* - channel) - 1962
    - Gallium Arsenide (GaAs under investigation)
  - Liquid (Dye) - Organic dyes as lasing medium
  - Chemical – extremely high powered, frequently used for military purposes

# High vs. Low Level Lasers

- High
  - Surgical Lasers
  - Hard Lasers
  - Thermal
  - Energy – 3000-10000 mW
- Low
  - Medical Lasers
  - Soft Lasers
  - Subthermal
  - Energy – 1-500 mW
  - Therapeutic (Cold) lasers produce maximum output of 90 mW or less
  - 600-1000 nm light

# Laser Light Properties

- Monochromaticity
  - 1 color – 1 wavelength
  - <400 nm
  - Ultraviolet spectrum
- Coherence
  - Waves same length & traveling in same phase relationship
  - 400-700 nm
  - Visible
- Collimation
  - Degree to which beam remains parallel with distance
  - 700-10,000 nm
  - Infrared

# Parameters

- Patient
  - Need medical history & proper diagnosis
    - Diabetes – may alter clinical efficacy
  - Medications
    - Photosensitivity (antibiotics)
  - Pigmentation
    - Dark skin absorbs light energy better
- Laser
  - Wavelength
  - Output power
  - Average power
  - Intensity
  - Dosage

# Parameters - Wavelength

- Nanometers (nm)
- Longer wavelength (lower frequency) = greater penetration
- Not fully determined
- Wavelength is affected by power

# Parameters – Power

- Output Power
  - Watts or milliwatts (W or mW)
  - Important in categorizing laser for safety
  - Not adjustable
- Power Density (intensity)
  - W or $mW/cm_2$
  - Takes into consideration – actual beam diameter If light spread over lager area – lower power density
  - Beam diameter determines power density
- Average Power
  - Continuous or pulse-train (burst) frequency mode
  - Knowing average power is important in determining dosage with pulsed laser
  - If laser is continuous – avg. power = peak output power
  - If laser is pulsed (burst) then avg. power is = to peak output power X duty cycle

# Parameters – Energy Density

- Dosage (D)
- Amount of energy applied per unit area
- Measured in Joules/square cm ($J/cm^2$)
  - Joule – unit of energy
  - 1 Joule = 1 W/sec
- Dosage is dependent on:
  - Output of laser in mW
  - Time of exposure in seconds
  - Beam surface area of laser in $cm^2$
- Various dosage ranges per site (1-9 $J/cm^2$)

# Parameters – Energy Density

- Recommended Dosage Range
  - Therapeutic response = 0.001-10 J/$cm_2$
  - Minimal window threshold to elicit response
  - Too much – suppressive effect
  - Open wounds – 0.5-1.0 J/$cm_2$
  - Intact skin – 2.0-4.0 J/$cm_2$
  - Average treatment – 6 /$cm_2$

# Helium Neon Lasers

- Uses a gas mixture in a pressurized tube
  - Now available in semiconductor laser
- Emits red light
- Wavelength:  632.8 nm
- Power output: 1.0-25.0 mW
- Energy depth: 6-10 mm

- The higher the output lasers (even though they are still low power) allow reduced delivery time

# Indium-Gallium-Aluminum-Phosphide

- InGaAip
- Replacing HeNe lasers
- Semiconductor
- Wavelength:  630-700 nm
- Power output:  same as HeNe
- Energy depth: superficial wound care

# Gallium Arsenide

- Semiconductor - produces an infrared (invisible) laser
- Wavelength:  904–910 nm
- Power output: may produce up to 100 mW
- Energy depth: 30-50 mm
- Short pulse-train (burst) duration (100-200 ns)

# Gallium Aluminum Arsenide

- GaAlAs
- Semiconductor
- Wavelength: 780-890 nm
- Power Output: 30-100 mW (up to 1000 mW)

# Indications

- ***Indications***
  - Soft tissue injuries
  - Fractures
  - Osteoarthritis, Rheumatoid Arthritis
  - Pain
  - Wounds & Ulcers
  - Acupuncture

# Contraindications

- ***Contraindications***
  - Application over eyes
  - Possibly can damage cellular structure or DNA
  - Cancerous growths
  - Pregnancy – over & around uterus
  - Over cardiac region & Vagus nerve
  - Growth plates in children
  - Over & around thyroid gland & endocrine glands
  - Patients who have been pre-treated with one or more photosensitizers

# Treatment Precautions

- Better to underexpose than to overexpose
- Avoid direct exposure into eyes (If lasing for extended periods of time, safety glasses are recommended)
- May experience a syncope episode during treatment during chronic pain, but very rare
- If icing – use BEFORE phototherapy
  - Enhances light penetration
- If using heat therapy – use AFTER phototherapy
  - Decreases light penetration

# Treatment Techniques

- Gridding Technique
  - Divide treatment areas into grids of square centimeters
- Scanning Technique
  - No contact between laser tip in skin; tip is held 5-10 mm from wound
- Wanding Technique
  - A grid area is bathed with the laser in an oscillating fashion; distance should be no farther than 1 cm from skin
- Point Application (Acupuncture point)

# Treatment Techniques

- Simple
- For general application, only treatment time & pulse rate vary
- Dosage
    - Most important variable in laser therapy & may be difficult to determine because of the above conditions
- Handheld applicator
- Tip should be in light contact with skin while laser is engaged for calculated time
- Maintain laser perpendicular to treatment surface
- Firm contact unless open wound
- Clean area prior to treatment
- Begin with minimal treatment and gradually increase
- Check for pre/post-treatment changes
- Ask the patient how they are doing prior to next treatment
    - May have to adjust dosage

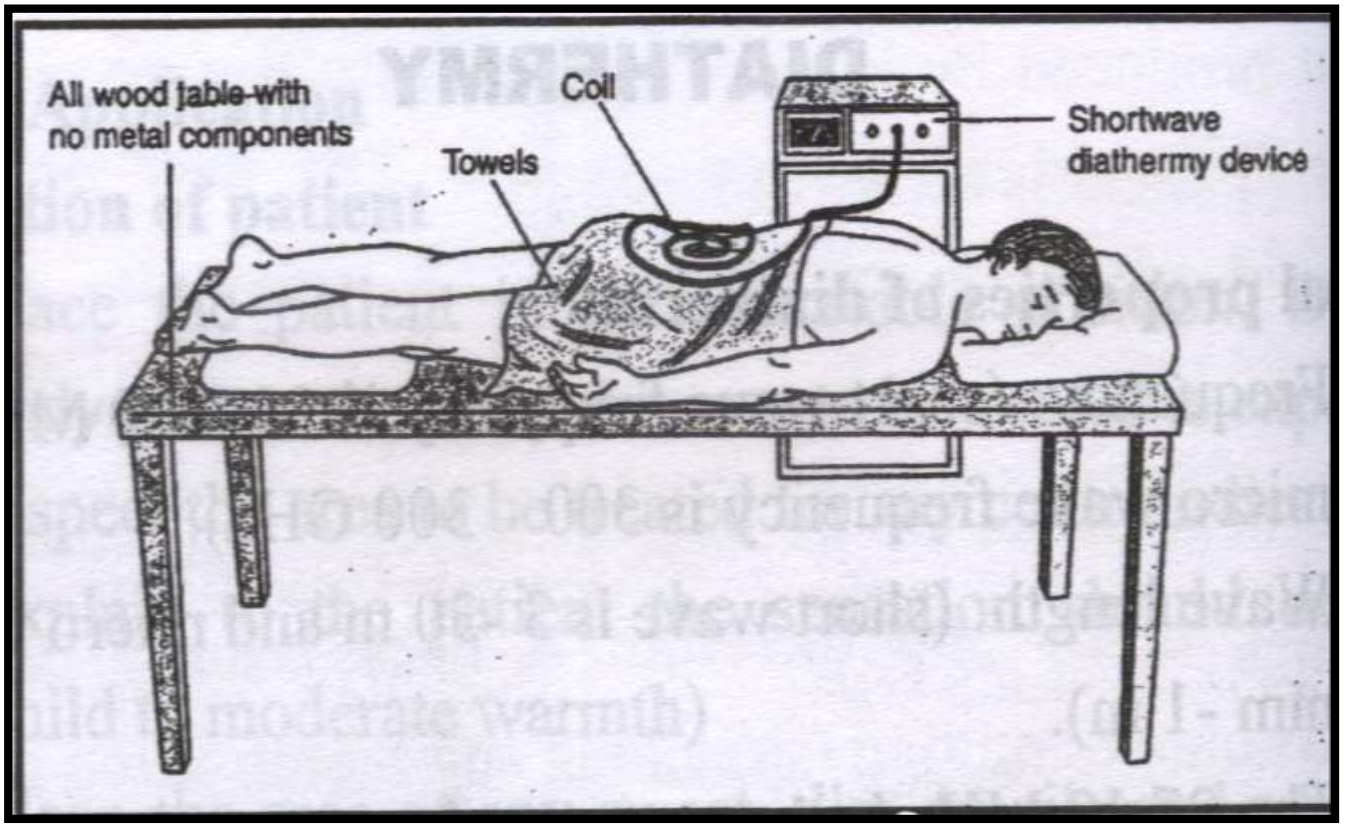
- Dynatron's Solaris D880 Infrared Therapy
  - 880 nm wavelength – SLD (32 ) (deep)
  - 660 nm – LED (4)  (superficial)
  - 10 minute max. treatment or 60 Joules
  - Place probe on treatment area.  Maintain constant contact with the skin.
    - Do not bathe the area with the probe.
  - FDA cleared to "provide topical heating for temporary increase in blood circulation, temporary relief of minor muscle & joint aches, pain & stiffness & relaxation of muscles; for muscle spasms & minor pain & stiffness associated with arthritis."
    - Dynatron Solaris 709

# DIATHERMY

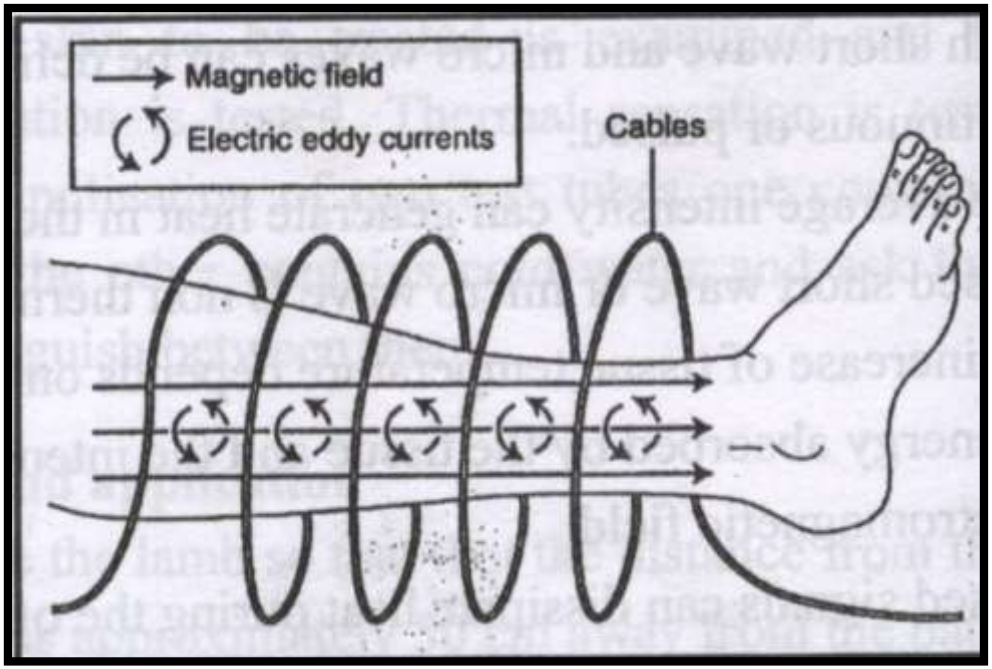
# DIATHERMY

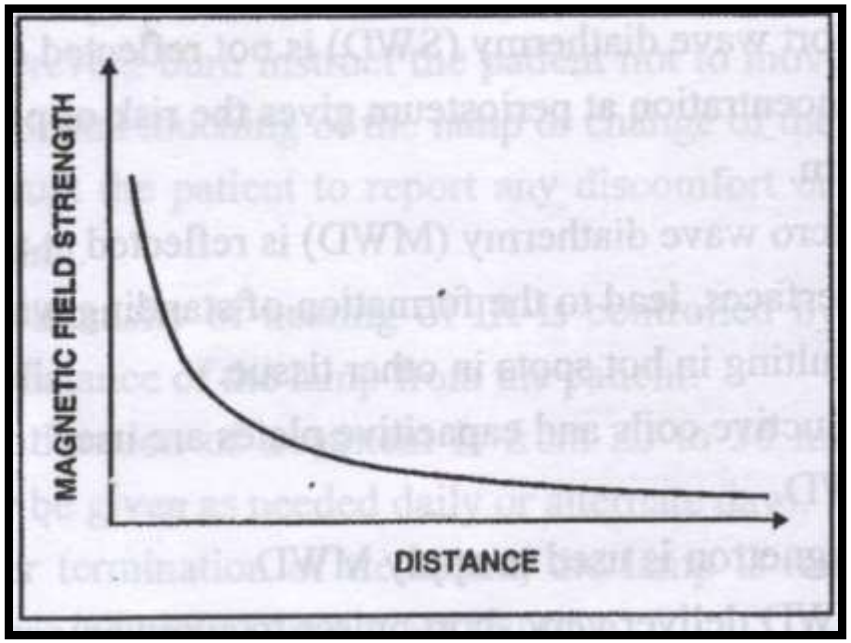
## Physical properties of diathermy

**Inductive coil**



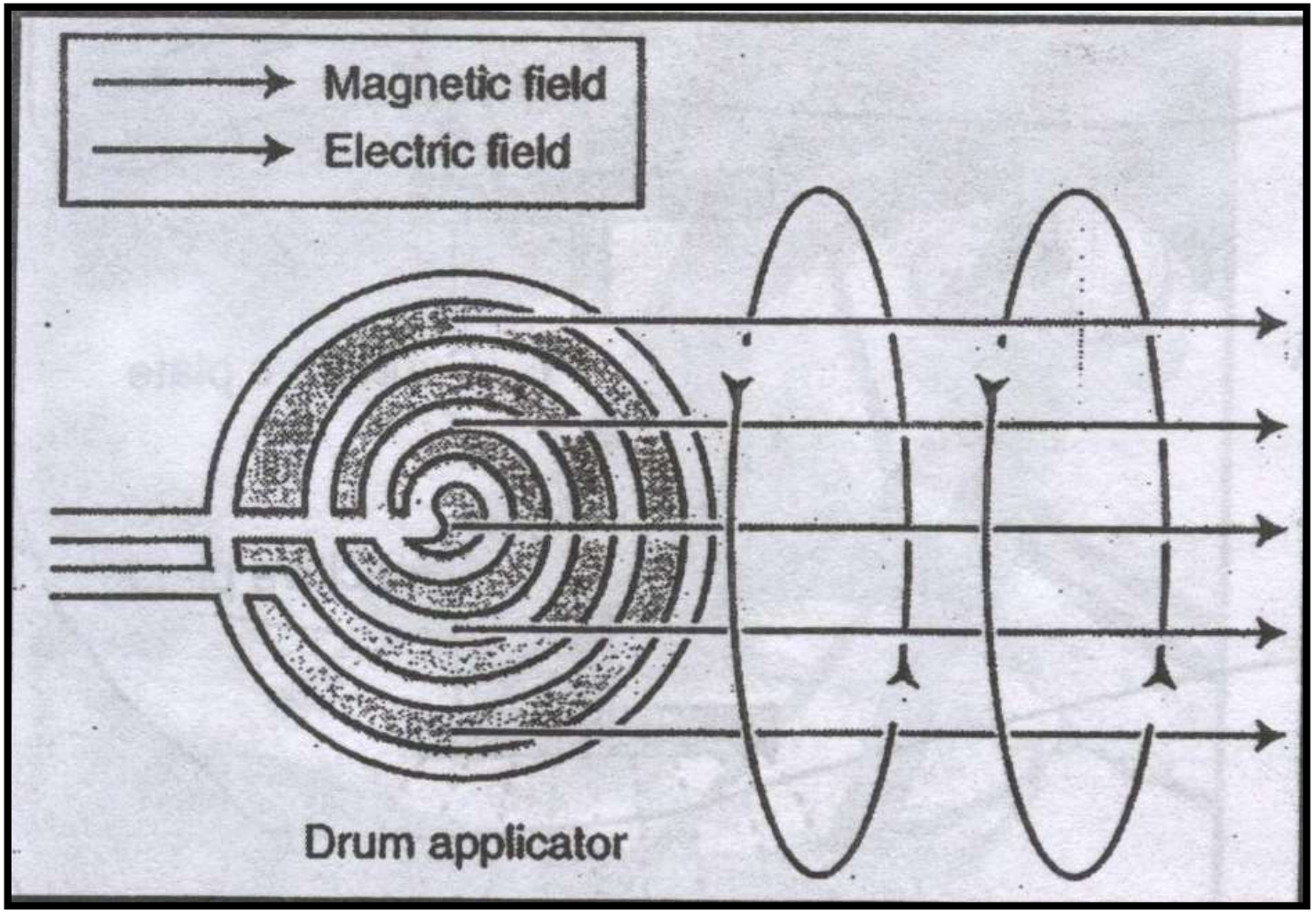
# Generation of magnetic field




# Behavior of magnetic field

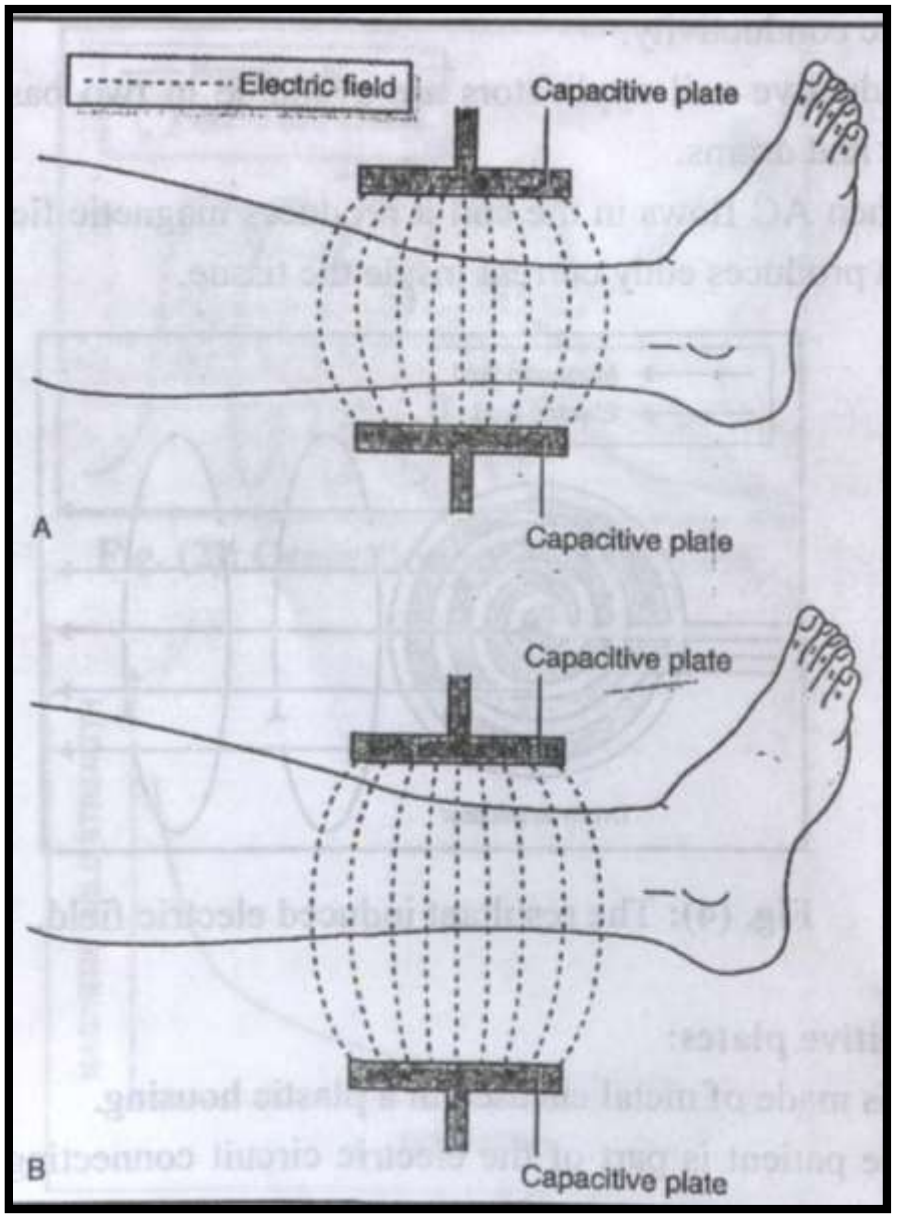
# Inductive coil



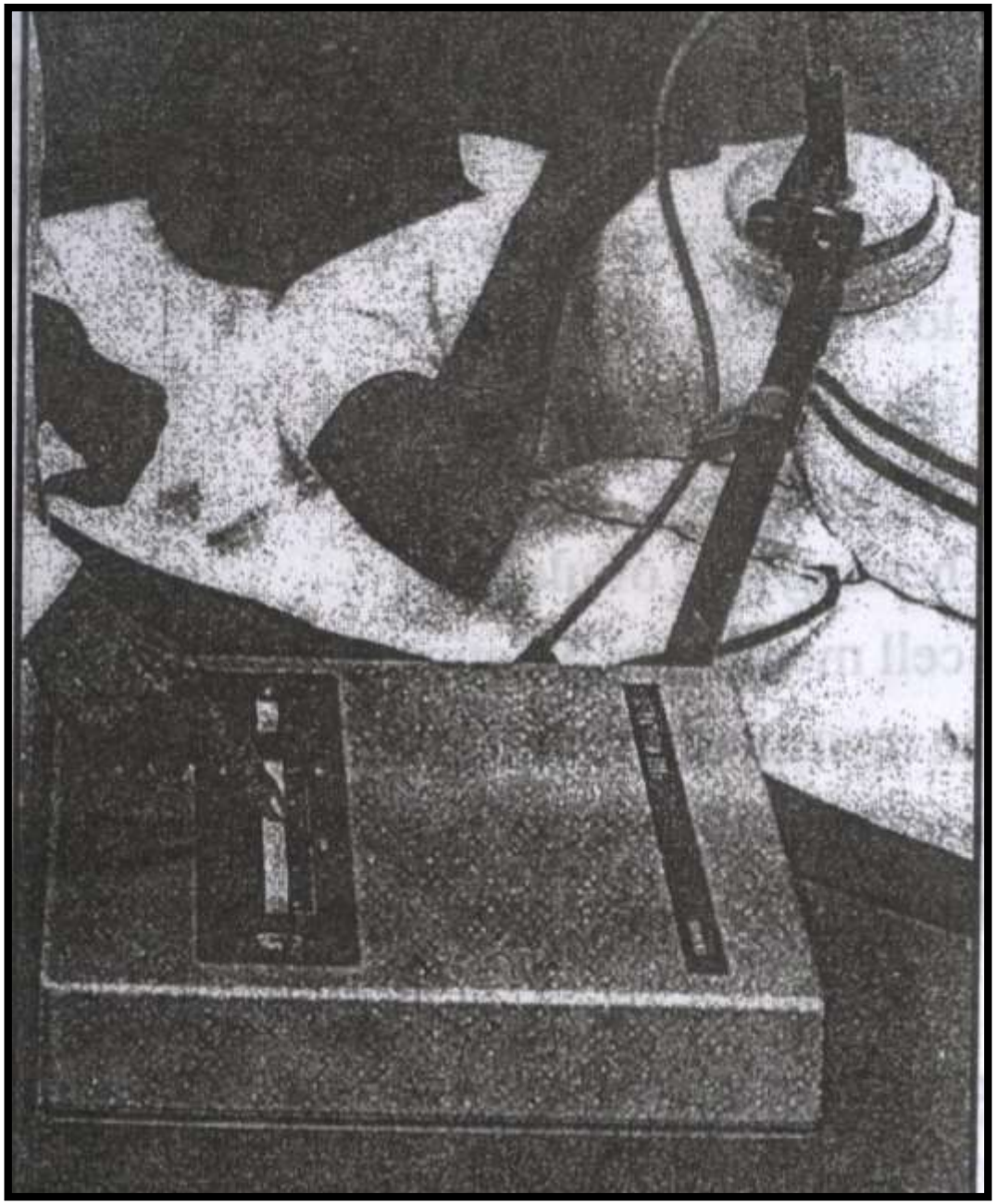

**The resultant induced electric field**

# Capacitive plates

**Electric field distribution**



# Magnetron



**Capacitive plates of diathermy applicator**

# *Effect of Diathermy:*

## Thermal effects

1. **Increase tissue temperature.**
2. **Vasodilatation.**
3. **Increased rate of nerve conduction.**
4. **Decrease pain.**
5. **Acceleration of enzymatic activity.**
6. **Increased soft tissue extensibility.**
7. **Increase cutaneous circulation.**
8. **Increase muscular circulation.**

# Non thermal effects

1. Any transient heat of tissue is dissipated by the blood per fusing the area during off time of the pulse.
2. Physiological effects are due to modification of ion binding and cellular functions by the incident electro magnetic field and the resulting electric current.
3. Increase local micro-vascular per fusion.
4. Increase local tissue oxygenation.
5. Increase tissue nutrients availability.
6. Increase phagocytosis.
7. Increase healing rate of ulcers.
8. Altered cell membrane function and cellular activity.
9. Change in myosin phosporylation.
10. Regulation of the cell cycle by altering calcium ion binding
11. Stimulation of ATP and protein synthesis.

## *Clinical Indication of Diathermy:*

### Thermal level diathermy:

1. **Decrease pain.**
2. **Accelerate healing.**
3. **Rheumatic pain.**
4. **Chronic sprains and strains.**
5. **Improve joint function, if applied in conjunction with stretching.**

# Non-thermal level:

- **Decrease pain.**
- **Decrease edema.**
- **Increase wound healing rate.**
- **Increase nerve healing rate.**
- **Increase bone healing rate.**
- **Management of neuropathy.**
- **Management of ischemic skin flaps.**

## *Contra Indications:*

### Thermal diathermy:

- Metal implants
- Malignancy
- Eyes
- Growing epiphysis
- Pacemaker
- Pregnancy
- Testes

### Non-thermal diathermy:

- Peace makers.
- Metal implants at the treatment site.
- Substitutes for conventional therapy for edema and pain.
- As a treatment of internal organs.

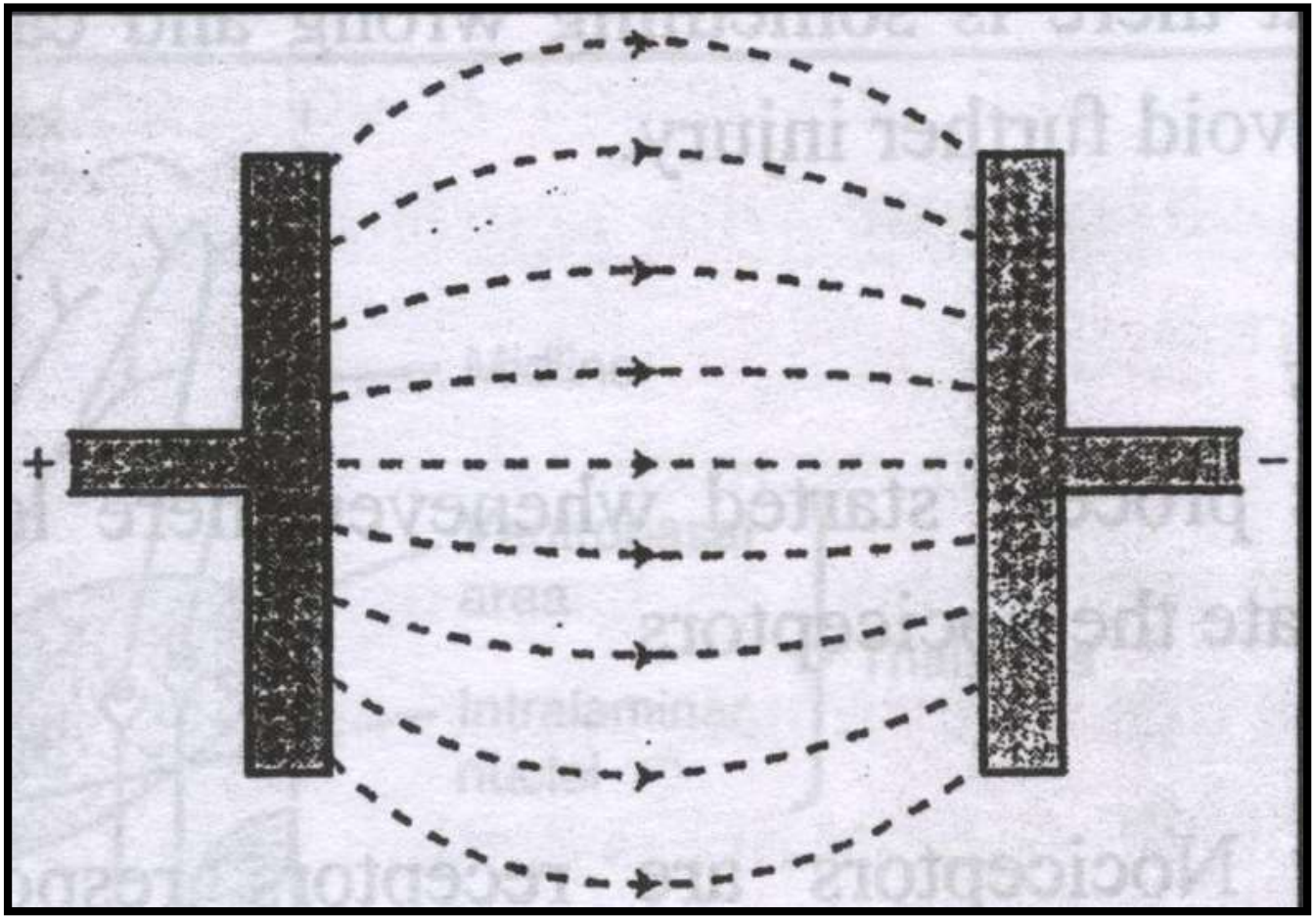
## *precautions:*

### Thermal diathermy:

- **Electronic or magnetic equipment in the field.**
- **Obesity.**
- **Copper bearing intra uterine contraceptive devices.**

### Non-thermal diathermy:

- **Pregnancy.**
- **Skeletal immature patients.**




# Electric field distribution in tissue

# ELECTROSURGICAL DIATHERMY

# ❑ PURPOSE

- ESU are used for surgical cutting and for controlling bleeding by causing coagulation “hemostasis” at the surgical site.

- It is “high frequency diathermy” involves the transference of electrical energy into heat which ,when impact to the bodily tissues, will heat the normal cell fluid, eventually through it is boiling point.

- What dose “DIATHERMY” mean?

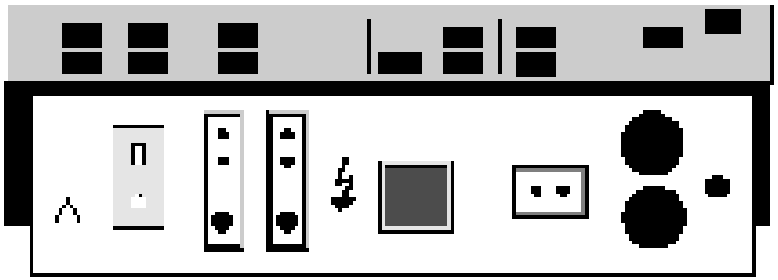
DIA = through

THERMO = temperature heat

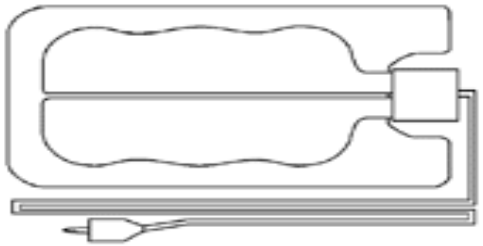
# ❑ Principle

- ESU machine is an alternating current source that operates at radio frequency “RF”.
- A high frequency current flowing through active electrode “high current concentration”.
- Cell ruptured-fumes or evaporates.
- Return path through dispersive electrode “low current and heat dissipates”.
- Patient is included in circuit.
- Current concentration or density depends on the size of the area through which the current flows.
- HF generation can be activated by a foot switch or finger switch on the surgical handle.

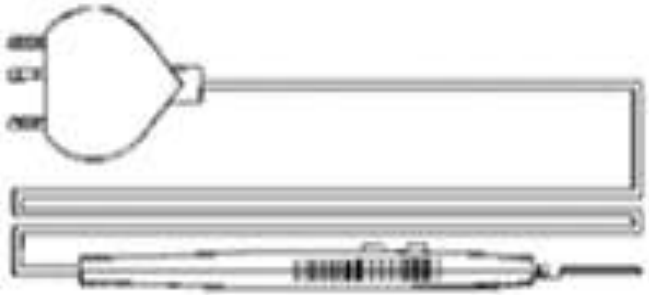
# System Components



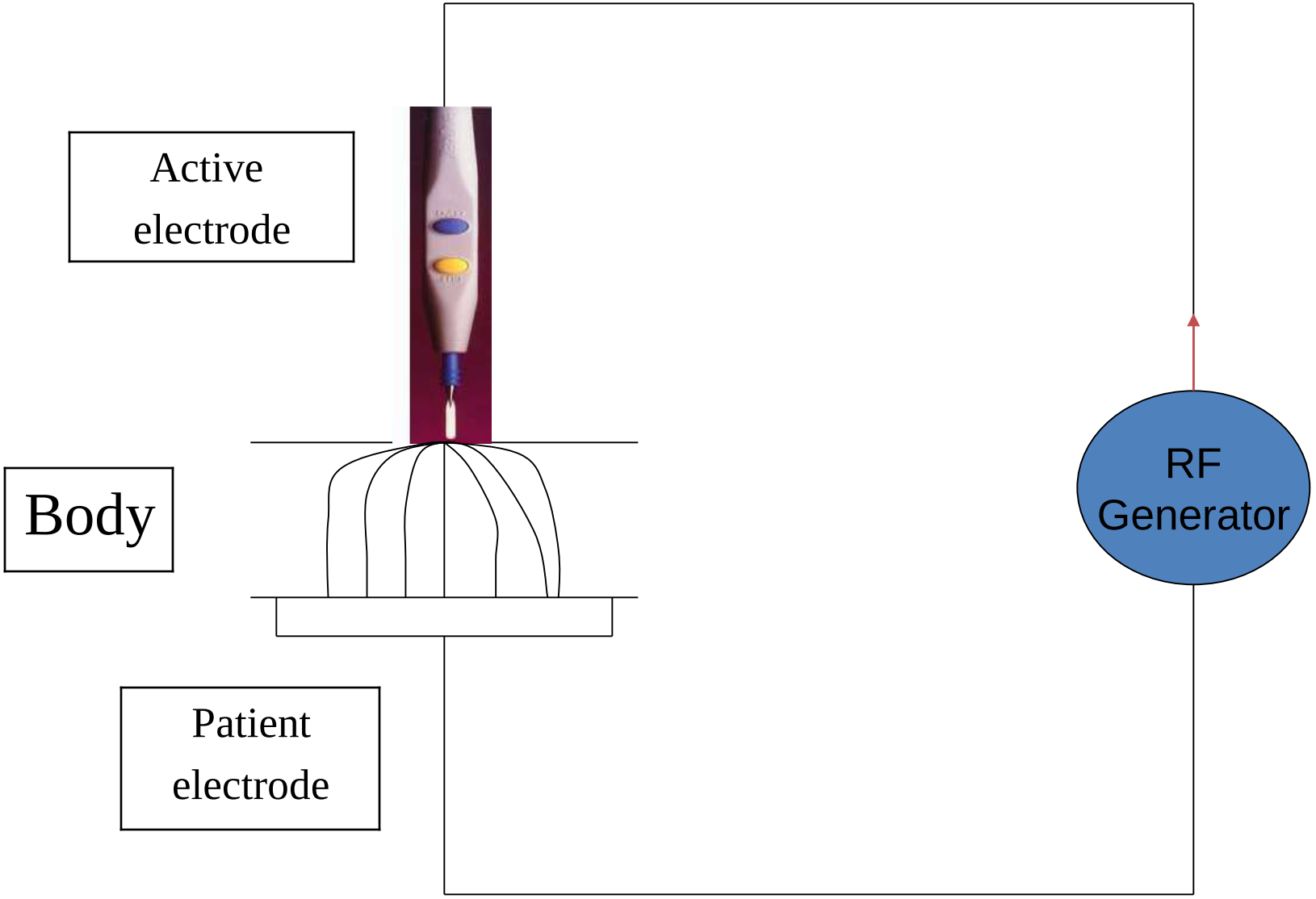
Electrosurgery Unit

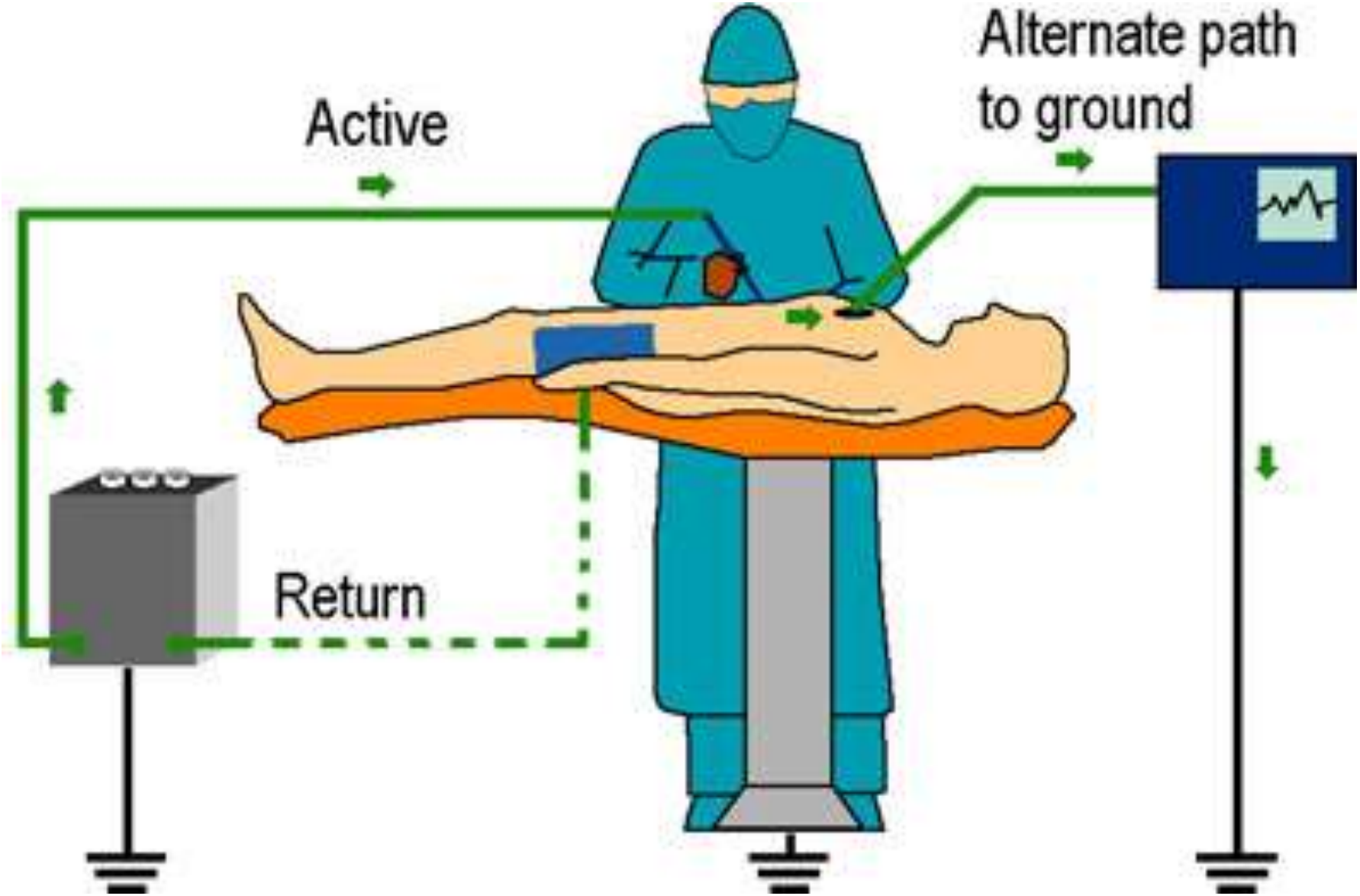


Dispersive Electrode



Active Electrode


Active electrode
Body
Patient electrode
RF Generator


Alternate path
to ground
Active
Return

# ❑ Effect of RF on cell

- When a high frequency current applied to the tissues the tissues gets turn apart and get the following effect:

1. Thermal effect.
2. Electrolytic effect.
3. Faradic effect.

# ❑ Operating frequency and typical value

- Operating frequency of solid state surgical diathermy machine is 300 KHz –to-3MHz
- Monopolar :CUT “0-to-350”watts for load 5
  COAG”0-to-100” watts
- Bipolar : CUT “0-to-50” watts
  COAG “0-to-10” watts

# ❑ Types of ESU

- ➢ Spark gap generator – 1924
- Still in use today “urology , open- heart surgery”.

- Spark gap / vacuum-tube device use spark –gap circuits to generate high frequency waveforms.

- It is not offer the same safety feature as solid state unites.

# ➢ Recent technology

- Argon/argon enhanced technology.
- It uses a computer-controlled tissue feedback system that senses tissue impedance and automatically adjusts the current and output voltage to maintain a constant surgical effect .
- It is reduces the need to adjust power setting for different types of tissue.
- It is also gives improved performance at low power setting to reduce the risk of patient injury.

# ➢ Solid state device - 1968

- It is more recent and more prevalently used technology.
- Contain  oscillator circuits and transistor-based amplifier that vary the frequency and modify the shape of the line signal to create an array of different waveforms for pure CUT,COAG, BLEEND .
- Highly safety.

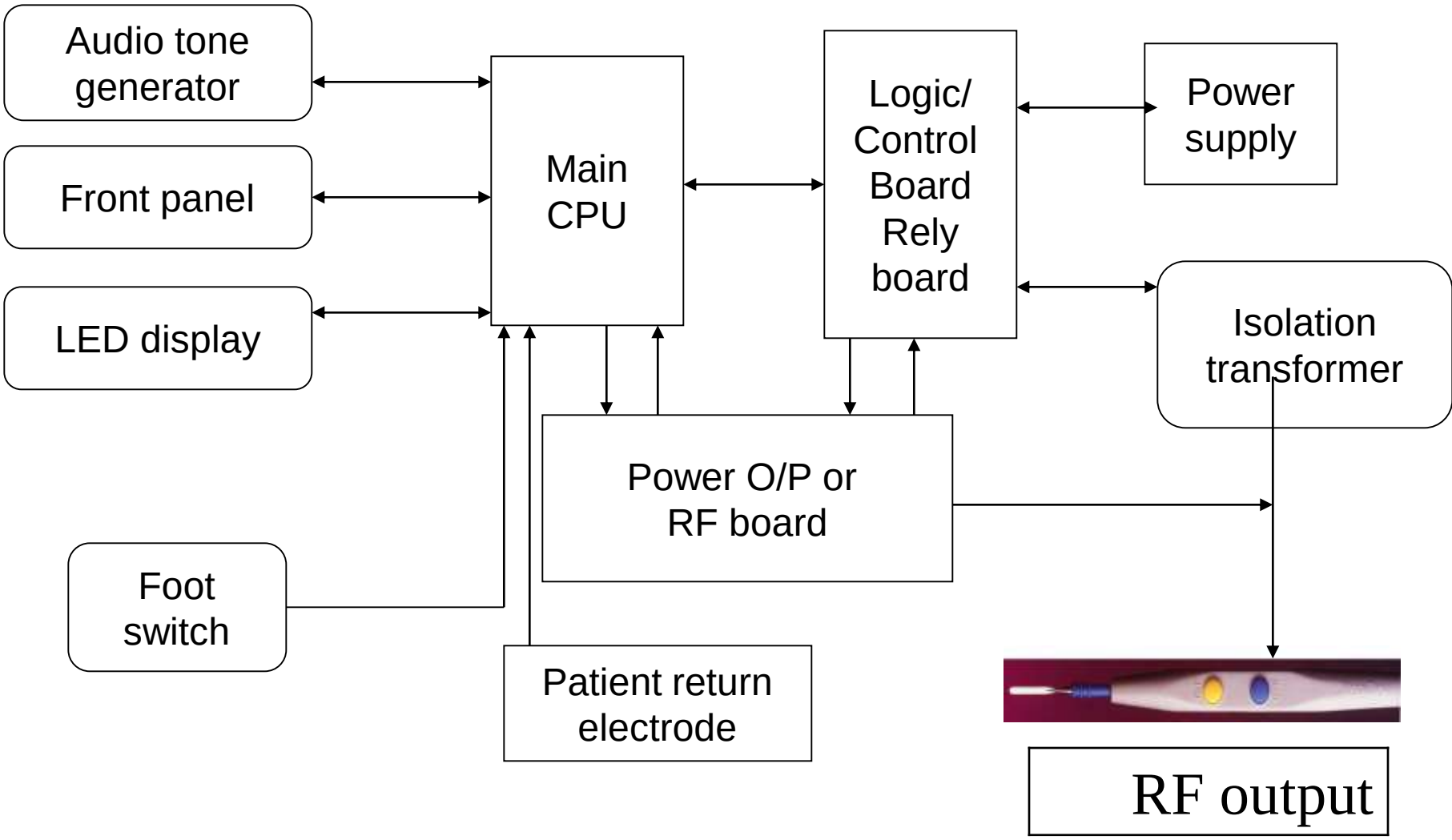
# ❑ Modes of Electro surgery

- Monopolar surgery
- Bipolar surgery

# ❑ Modes of electrosurgery

- Electrotomy/cutting
- desiccation / coagulation
- Blend
- fulgurations

# General Block Diagram



# ULTRASOUND DIATHEMRY

# Ultrasound

- Ultrasound is the most commonly used deep heating modality in use today.  Penetration is between 3-5 cm.
- Acoustical energy, not electromagnetic as most other units
- frequency is between .8 and 3 MHz (audible f= 15-20,000 Hz)

# Purpose and Use of Ultrasound

- Thermal
  - ↑ Blood Flow
  - ↓ Spasms
  - ↓ Pain
  - ↓ Collagen Extensibility
- Non-thermal
  - ↓ Subacute and chronic inflammation
  - Tissue changes resulting from mechanial effect
    - increase in cell permeability
    - collagen synthesis and realignement

# Equipment

- Electrical generator with step up or down transformer to overcome impedance of the crystal
- Oscillating circuits: optimizing frequency and allows us to impose a duty cycle
- coaxial cable carries current and minimizes any distortion
- transducer converts electrical energy into crystal into mechanical vibration (sound waves)

# The Crystal

- piezoelectric effect: *electricity* across the crystal causes deformation and vibration
- The quartz crystal requires high amount of voltage to cause piezoelectric effect and must therefore have well insulated coaxial cables to deliver electricity to the transducer.
- Capable of delivering mechanical and thermal effects to the tissue

# Terminology for Effects:

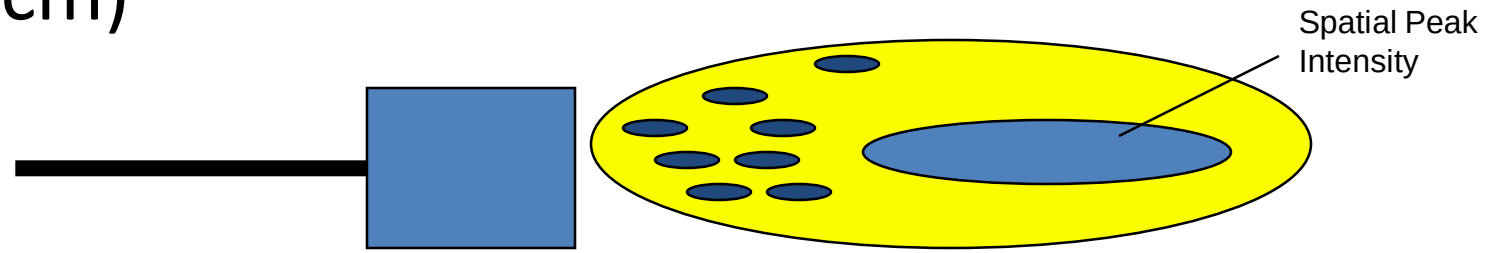
- Continuous or pulsed: this determines the production of heat. If the US is pulsed the % means the percent of time the sound will be delivered in a unit of time (i.e. 20% duty cycle will give 2 msec of sound every sec.)
- Condensation: areas of high energy collection
- Rarefraction areas of lower energy, gaps between waves of molecules

# Propagation:

- Sound waves are most effectively transmitted through dense materials.
  - Soft tissue is analogous to liquid when US travels in longitudinal manner
  - Bone may be longitudinal or transverse. Bone can cause a shear force near tissue interfaces
  - US travels best in homogeneous material, interfaces cause more scattering of waves.
    - since fat is homogeneous it will transmit the waves and allow deeper penetration

# Special considerations for Equipment

- Spatial peak intensity: because the US beam is not uniform, some regions will be more intense.  The spatial peak intensity is the greatest intensity anywhere within the beam
- Spatial average: a measurement of the average intensity It is a measurement of the total power output (Watts) divided by the area (cm)



# Effect Radiating Area (ERA)

- Area of the sound head that produces US waves. Measured in square centimeters
- ERA is always smaller than the transducer surface area. Manufacturers will typically list the ERA and not the surface area when referring to the size of the transducer head.
- The closer the ERA and transducer surface area the better. This will allow a more consistent contact and therapeutic dose.

# Beam Non-uniformity Ratio (BNR)

- Describes the consistency (uniformity of the US output ratio.
  - This factor is the determining factor in purchasing a unit.
  - It tells the quality of the crystal.
- Lower the BNR more uniform the beam.
- The BNR is expressed in ratio from 10:1 down to 2:1.
  - A 6:1 BNR is acceptable but a 3:1 or 2:1 is best.8:1 is considered unsafe

# US effects in tissues

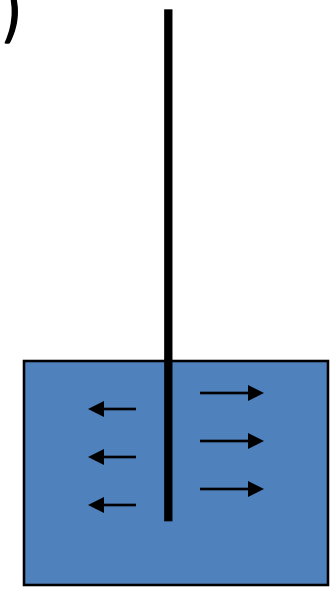
- Depth of penetration depends on the absorption and scattering of the US beam as it travels through the tissue. The frequency of oscillation determines the depth of penetration (the lower the frequency, the deeper the penetration)
- Absorption: the uptake of heat converted from acoustic energy by propagation of US through the tissues.

# Absorption

- Directly proportional to the protein content of the tissues sonated.
  - bone, cartilage, tendon and skin are 20-25% protein content
  - blood vessels are 15-20%
  - muscle, fat and blood are 10-15%
- Tissues which are selectively heated by US are the "target tissues" for US use.
  - Superficial bone, joint capsules, tendon, scar tissue, peripheral nerves, myofascial interface and cell membranes

# Absorption Cont.

- The more homogeneous the tissue, the less US energy is absorbed
  - example: fat, metallic and synthetic implants are very homogeneous and US produces very little temperature increase.
- High frequency sound (3 MHz) is absorbed more readily than lower frequencies (1 MHz)

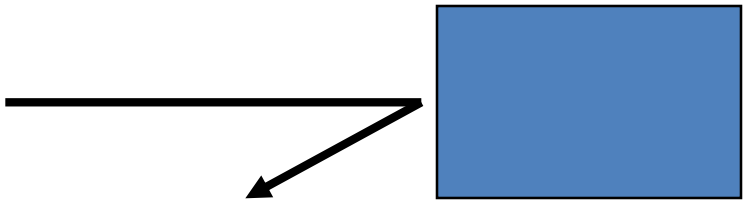


# Scattering

- The diffuse reflection or refraction of US from irregular surfaces or in homogeneities within the tissues
  - Reflection: the reversal of the direction of propagation of the ultrasound wave
  - Refraction: the reflection of energy from a straight path when passing obliquely from one medium to another

# Reflection:

- Reflection occurs when there is a mismatch of acoustic impedance between two tissue levels. The greater the acoustical impedance difference, the great the heat generated.
  - Acoustic impedance of muscle, fat and water is low with about 1% of the energy reflected

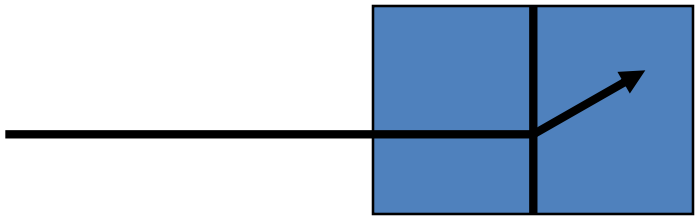


# Reflection Cont.

- Impedance of bone is high with about 25% of the energy reflected from the bone into the adjacent tissues
  - Results are significantly higher intensity in tissues close to the bone: periosteum, tendons, and aponeurotic attachment of muscle, cartilaginous coverings of joint surfaces, and peripheral nerves lying close to bones.
  - Poor blood supply in these tissues offers little heat dissipation by circulation which can lead to pain

# Refraction:

- The bending of energy can lead to concentrations of US at the point of refraction
  - Example: where tendon joins bone



# US Output Parameters

- Frequency (MHz)
  - The effective depth of penetration (1 or 3 MHz)
- Intensity
  - The amount of power generated by unit

# Treatment Parameters

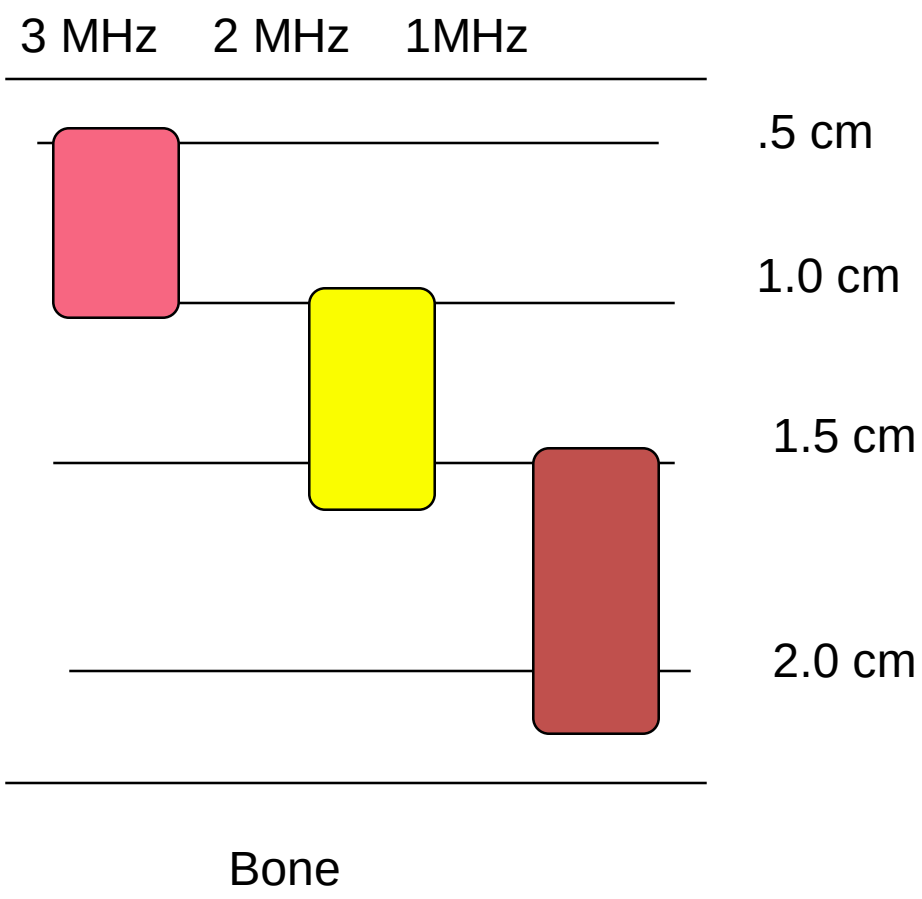
- Intensity: the rate at which energy is delivered per unit area and is expressed in $W/cm^2$
- Power: the total output of the transducer and is expressed in watts.  it is measured on an US power meter
- Frequency: the number of sound oscillations in one second and is expressed in MHz.
- Transducer Size: the smaller the transducer surface area the greater the be a divergence. Always select the largest size transducer with the best ERA and lowest BNR that will offer the most consistent contact with surface.

# Intensity:

- Everyone's tolerance is different
- The feeling of warmth is desired (if using for thermal properties)
- Begin at 1.0 $W/cm^2$ and increase intensity until the patient feels heat (not pain) and reduce until a gentle heating if felt
- Some researchers site: 1.0 $W/cm^2$ for "thin" tissues and 1.0-2.0 $W/cm^2$ for "thick" tissues

# Frequency

- 3MHz 0-1cm
- 2 MHz 1-2 cm
- 1 MHz 2-3 cm



# Transducer:

- Choose an area that is an appropriate size
  - no greater than 1.5 to 2 times the ERA
- Speed of rotation will vary the heat

# Therapeutic Applications

| Effect | Temp. Increase | Application |
|---|---|---|
| Non Thermal | None | Acute, Injury, Edema, Healing |
| Mild Thermal | 1° C | Sub Acute Injury Hematoma |
| Moderate Thermal | 2° C | Trigger points |
| Vigorous | 3° C | Stretch Collagen |

# US Application Time

- Continuous: A duty factor of 100% is needed to elevate tissue temperature to physiologically significant temperature (104-112 degrees F)
  - This results in a reduction of pain and muscle spasm as well as an increase in tissue extensibility and increase blood flow.
- Pulsing: the sound wave will decrease the depth of US delivery
  - Current machines have % pulsed, thus you can modify depth of delivery

# Application Techniques

- Coupling Medium: US energy will not pass through the air or skin without the presence of a coupling medium. The ideal coupling medium should have the following qualities:
  - High transmission and low absorption of US energy
  - Exclude air, minimal air entrapment
  - good impedance
  - low drag coefficient
  - good viscosity
  - low salt content
  - economical cost
  - easy to use

# Coupling Agents

- Gel
- Water Immersion
- Bladder Method (water filled balloon)
- Phonophoresis

# Application Techniques

- Researchers note best medium is aqueous gel (different from electrical stim. gel)
- Water meets all of the criteria, good for irregular or small body parts (aqueous gels are mainly water)
- Biofreeze or Flex-all does not allow as great a healing effect
- Phonophoresis “jury still out”

# Water Immersion Bath

- Use room temperature degassed water in a plastic treatment tub
  - Do not use in a metal tank!
- The transducer should be applied in a moving technique as close as possible, but still remaining perpendicular to the treatment area.
- Precaution is advised when immersing the clinician’s hand into the water bath during treatment or when removing bubbles from the transducer's face since the dangers of long term exposure to US are not known at this time.

# Stretching

- Stretching window is 3 minutes
  - After 3 minutes the tissues temperature drops past tissue extensibility

# PreHeating

- Preheating should be a decision based on patient comfort
- Research indicates that pre heating (HP, emersion) increased superficial heat temperatures significantly
  - Deep tissues are unaffected

# PreCooling

- Research has indicated that precooling retard increase of heat in the tissue
- Cooling may also anesthetize the area limiting sensation

# Ultrasound and Electrical Stimulation

- Theoretically to create effects of both US and electrical stim
- Research is lacking but claims for use include:
  - trigger points
  - superficial pain areas
  - decrease adhesions

# Diathermy

# Diathermy

- Uses energy similar to broadcast radio waves with shorter wavelength.
- Energy is alternating current lacking properties to depolarize motor sensory nerves
- Fiction caused by the movement6 of ions from the High Frequency electromagnetic energy causes heating

# Diathermy

- Tissues with high water content (Fat, blood and muscle) are selectively heated at depth of 2-5cm.
- Local tissue temp. may reach 107ºF, but fat layer dissipated heat secondarily heating muscles
- Deep heating effects last longer than US due to large area heated

# Delivery of Diathermy

- Pulsed
  - Acute and subacute conditions
  - heating related to rations of time “on” and “off”
  - Heating occurs when total amount of energy delivered is greater than 38 watts, below this receive non-thermal effects
- Continuous
  - Mainly used
  - For chronic injuries

# Effect on Injury Response

- Response similar to effects of heat
  - Skin temp raises 4.3ºF
  - Intra-articular temp raises 2.5 ºF
  - Blood flow increases
  - fibroblastic activity, collage deposition and new capillary growth stimulated
  - muscle spasm is resuced by sedation of sensory and motor nerves
  - local increase in cellular metabolic rate

# Set-up and Application of Diathermy

- Condenser and Induction Method will be demonstrated in lab
- General Prep.
  - No metal (including removal of all rings, watches, hairpins etc.)
  - Cover area with terrycloth towel to eliminate sweat
  - Explain to patient warmth should be felt, but no unusual sensations

# Diathermy Set-up

- Duration of Tx
  - 20-30 minutes
  - 2 weeks
  - when using higher tx temp, decrease the duration of tx and apply on alternate days
- Indications
  - Joint Inflammation
  - Larger areas than US
  - Fibrosis
  - Myositis
  - Subactue and Chronic Inflam.
  - Oasteoarthritis

# Diathermy Precautions

- Physician's Prescription (some states)
- Never allow cables to touch (short circuit)
- Do not allow for perspiration
- Never allow direct contact with skin
- Excessive fat in area may overheat area
- Difficult to tx localized areas
- Overheating tissues may cause damage
  - deep acing
  - fat neurosis
  - burning

# Diathermy Contraindications

- Ischemic Areas
- Peripheral vascular disease
- Metal Implants
- Perspiration
- Tendency to hemorrage including menstration
- Cancer
- Fever
- Sensory loss
- Pregnancy
- Cardiac pacemakers
- Areas of particular sensitivity
  - epiphyseal plates
  - genitals
  - infection
  - abdomen
  - eyes and face

# Dosage Parameters

| Dose | Temp. Sensation | Indications | Pulse Width | Pulse Rate |
|---|---|---|---|---|
| NT | NO detectable warmth | Acute trauma, inflam, edema reduction | 65μsec | 100-200 pps |
| 1 | Mild Warmth | Subacute inflamation | 100μsec | 800pps |
| 2 | Moderate warmth | Pain, muscle spasm, Chronic inflam, inc. blood flow | 200μsec | 800pps |
| 3 | Vigorous heating | Stretching collagen tissues | 400μsec | 800pps |

# Electrical Safety in Biomedical Equipment

# Objectives

- **Discuss the role and responsibilities of a biomedical equipment technician (BMET).**
- **Identify two safety responsibilities of a BMET.**
- **Compare the roles and responsibilities of the biomedical engineer and the industrial hygienist.**

# Objectives (cont.)

- **Identify safe electric current leakage limits for biomedical equipment.**
- **Identify the two classes of medical equipment that are safety-tested.**

# Objectives (cont.)

- **Identify wire color codes used in hospitals.**
- **Define preventive maintenance.**
- **Define macroshock and microshock.**
- **Successfully complete 1 procedure in biomedical technology.**

# Biomedical Equipment Technician

- **The need for biomedical equipment technicians (BMETs) arose with the introduction of complex equipment to diagnose, prevent, and cure disease and illness.**

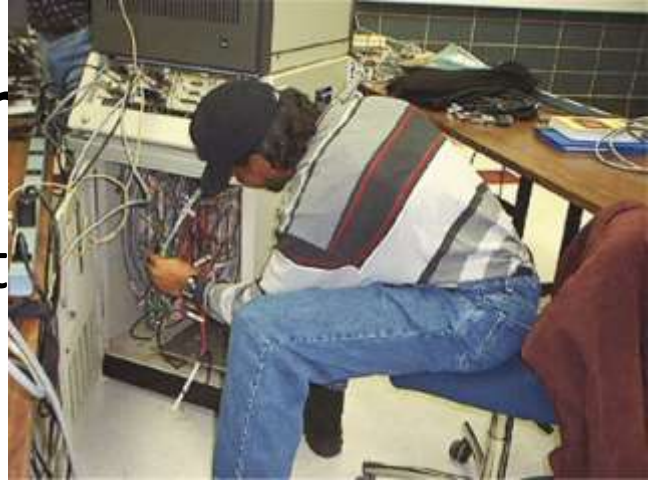
# Biomedical Equipment Technician (cont.)

- **A BMET is knowledgeable about:**
  - **The theory of operation.**
  - **The underlying physiologic principles.**
  - **The practical, safe clinical application of biomedical equipment.**

# Biomedical Equipment Technician (cont.)

- **The Job of the Biomedical Equipment Technician**
  - **BMETs work for:**
    - **Large hospitals.**
    - **Medical equipment manufacturers and distributors.**
    - **Medical supply firms.**
    - **Medical research organizations.**
    - **Teaching establishments.**

# Biomedical Equipr Technician (cont



- **The Job of the Biomedical Equipment Technician (cont.)**
  - **BMETs should have:**
    - **Better than average manual dexterity.**
    - **Mechanical and electrical inclination.**
    - **Numerical ability.**
    - **Color vision.**
    - **An above-average work ethic.**

# Biomedical Equipment Technician (cont.)

- **The Job of the Biomedical Equipment Technician (cont.)**
  - **Install, calibrate, and service equipment.**
  - **Train new users.**
  - **Apply basic troubleshooting to unfamiliar layout and operations.**

# Biomedical Equipment Technician (cont.)

- **The Job of the Biomedical Equipment Technician (cont.)**
  - **Evaluate equipment for servicing.**
  - **Repair equipment.**
  - **Maintain parts inventory.**
  - **Test for electrical safety.**

# Biomedical Equipment Technician (cont.)

- **Education and Internship**
  - **College programs include the study of:**
    - **Details of electronic components and circuits.**
    - **Design and construction of biomedical equipment.**
    - **Physiologic and electronic principles.**
    - **Physics.**
    - **Medical terminology.**
    - **Anatomy and physiology.**

# Biomedical Equi
# Technician (c

- **Job Responsibilities**
  - **Carry out preventive maintenance.**
  - **Train personnel on the use and care of equipment.**
  - **Track maintenance and service.**
  - **Make recommendations on replacements.**

# Biomedical Engineer

- **Uses skills to analyze and solve problems in biology and medicine.**
- **Designs and develops biomedical equipment.**
- **Sometimes called a clinical engineer.**
- **Education ranges from associate degree to Ph.D. degree.**

# Biomedical Engineer (cont.)

- **The Job of the Biomedical Engineer**
  - **Works in specialty areas including biomaterials, biomechanics, medical imaging, rehabilitation, and orthopedic engineering.**
  - **Works with other health care professionals including physicians, nurses, therapists, and technicians.**

# Biomedical Engineer (cont.)

- **Job Responsibilities**
  - **Develop devices such as hearing aids; cardiac pacemakers; artificial kidneys and hearts; synthetic blood vessels; and prosthetic joints, arms, and legs.**
  - **Oversee automated client monitoring during surgery or in intensive care.**
  - **Monitor healthy people in unusual environments such as space.**

# Biomedical Engineer (cont.)

- **Job Responsibilities (cont.)**
  - **Develop therapeutic and surgical devices such as laser systems for eye surgery and automated delivery of insulin.**
  - **Advise on sports medicine, rehabilitation, and support devices.**
  - **Design computerized blood sample analyzers, cardiac catheters, and other equipment for use in clinical laboratories.**

# Biomedical Technology Procedures 30-2

- **Safety**

# Biomedical Technology Procedures (cont.)

- **The Association for the Advancement of Medical Instrumentation (AAMI) developed the first standards for the manufacture and safety of medical equipment.**
- **Biomedical technology departments are expanding into the areas of telemedicine and teleradiology.**

# Safety

- **A current of more than 10 milliamperes can cause paralysis in the human body.**
- **Electrical inspection has become a very complete preventive maintenance (PM) inspection, due to the requirements of the Joint Commission on Accreditation of Healthcare Organizations (JCAHO).**

# Safety (cont.)

- **Electrical Safety Testing**
  - **Keep electricity in its place.**
  - **Medical treatment facilities (MTF) use color-coded wires, plugs, and outlets marked “hospital-grade.”**
  - **Electric currents that continue for more than one heart cycle may cause fibrillation.**

# Safety (cont.)

- **Equipment Classes**
  - **The two classes of medical equipment are class A and class B.**

# Safety (cont.)

- **Class A Equipment**
  - **Used in critical client care areas.**
  - **Usually, with class A equipment, the client has a direct line of electrical conduction to the heart.**
  - **Operating rooms, emergency rooms, and recovery rooms are examples of class A areas.**

# Safety (cont.)

- **Class B Equipment**
  - **Used in general client care and examination rooms.**
  - **Examples of class B equipment are examination tables, electric hospital beds, and laboratory equipment.**

# Safety (cont.)

- **Leakage Current**
  - **Naturally occurring current that results from distributed capacitance within equipment or power cords and that leaks from electronics to the metal chassis of the equipment to ground.**
  - **The acceptable leakage current in class A areas is 10 microamps.**
  - **The acceptable leakage current in class B areas is 500 microamps.**

# Safety (cont.)

- **Leakage Current (cont.)**
  - **The 6 main categories of leakage current are:**
    - **Loss of instrument ground.**
    - **Voltage variations caused by inadequate grounding or improper ground wiring.**
    - **Current originating from an instrument during use on a client.**

# Safety (cont.)

- **Leakage Current (cont.)**
  - **The 6 main categories of leakage current are (cont.):**
    - **Inducted current from other high-energy sources.**
    - **Self-generating currents or voltage differentials.**
    - **Other modes of leakage or means of generating current.**

# Safety (cont.)

- **Macroshock and Microshock**
  - **Macroshock is a large value of electric current that passes from one arm to the other, usually externally on the skin.**
  - **Microshock is a small value of electric current that passes directly through the heart.**

# UNIT 1

# ORIGIN OF BIOPOTENTIALS

# Historical Background

- In 1786, Luigi Galvani found electricity in the muscle of a frog's leg.
- In 19$^{th}$ century other scientists found same effect in animals and man.
- 1903, William Einthoven introduced the string galvanometer, and measured these potentials.

# Biopotential

Definition:

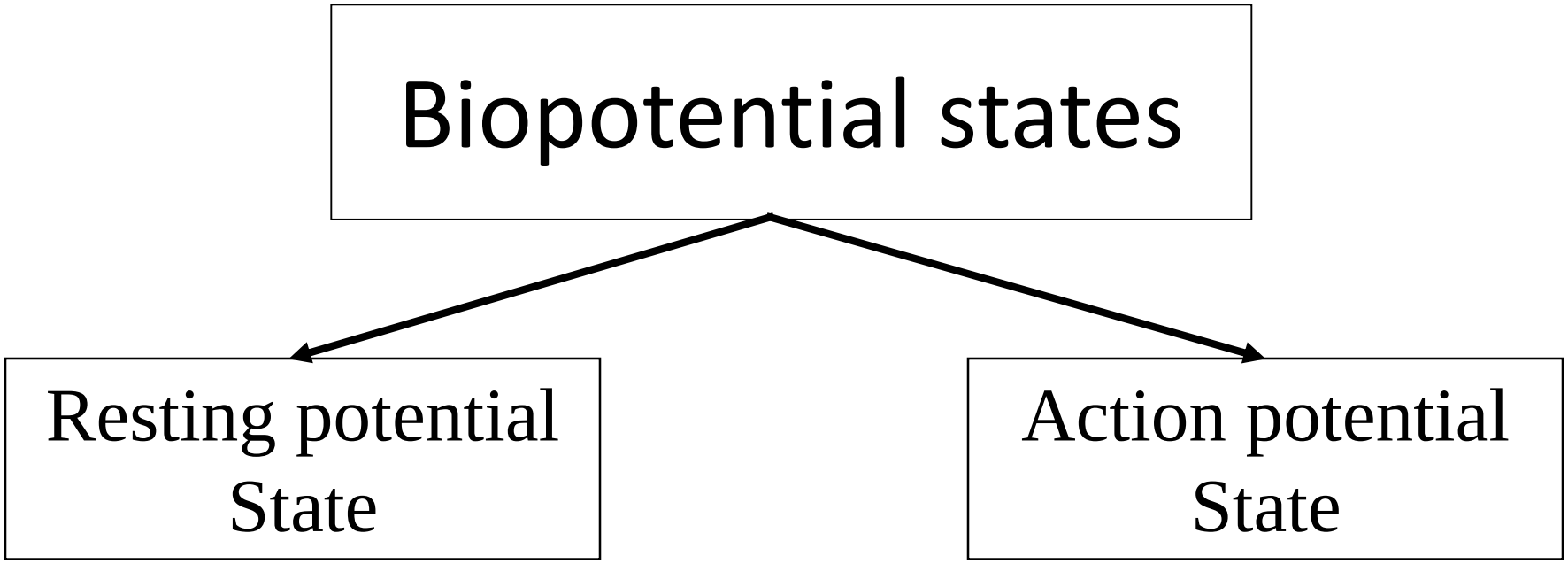
- Ionic voltages produced as a result of the electrochemical activity of *excitable cells.*

Measurement:

- Using transducers to convert ionic potentials into electrical potentials

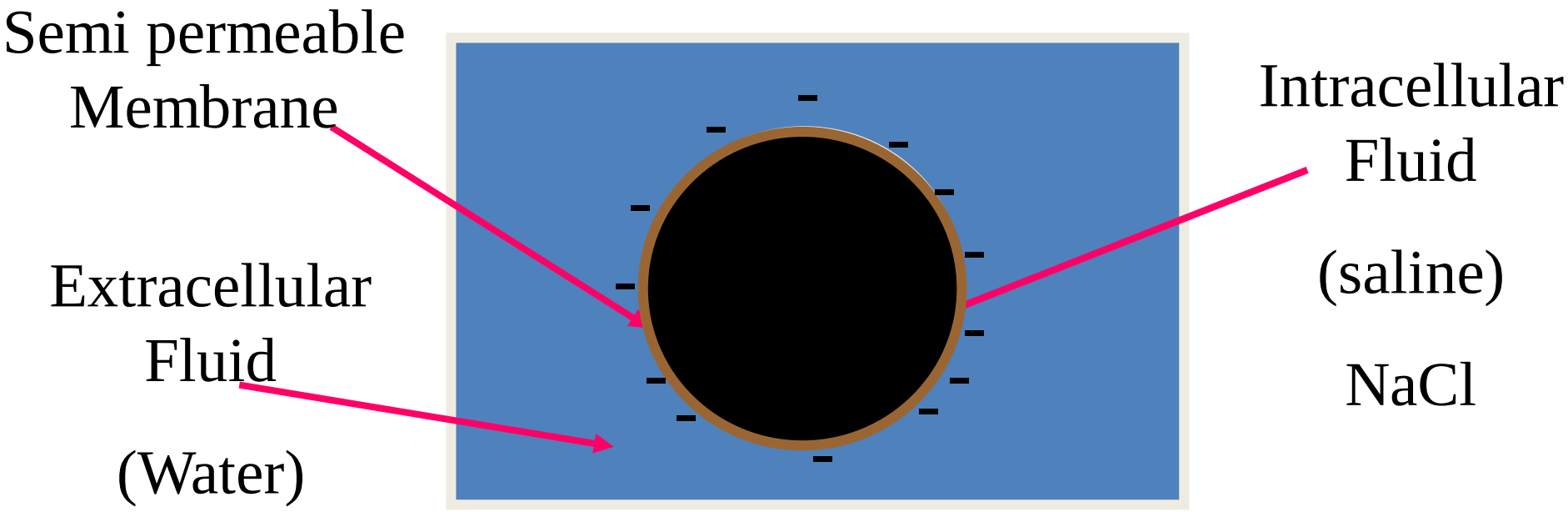
# Excitable Cells

- Are components of nervous, muscular or glandular tissue
- Can produce bioelectric potentials as a result of electrochemical activity.


Biopotential states
Resting potential State
Action potential State

# Origin of Biopotential

- Diffusion Gradient
- Electrostatic force of repulsion



# Living cell properties

- Intra- and Extracellular fluids : Na+, Cl-, K+
- Membrane keeps high $K_i$+ , Low $Na_i$+ and Low $Cl_i$-
- Membrane  7- 15  nm thick lipoprotein
- Membrane impermeable to intracellular protein
- Membrane is moderately permeable to Na+ and freely permeable to K+ and Cl-

# Resting Potential Equation

$$E_{Na} = \frac{RT}{F} \ln \left\{ \frac{Na_O}{Na_I} \right\} \quad = + 60 \text{ mv}$$

$$E_{K} = \frac{RT}{F} \ln \left\{ \frac{K_O}{K_I} \right\} \quad = -85 \text{ mv}$$

$$E_{Cl} = \frac{RT}{F} \ln \left\{ \frac{Cl_I}{Cl_O} \right\} \quad = -66 \text{ mv}$$

- **R**: Universal Gas Constant
- **F**: Faraday Constant
- **T** : Absolute Temp in degree Kelvin
- **P** : Permeability
- $\mathbf{K_o}$, $\mathbf{Na_o}$, $\mathbf{Cl_o}$ : ion concentration outside cell
- $\mathbf{K_i}$, $\mathbf{Na_i}$, $\mathbf{Cl_i}$ : ion concentration inside cell

# Resting Potential Equation

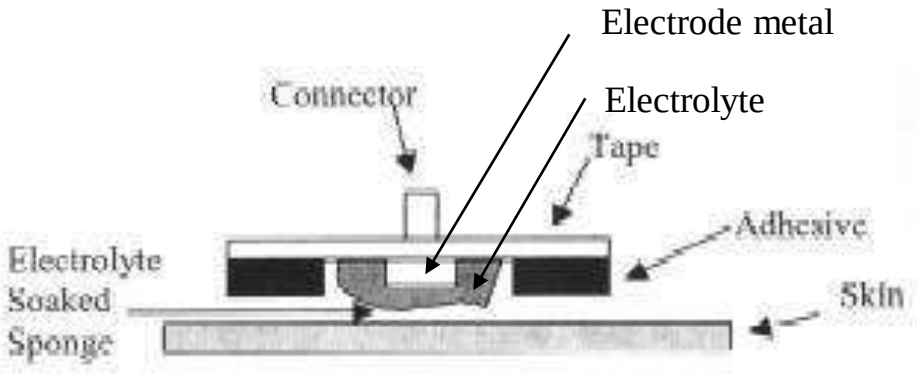
$$E = \frac{RT}{F} \ln \left\{ \frac{P_k\ K_O + P_{Na}\ Na_O + P_{Cl}\ Cl_I}{P_k\ K_I + P_{Na}\ Na_I + P_{Cl}\ Cl_O} \right\}$$

# Notes

- $N_{atoms}$= total charge / electron charge  (electrolysis)
- $N_{moles}$ = $N_{atoms}$ / Avogadros Number
- Weight (in gram) = Molecular Weight * $N_{moles}$
- Avogadro's Number = $6.03 * 10^{23}$  atoms/mole

# BIO-POTENTIAL ELECTRODES

# Body Surface Recording Electrodes

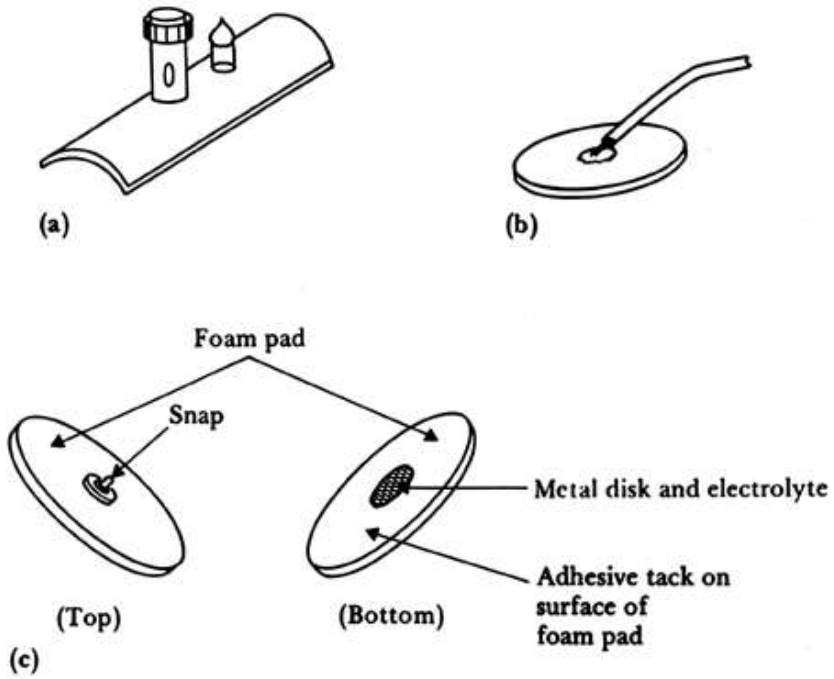



1. Metal Plate Electrodes
2. Suction Electrodes
3. Floating Electrodes
4. Flexible Electrodes

# Commonly Used Biopotential Electrodes

**Metal plate electrodes**

- Large surface: Ancient, therefore still used, ECG
- Metal disk with stainless steel; platinum or gold coated
- EMG, EEG
- smaller diameters
- motion artifacts
- Disposable foam-pad: Cheap!




(a) Metal-plate electrode used for application to limbs.
(b) Metal-disk electrode applied with surgical tape.
(c)Disposable foam-pad electrodes, often used with ECG

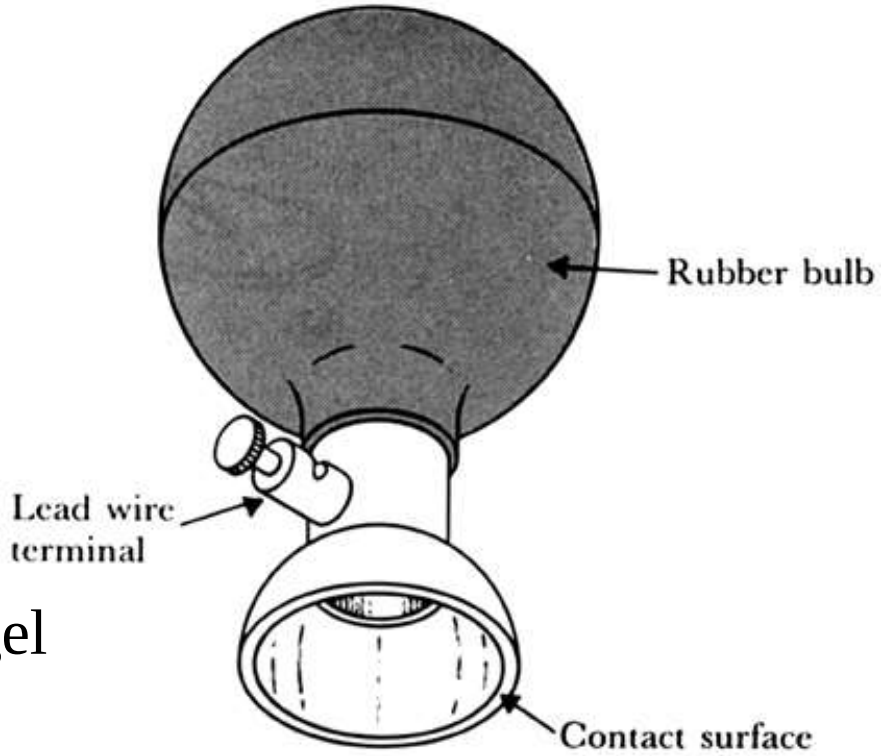
# Commonly Used Biopotential Electrodes

**Suction electrodes**

- No straps or adhesives required
- precordial (chest) ECG
- can only be used for short periods

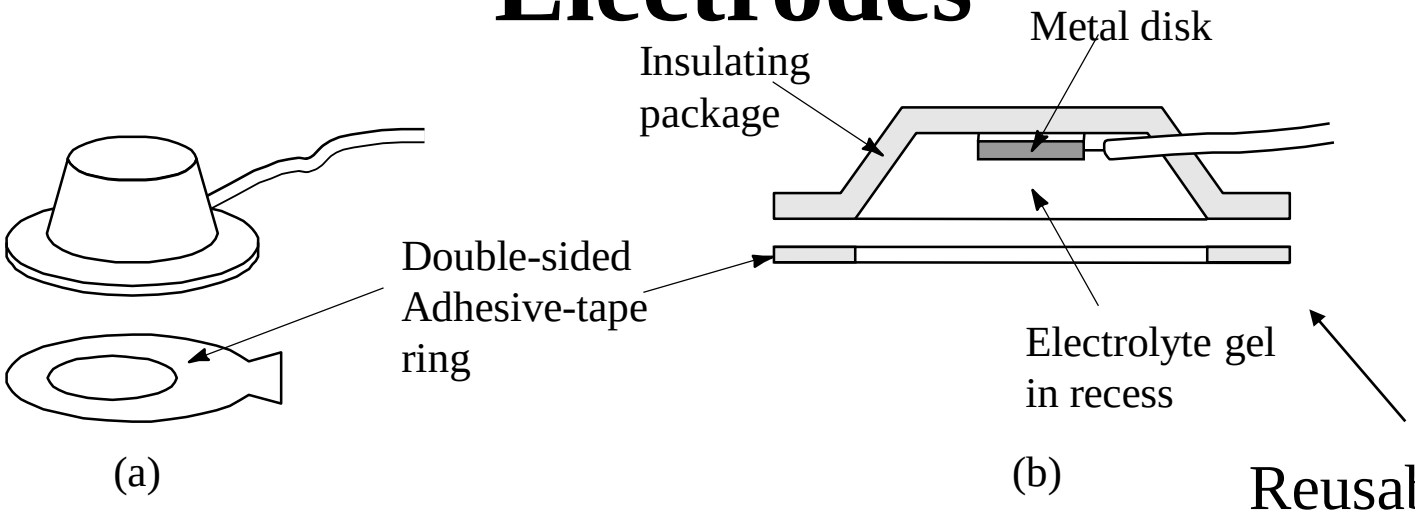
**Floating electrodes**

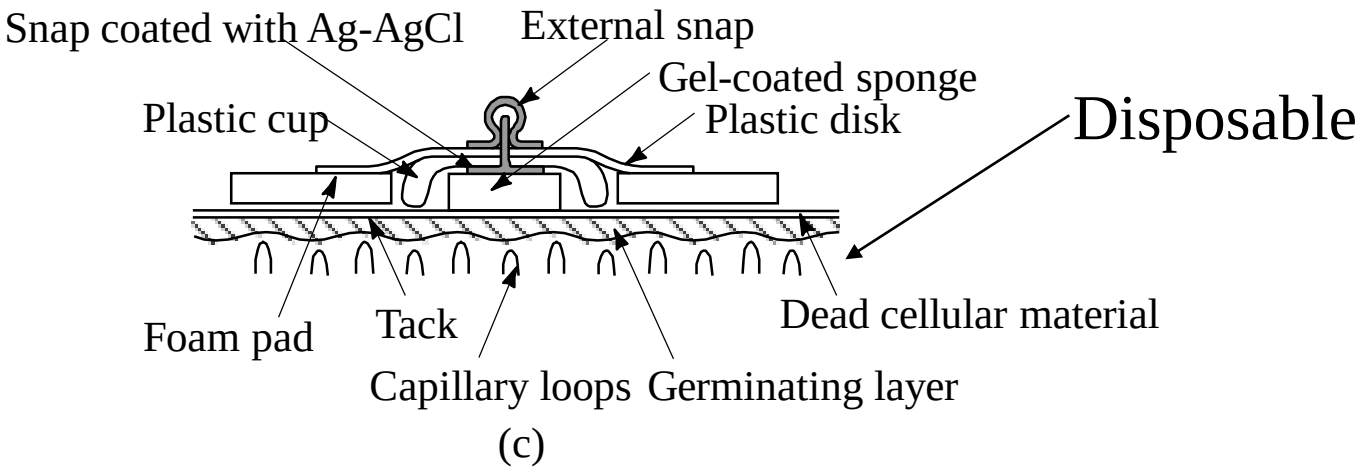
- metal disk is recessed
- swimming in the electrolyte gel
- not in contact with the skin
- reduces motion artifact




Suction Electrode

# Commonly Used Biopotential Electrodes



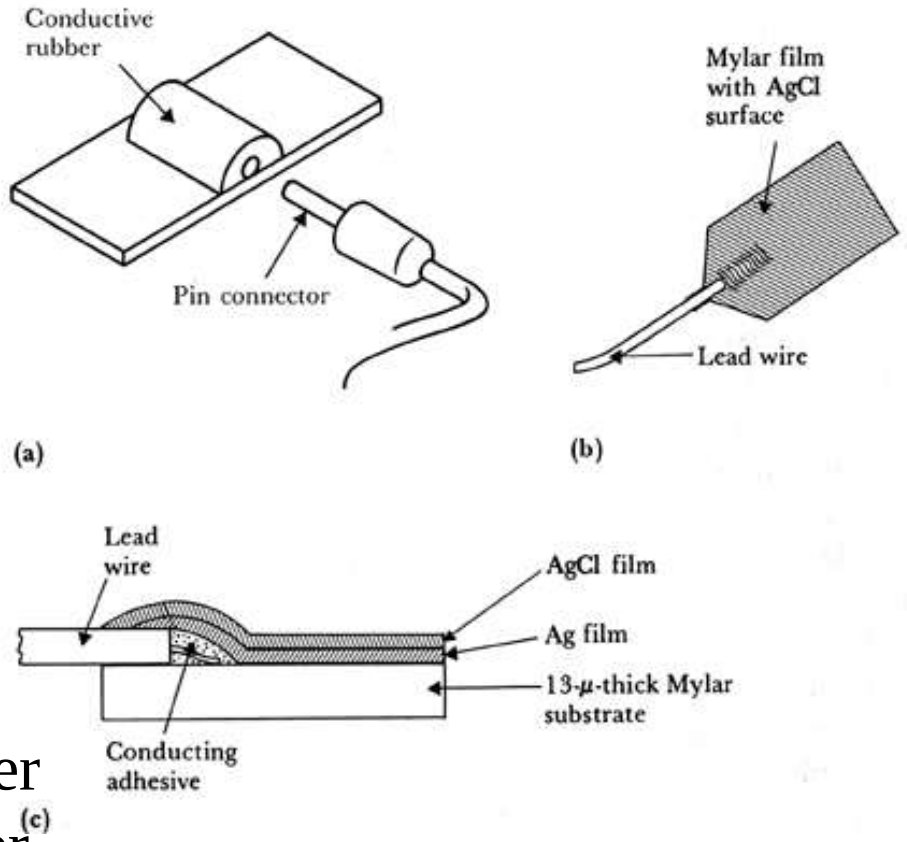




## Floating Electrodes

# Commonly Used Biopotential Electrodes

**Flexible electrodes**

- Body contours are often irregular
- Regularly shaped rigid electrodes
  may not always work.
- Special case : infants
- Material :
  - Polymer or nylon with silver
  - Carbon filled silicon rubber (Mylar film)

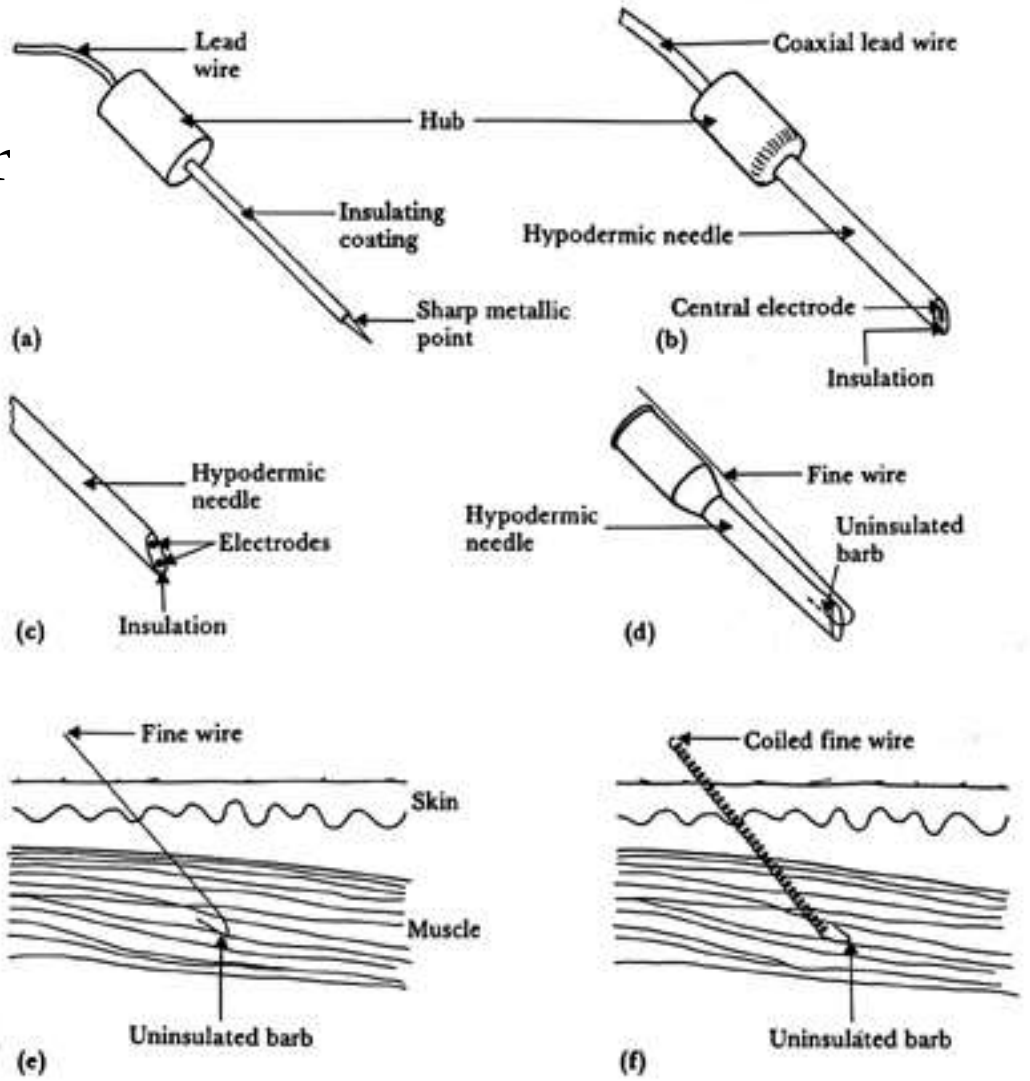



(a) Carbon-filled silicone rubber electrode.
(b) Flexible thin-film neonatal electrode.
(c) Cross-sectional view of the thin-film electrode in (b).

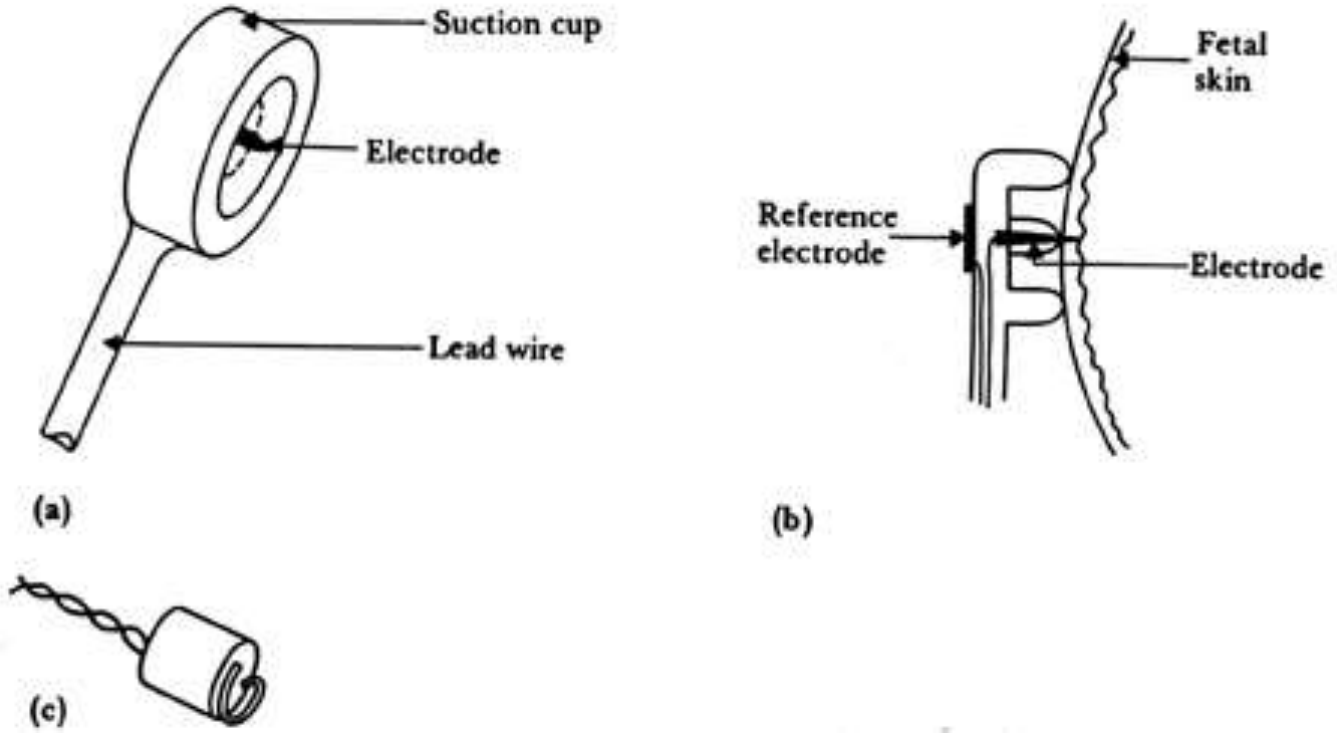
# Internal Electrodes

Needle and wire electrodes for percutaneous measurement of biopotentials

(a) Insulated needle electrode.
(b) Coaxial needle electrode.
(c) Bipolar coaxial electrode.
(d) Fine-wire electrode connected to hypodermic needle, before being inserted.
(e) Cross-sectional view of skin and muscle, showing coiled fine-wire electrode in place.

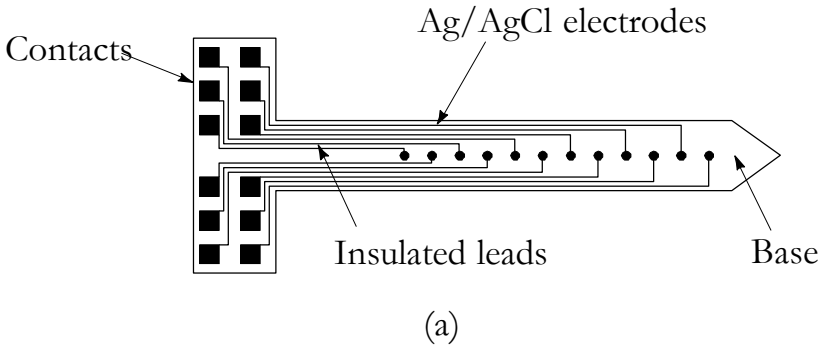


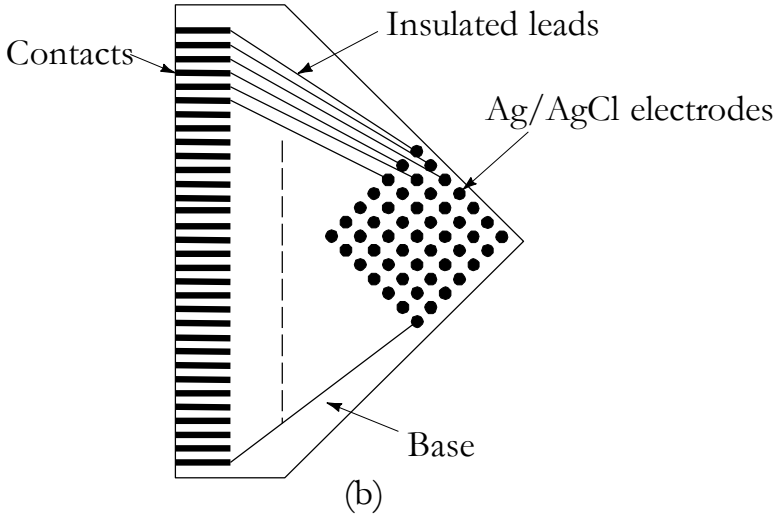
# Fetal ECG Electrodes

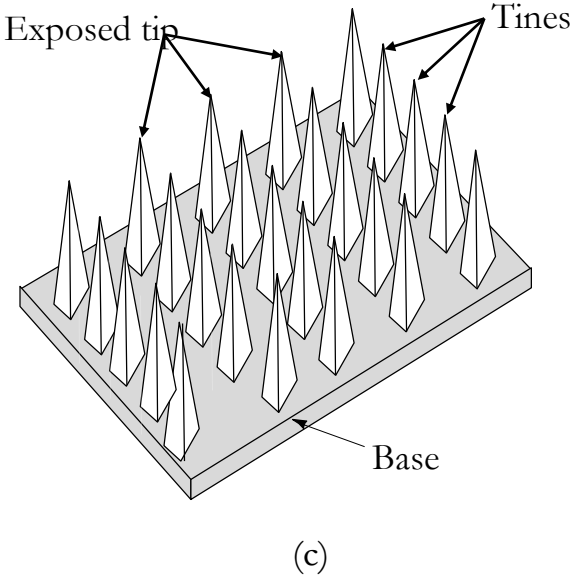



Electrodes for detecting fetal electrocardiogram during labor, by means of intracutaneous needles (a) Suction electrode. (b) Cross-sectional view of suction electrode in place, showing penetration of probe through epidermis. (c) Helical electrode, which is attached to fetal skin by corkscrew type action.

# Electrode Arrays




Examples of microfabricated electrode arrays.
(a) One-dimensional plunge electrode array,
(b) Two-dimensional array, and
(c) Three-dimensional array

# Microelectrodes

Measure potential difference across cell membrane

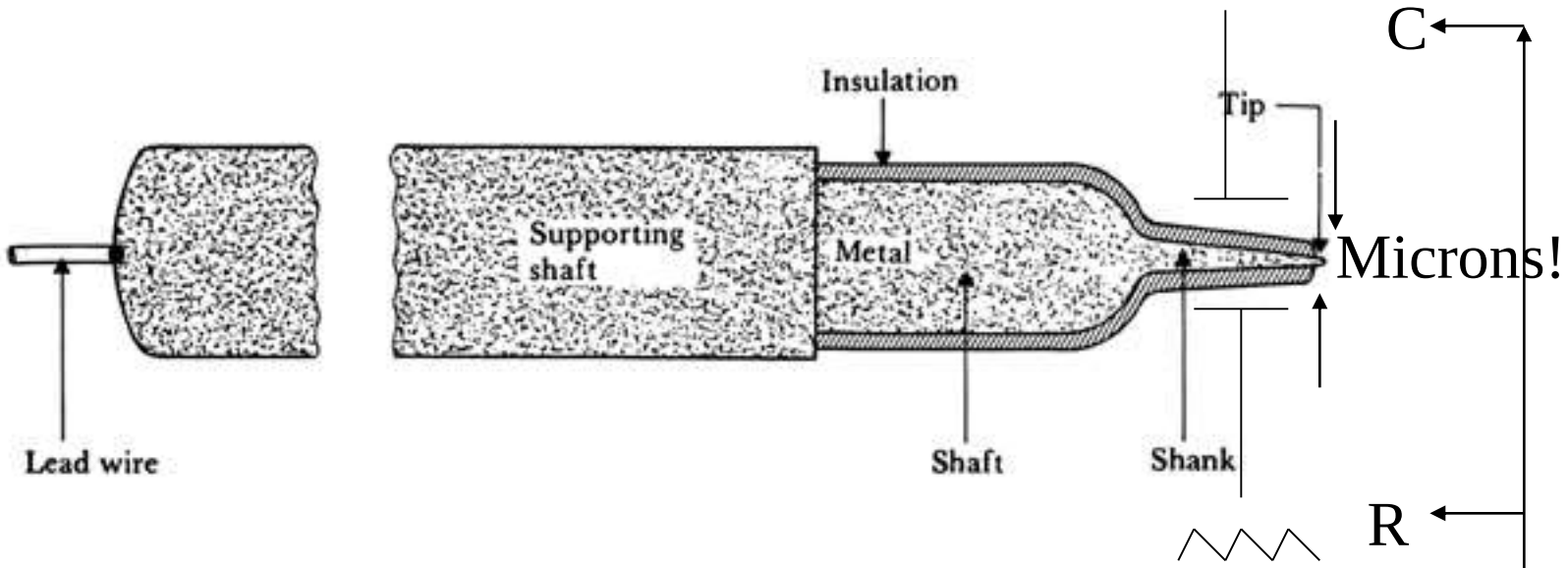
**Requirements**

- Small enough to be placed into cell
- Strong enough to penetrate cell membrane
- Typical tip diameter: 0.05 – 10 microns

**Types**

- Solid metal -> Tungsten microelectrodes
- Supported metal (metal contained within/outside glass needle)
- Glass micropipette -> with Ag-AgCl electrode metal

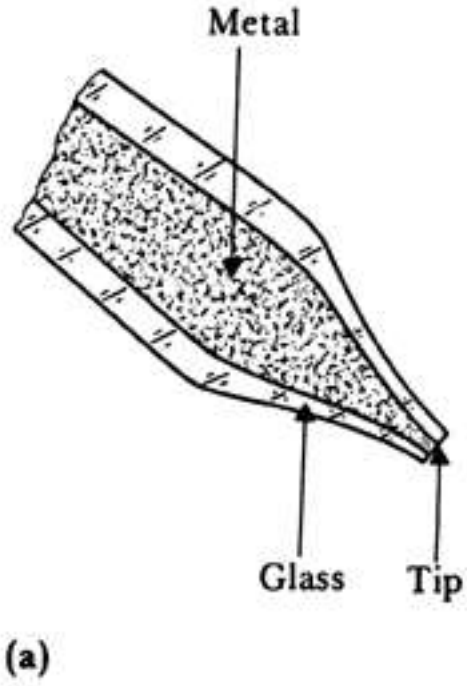
# Metal Microelectrodes

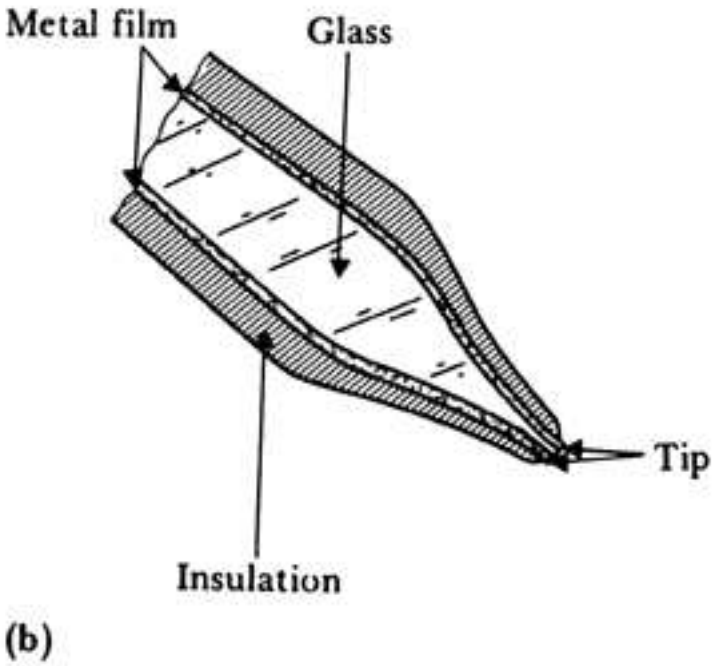



Extracellular recording – typically in brain where you are interested in recording the firing of neurons (spikes).

Use metal electrode+insulation -> goes to high impedance amplifier…negative capacitance amplifier!

# Metal Supported Microelectrodes

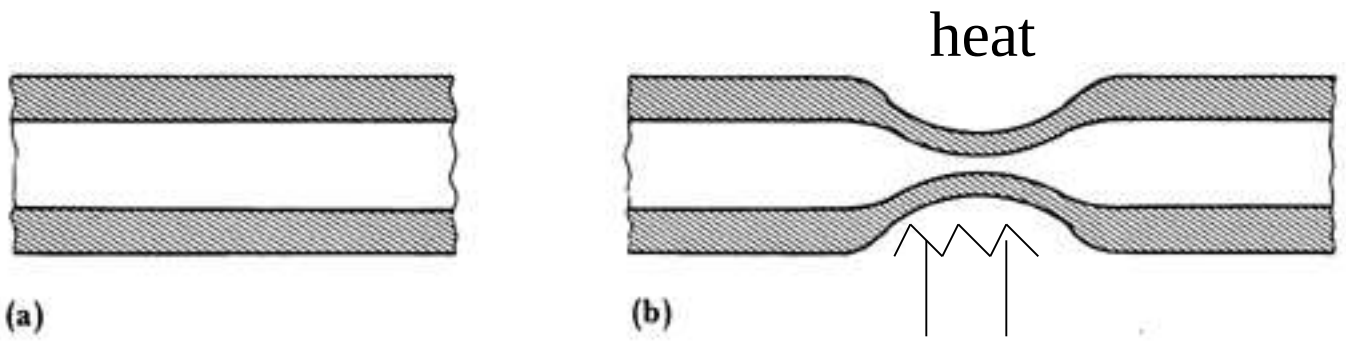


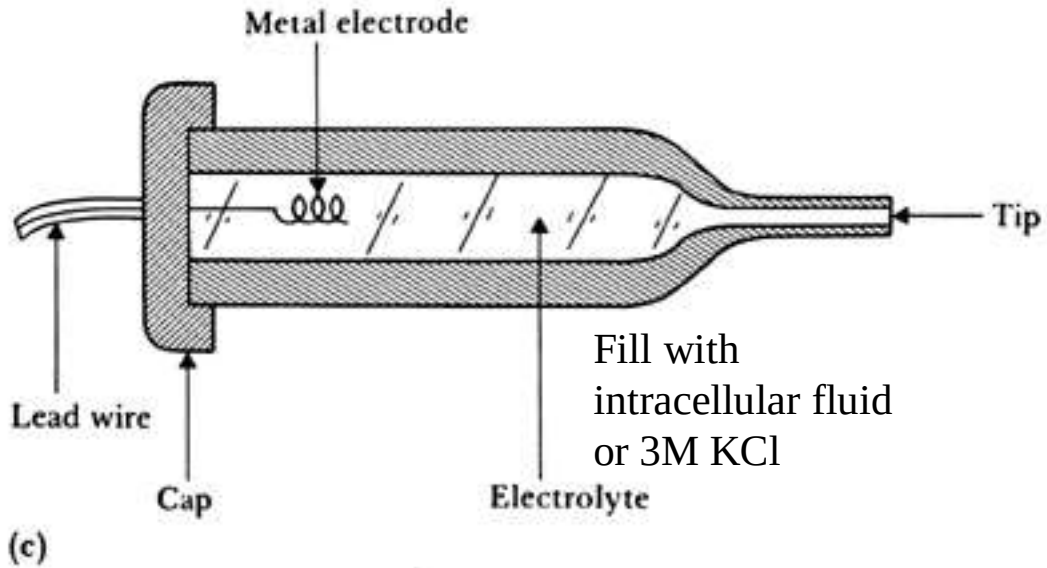




(a) Metal inside glass

(b) Glass inside metal

# Glass Micropipette



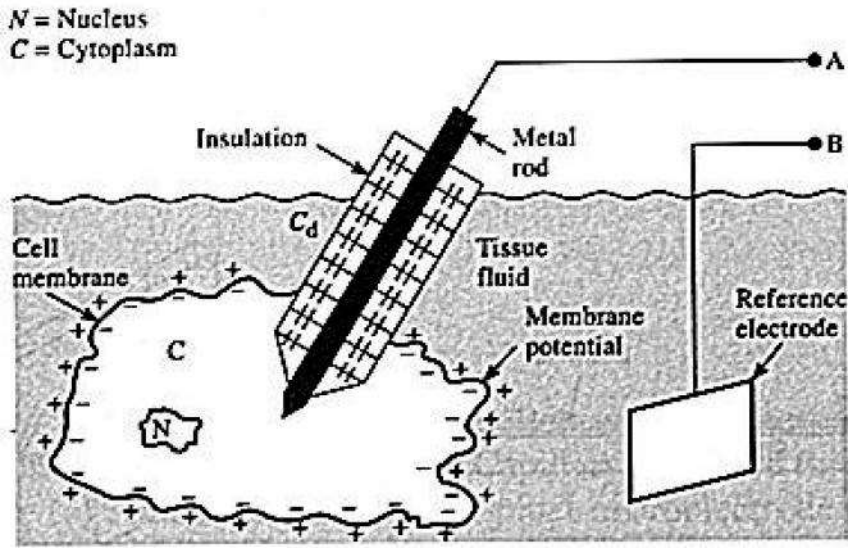

A glass micropipet electrode filled with an electrolytic solution
(a) Section of fine-bore glass capillary.
(b) Capillary narrowed through heating and stretching.
(c) Final structure of glass-pipet microelectrode.

Intracellular recording – typically for recording from cells, such as cardiac myocyte

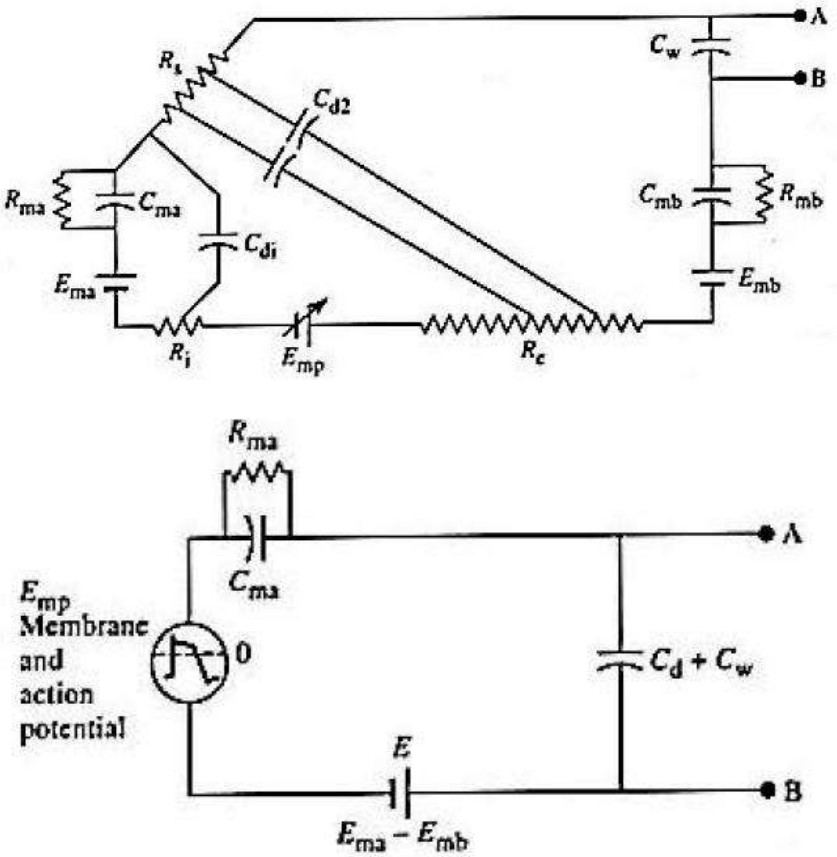
Need high impedance amplifier…negative capacitance amplifier

# Electrical Properties of Microelectrodes

## Metal Microelectrode




Metal microelectrode with tip placed within cell

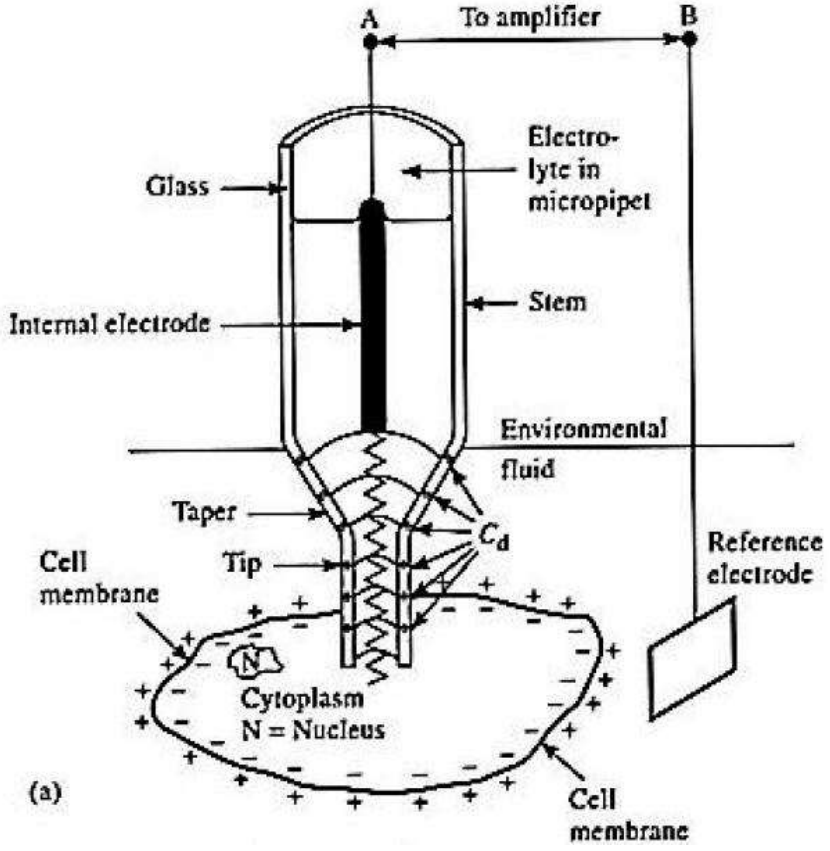


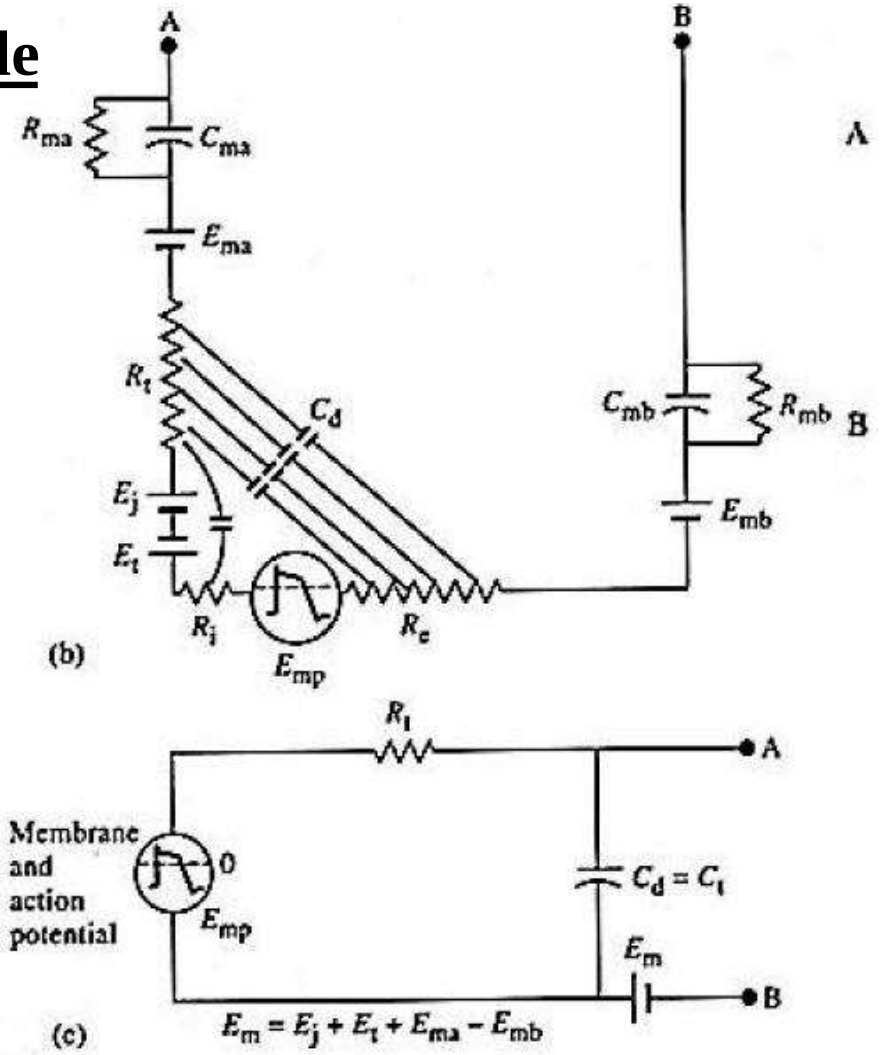

Equivalent circuits

Use metal electrode+insulation -> goes to high impedance amplifier…negative capacitance amplifier!

# Electrical Properties of Glass Intracellular Microelectrodes

## Glass Micropipette Microelectrode



# BIOPOTENTIAL AMPLIFIERS

# Biopotential Amplifiers

- Biopotential amplifier is a term given to amplifiers used to process biopotential signals (e.g., ECG, EMG, EEG, EOG, … etc.).
- The designation applies to a large number of different types of amplifiers (i.e., instrumentation amplifier, isolation amplifier, etc.).
- The basic function of biopotential amplifier is to increase the amplitude of a weak electric signal of biological origin.
- Biopotential amplifiers typically process voltages, but in some cases they also process currents.
- The frequency response of typical bioelectric amplifiers may be from dc (or near dc, i.e., 0.05 Hz) up to 100 kHz.

# Biopotential Amplifiers

- Some biopotential amplifiers are ac-coupled, while some are dc-coupled.
- The dc-coupling is required where input signals are clearly dc or changes very slowly.
- At frequencies as low as 0.05Hz, the ac-coupling should be used instead of dc-coupling.
- This is to overcome the electrode offset potential.
- Also, the skin-electrode interface generates dc offsets.
- The gain of biopotential amplifiers can be low, medium or high (x10, x100, x1000, x10000).

# Biopotential Amplifiers

## Low Gain Biopotential Amplifiers

i. Gain factors x1 and x10.

ii. The unity-gain amplifier is mainly for isolation, buffering and possibly impedance transformation between signal source and readout device.

iii. Used for measurement of action potentials and other relatively high-amplitude bioelectric events.

# Biopotential Amplifiers

## Medium Gain Biopotential Amplifiers

i. Gain factors x100 and x1000.

ii. Used for recording of ECG, EMG, etc.

# Biopotential Amplifiers

## High Gain Biopotential Amplifiers

i. Gain factors over x1000.

ii. Used in very sensitive measurement such as EEG.

# Typical Biopotential Amplifier Requirements

The basic requirements that a biopotential amplifier has to satisfy are:

1. Biopotential amplifiers should have high input impedance i.e., greater than 10 MΩ.

2. Safety: the amplifier should protect the organism being studied.
   Careful design to prevent macro and micro shocks.
   Isolation and protection circuitry to limit the current through the electrode to safe level.

3. Output impedance of the amplifier should be low to drive any external load with minimal distortion.

4. Gain of the amplifier is greater than x1000 as biopotentials are typically less than a millivolt.

# Typical Biopotential Amplifier Requirements

6. Most biopotential amplifiers are differential amplifier as signals are recorded using a bipolar electrodes which are symmetrically located.

7. High common mode rejection ratio (CMMR): biopotentials ride on a large offset signals or noise.

8. Rapid calibration of the amplifier in laboratory conditions.

9. Adjustable gains:

- Often the change in scale is automatic.
- Therefore calibration of the equipment is very important.

# Typical Biopotential Amplifier Requirements

10. The physiological process to be monitored should not be influenced in any way by the amplifier.

11. The measured signal should not be distorted.

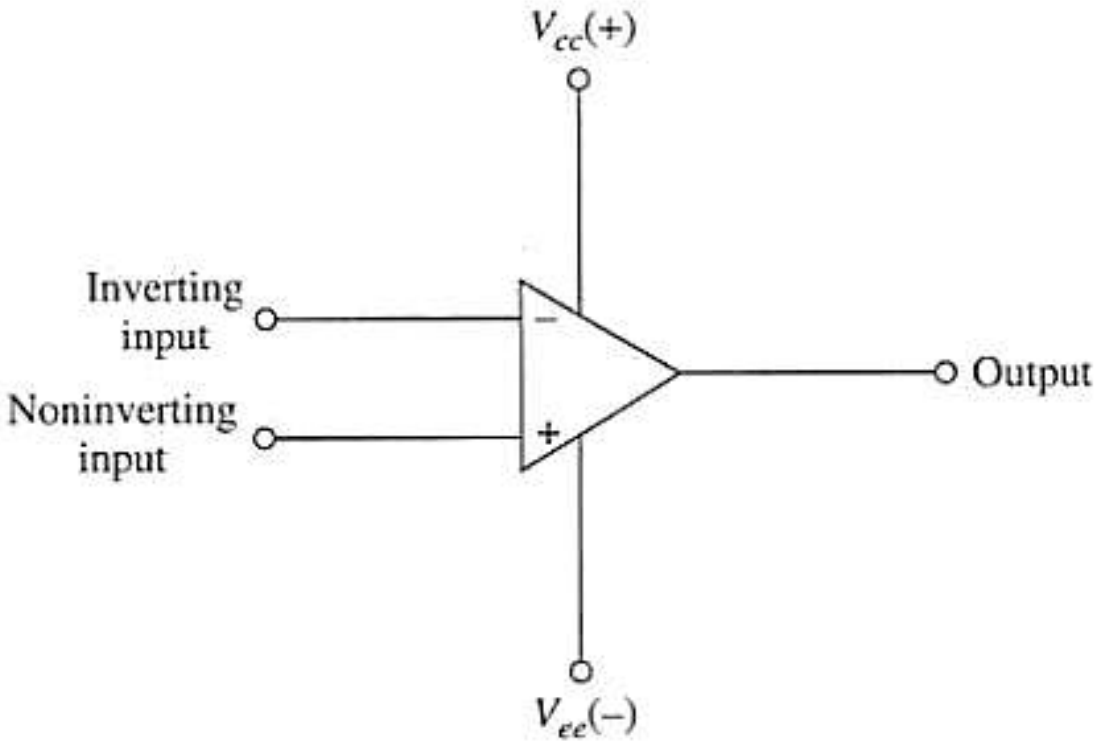
12. The amplifier should provide the best possible separation of signal and interferences.

13. The amplifier has to offer protection of the patient from any hazard of electrical shock.

14. The amplifier itself has to be protected against damages that might result from high input voltages as they occur during the application of defibrillators or electrosurgical instrumentation.

# Operational Amplifiers

**Operational Amplifier Circuit Symbol**



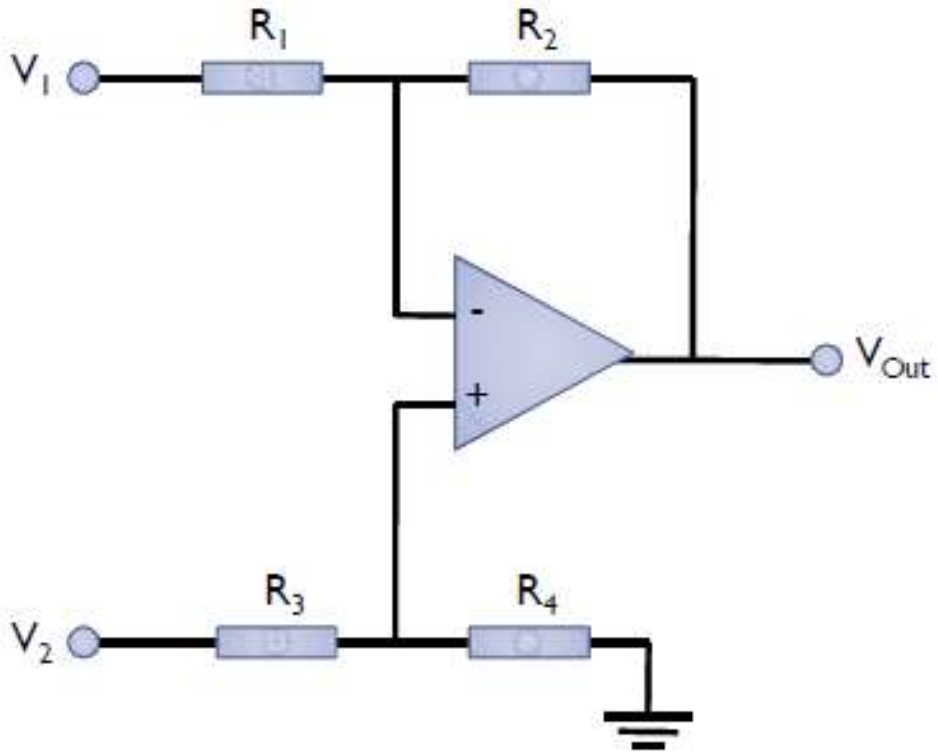
# Operational Amplifiers

## The properties of Ideal Operational Amplifiers

1. Infinite open-loop voltage gain ($A_{vol} = \infty$)
2. Zero output impedance ($Z_o = 0$)
3. Infinite input impedance ($Z_i = \infty$)
4. Infinite frequency response
5. Zero noise contribution

# Differential Amplifier

- A differential amplifier produces an output voltage that is proportional to the difference between the voltage applied to the two input terminals.



# Differential Amplifier

- The voltage gain for the differential signals is the same as for the inverting followers, provided the ratio equality of R2/R1 = R4/R3 is maintained.

- Differential amplifiers are useful because it rejects common voltages while amplifying the differential signal of interest.

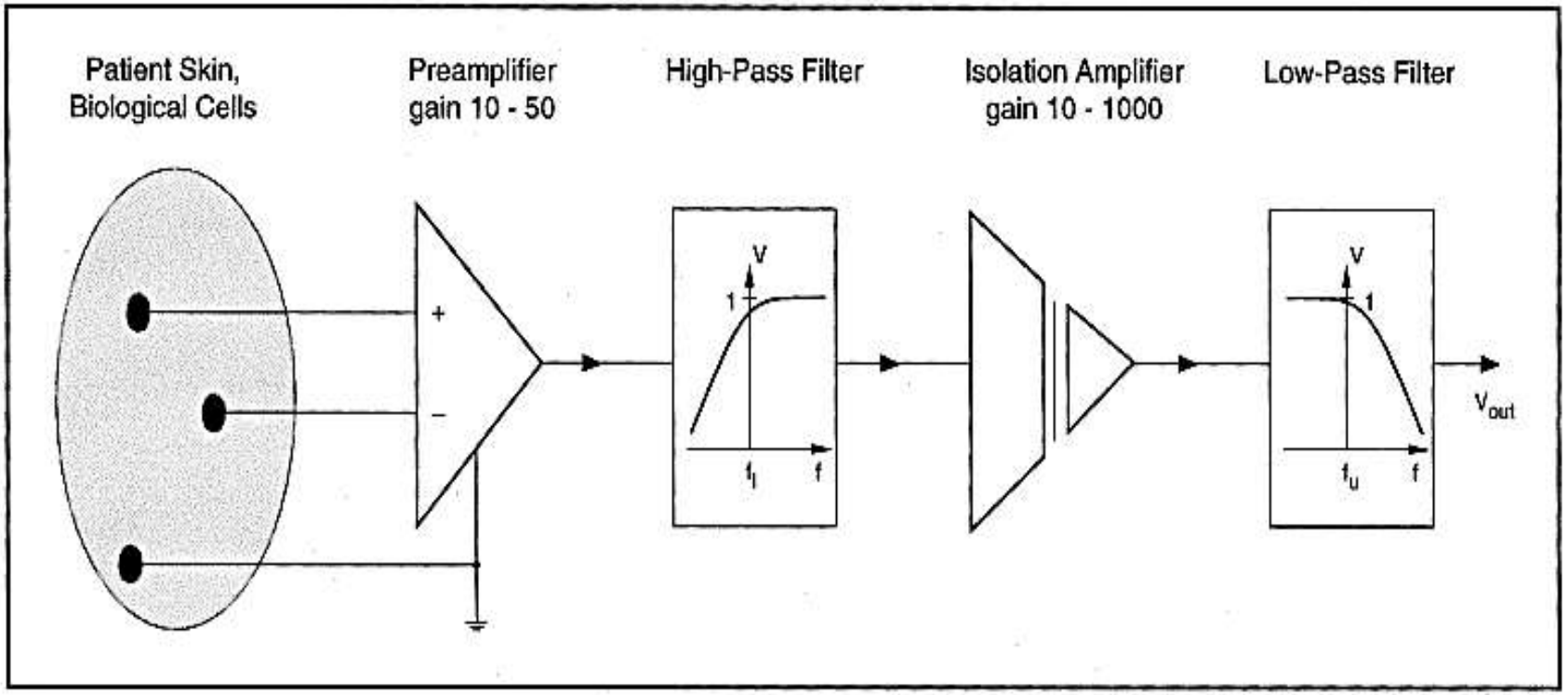
Example:

- Suppose equal 50 Hz supply noise is present on each input of the differential amplifier, and one input is at 5 Vdc while the other is at 1 Vdc.

- The circuit removes the noise and amplifies the 4 Vdc differential signal.

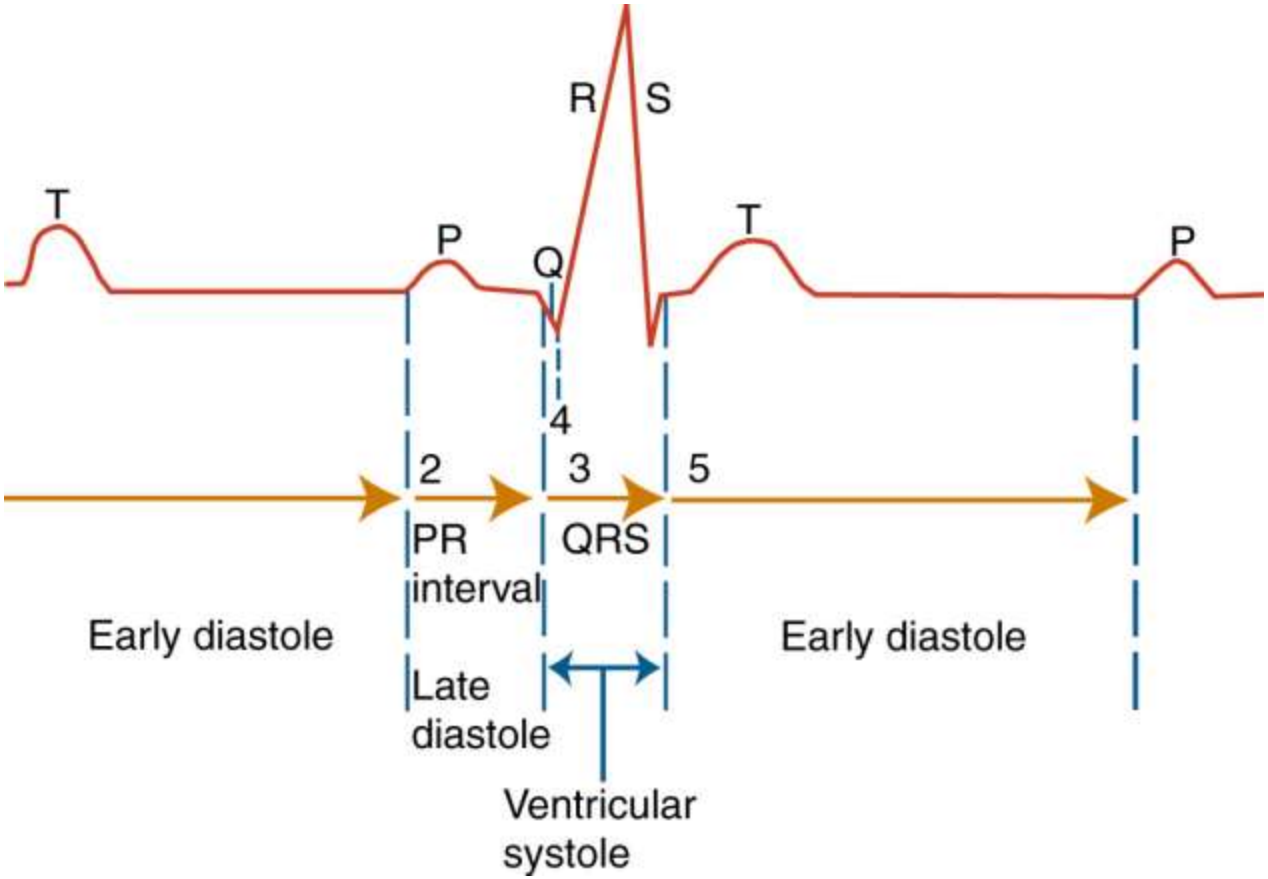
# Main Stages of a Biopotential Amplifier

- Three electrodes connect the patient to a preamplifier stage.
- After removing dc and low-frequency interferences, the signal is connected to an output low-pass filter through an isolation stage which provides electrical safety to the patient, prevents ground loops, and reduces the influence of interference signals.



# Electrocardiography

# ECG Waveform



# Definition of ECG

- The ECG is a graphic representation of the electrical impulses that the heart generates during the cardiac cycle.
- These electrical impulses are conducted to the body's surface, where they are detected by electrodes placed on the patient's limbs and chest.
- The monitoring electrodes detect the electrical activity of the heart from a variety of spatial perspectives.
- The ECG lead system is composed of several electrodes that are placed on each of the four extremities and at varying sites on the chest. Each combination of electrodes is called a *lead*.

# *12-lead ECG*

- It provides a comprehensive view of the flow of the heart's electrical currents in two different planes.
- There are six limb leads (combination of electrodes on the extremities) and six chest leads (corresponding to six sites on the chest).
- standard *limb* leads
- Leads I: records the difference in electrical potential between the left arm (LA) and the right arm (RA).
- Lead II: records the electrical potential between the RA and the left leg (LL).
- Lead III reflects the difference between the LA and the LL. The right leg (RL) electrode is an inactive ground in all leads.

# *Augmented* limb leads

- aVR
- aVL
- aVF
- The augmented leads measure the electrode potential between the center of the heart and the right arm (aVR), the left arm (aVL), and the left leg (aVF).

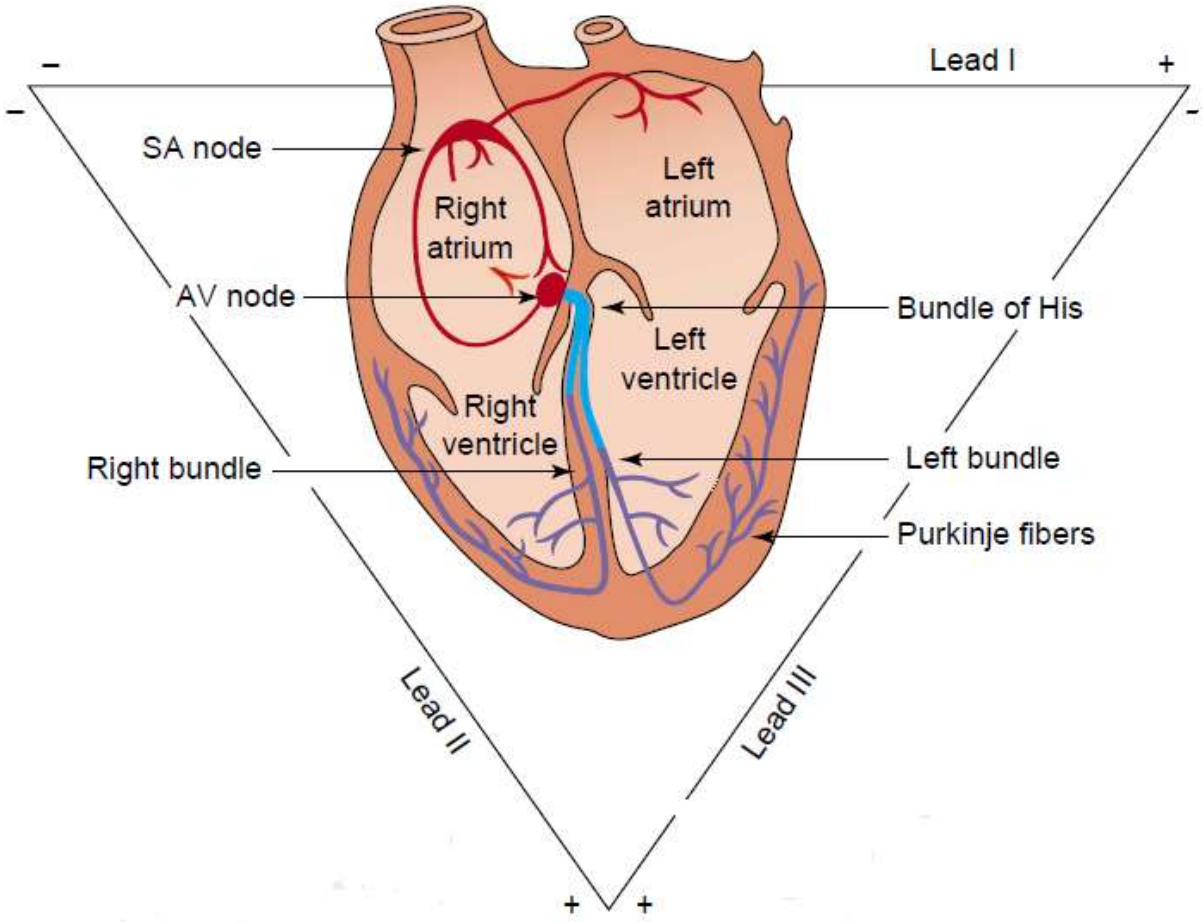
# Limb leads

1. Rt arm (avr) Red color.
2. Lt arm (avl) Yellow color.
3. Lt leg (avf) Green color.
4. Rt leg, black color.

# Chest, or precordial leads

- The six standard, (V1, V2, V3, V4, V5, V6) are placed at six different positions on the chest, surrounding the heart.
- In general, it is said that leads II, III and aVF look at the inferior part of the heart, leads aVL and I look at the lateral part of the heart, and leads V2-V4 look at the anterior part of the heart.

# Einthoven Triangle



# ECG waves

- ***P wave:*** This represents atrial electrical depolarization associated with atrial contraction. It represents electrical activity associated with the spread of the original impulse from the sinoatrial (SA) node through the atria.
- ***PR interval:*** This represents the time required for the impulse to travel from the SA node to the atrioventricular (AV) node.

  If prolonged PR interval: a conduction delay exists in the AV node (e.g., a first-degree heart block).

  If the PR interval is shortened: the impulse must have reached the ventricle through a "shortcut" (as in Wolff-Parkinson-White syndrome).

# ECG waves

- ***QRS complex***. This represents ventricular electrical depolarization associated with ventricular contraction. This consists of:

➢ initial downward (negative) deflection (Q wave)

➢ a large upward (positive) deflection (R wave)

➢ a small downward deflection (S wave).

A widened QRS complex: indicates abnormal or prolonged ventricular depolarization time (as in a bundle-branch block).

# ECG waves

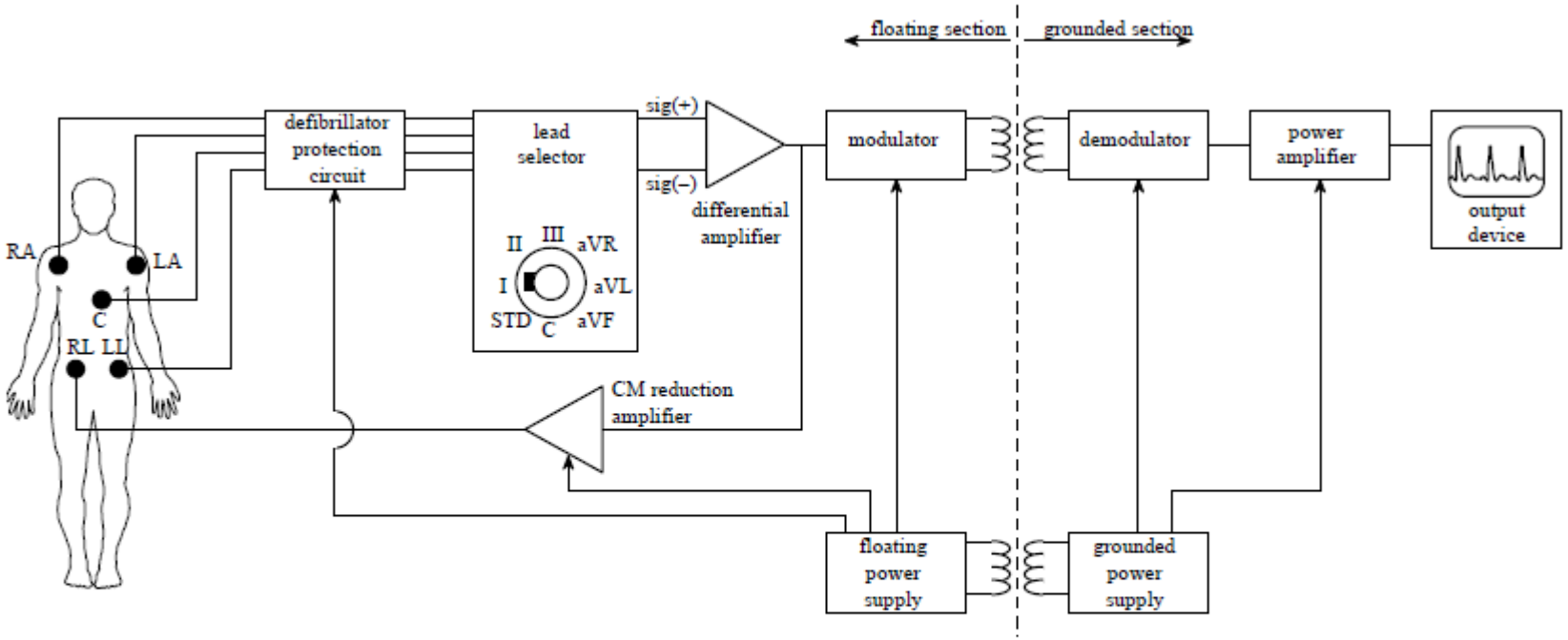
- ***ST segment***. This represents the period between the completion of depolarization and the beginning of repolarization of the ventricular muscle.

  This segment may be elevated or depressed in transient muscle ischemia (e.g., angina) or in muscle injury (as in the early stages of myocardial infarction).

- ***T wave:*** This represents ventricular repolarization (i.e., return to neutral electrical activity).

- ***U wave:*** This deflection follows the T wave and is usually quite small. It represents repolarization of the Purkinje nerve fibers within the ventricles

# Simplified Block Diagram (ECG)



# ECG Graph Paper

- Runs at a paper speed of 25 mm/sec
- Each small block of ECG paper is 1 mm2
- At a paper speed of 25 mm/s, one small block equals 0.04 s
- Five small blocks make up 1 large block which translates into 0.20 s (200 msec)
- Hence, there are 5 large blocks per second
- Voltage: 1 mm = 0.1 mV between each individual block vertically

# ELECTROENCEPHALOGRAPHY

# Electroencephalography

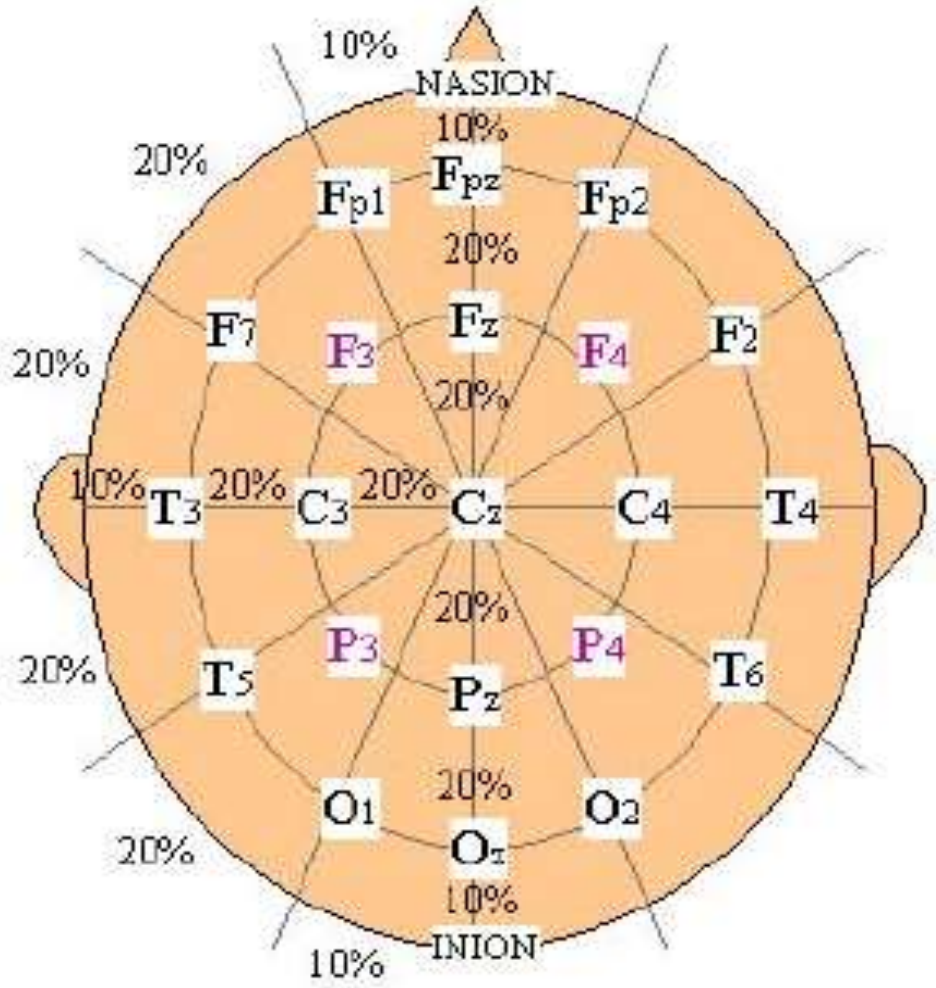
- **Electroencephalography** (**EEG**) is the recording of electrical activity along the scalp.
- EEG refers to the recording of the brain's spontaneous electrical activity over a short period of time, usually 20–40 minutes, as recorded from multiple electrodes placed on the scalp.

# Scalp Electrodes

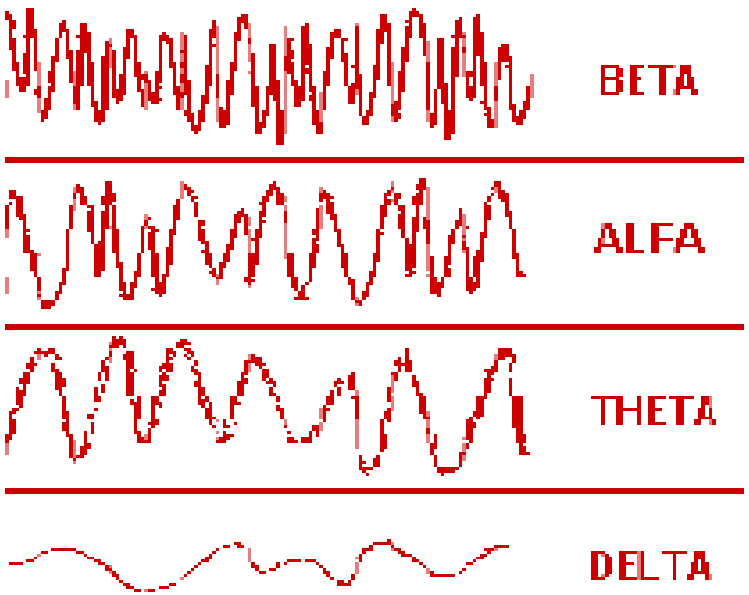
# 10-20 system (EEG)

- The "10" and "20" refer to the fact that the actual distances between adjacent electrodes are either 10% or 20% of the total front–back or right–left distance of the skull.
- Each site has a letter to identify the lobe and a number to identify the hemisphere location. The letters F, T, C, P and O stand for frontal, temporal, central, parietal, and occipital lobes, respectively

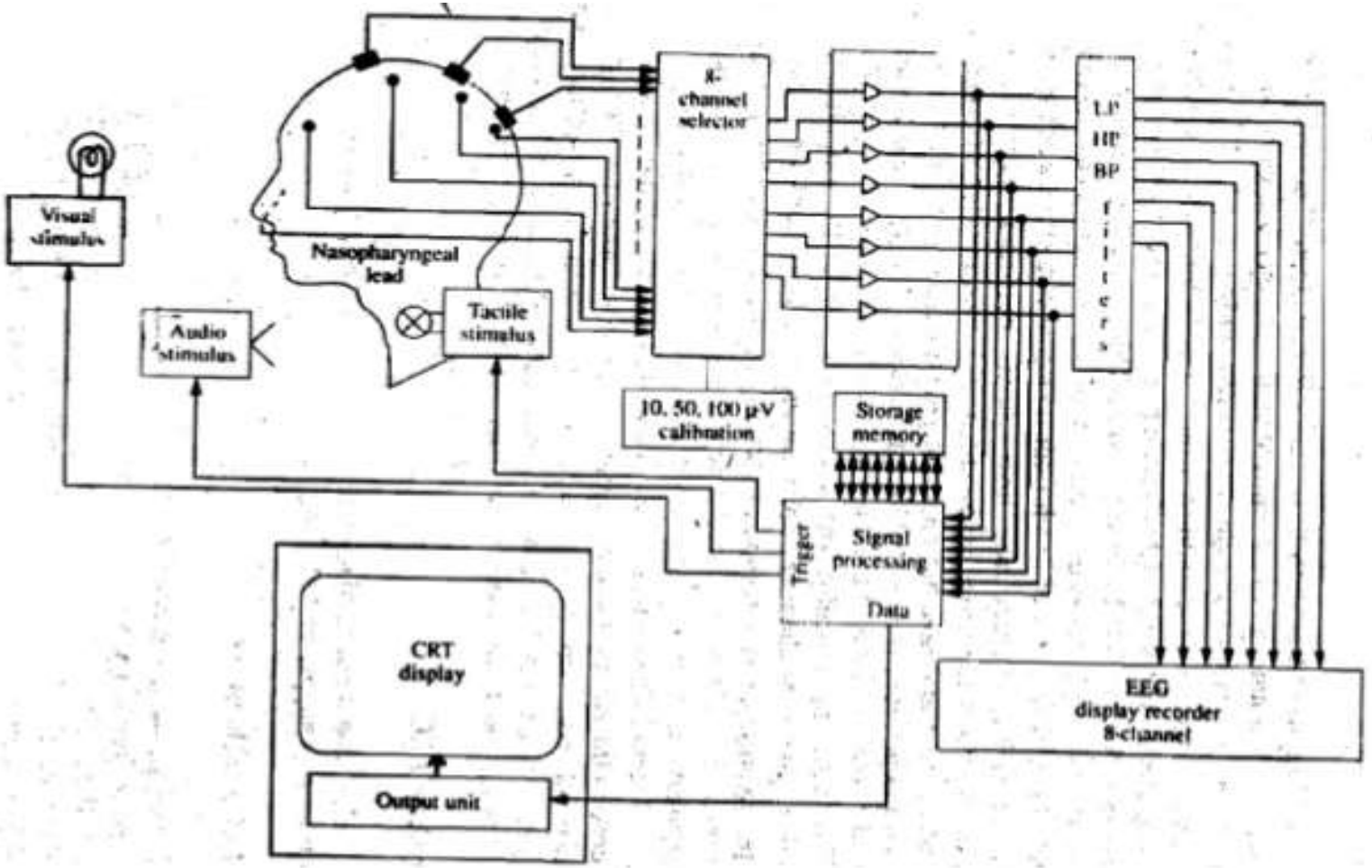
# 10-20 system (EEG)



# EEG Waves



# EEG Recording Setup



# EEG Recording Setup

- Electrodes attached to different parts of the skull of a patient.
- **8 channel EEG recorder**:-
  - Patient cable consists of 21 electrodes
  - Electrodes connected to selector in groups of 8- **Montage of electrodes**
  - Right ear electrode → reference electrode→ right brain electrodes
  - Left ear electrode → reference electrode→ left brain electrodes

# EEG Recording Setup

- Interference problem is reduced by differential amplifier(preamplifiers)
- Filter bank:- consists of appropriate filters to select different types of brain waves.
- Output can be given to 8-channel pen recorder, display unit, computer storage memory for further processing.
- Evoked Potential:- Measure of the “disturbance” in the EEG pattern that results from external stimuli.
- Time delay between stimulus and response can be measured in signal processing unit.

# Artifacts

- Three sources
  - 60-cycle noise
  - Muscle artifact
  - Eye Movements

# Dealing with artifacts

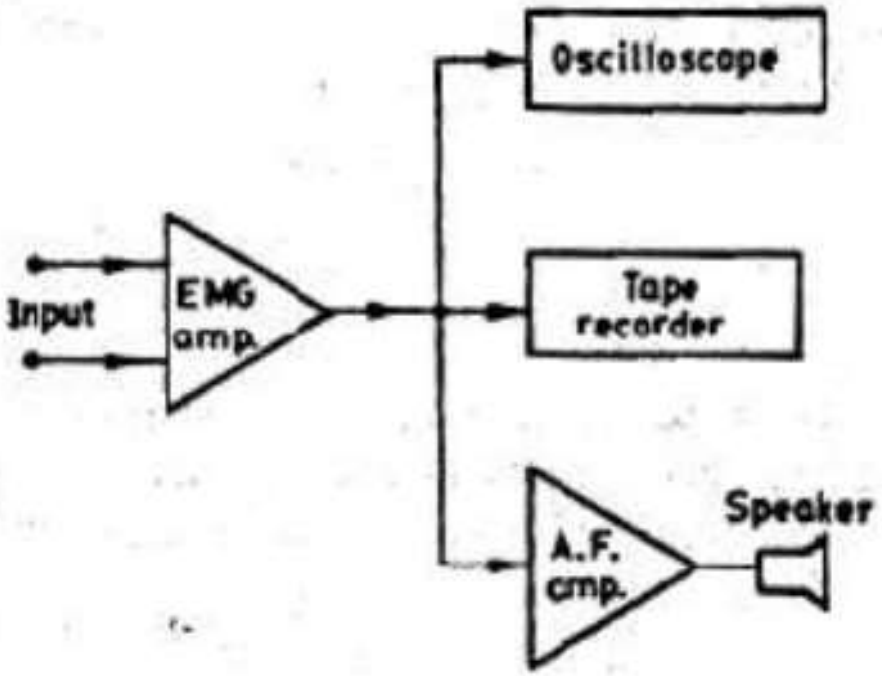
- 60-cycle noise
  - Ground subject
  - 60 Hz Notch filter
- Muscle artifact
  - No gum!
  - Use headrest
  - Measure EMG and reject/correct for influence
  - Statistically control for EMG
  - Hand score
- Eye movements
  - Eyes are dipoles
  - Reject ocular deflections including blinks
  - Computer algorithms for EOG correction

# ELECTROMYOGRAPHY

# Electromyography

- **Electromyography** (**EMG**) is a technique for evaluating and recording the electrical activity produced by skeletal muscles.
- EMG is performed using an instrument called an**electromyograph**, to produce a record called an **electromyogram**.

# EMG Recording Setup



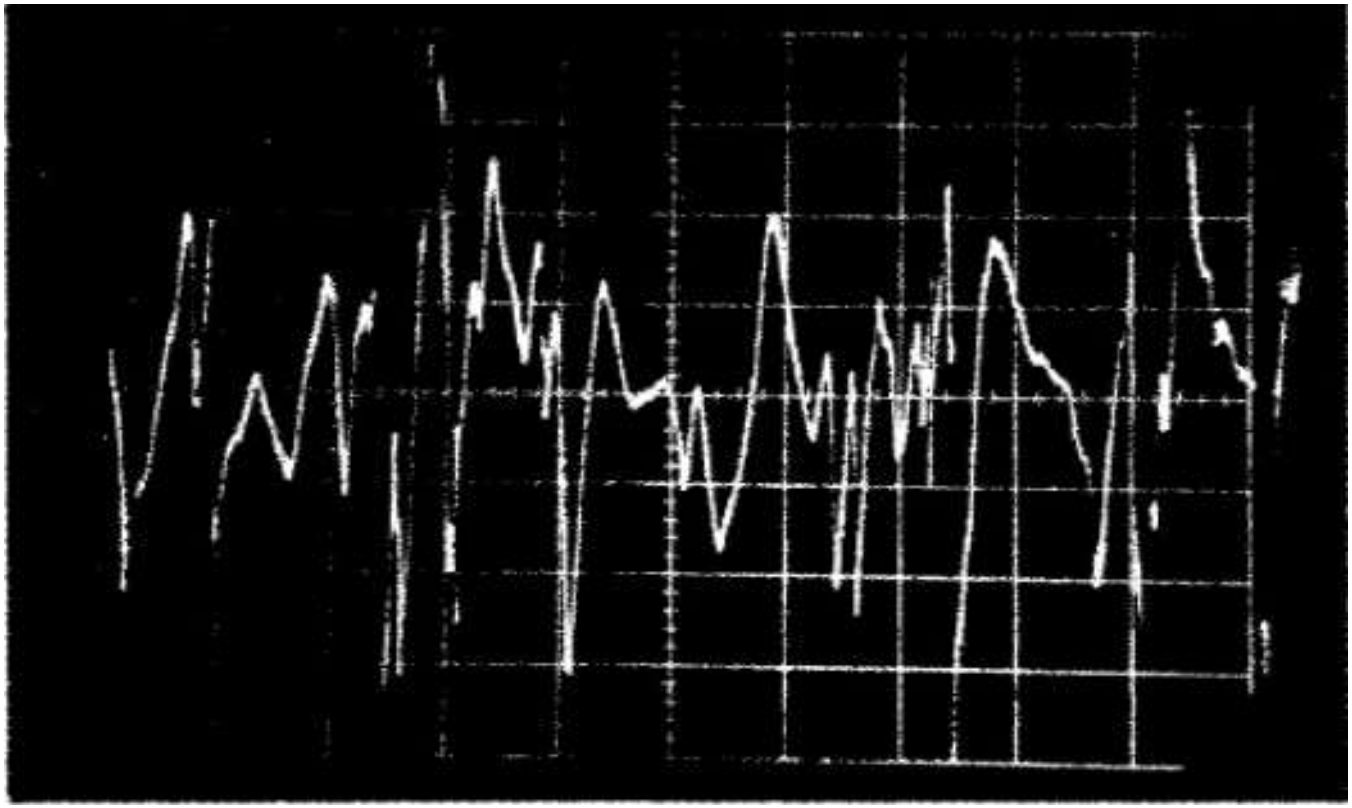
# EMG Recording Setup

- potentials measured by placing surface electrodes on the skin.
- Individual cell potential measured by means of needle electrode
- EMG appears like random noise waveform.
- Contraction of muscle fibers produce action potentials

# EMG Recording Setup

- Amplitude of EMG signals depends
  - Type & placement
  - Degree of muscular exertions
- Normal frequency of EMG signals is 60 Hz
- EMG signal amplitude ranges from 0.1 to 0.5 mV.
- Amplifier with high CMRR and input impedance
- Output can be given to oscilloscope, tape recorder or AF amplifier.

# EMG Waveform



# PHONOCARDIOGRAPHY

# Phonocardiography

- A **Phonocardiogram** or **PCG** is a plot of high fidelity recording of the sounds and murmurs made by the heart with the help of the machine called phonocardiograph
- Recording of the sounds made by the heart during a cardiac cycle
- The sounds are thought to result from vibrations created by closure of the heart valves

# Phonocardiography

- There are at least two: the first when the atrioventricular valves close at the beginning of systole and the second when the aortic valve closes at the end of systole.
- It allows the detection of sub-audible sounds and murmurs, and makes a permanent record of these events.
- In contrast, the ordinary stethoscope cannot detect such sounds or murmurs, and provides no record of their occurrence.

# Phonocardiography

- The ability to quantitative the sounds made by the heart provides information not readily available from more sophisticated tests, and provides vital information about the effects of certain cardiac drugs upon the heart.
- It is also an effective method for tracking the progress of the patient's disease.

# ELECTRO-OCULOGRAPHY

# DEFINITION

- The clinical electro-oculogram is an electrophysiological test of function of the outer retina and retinal pigment epithelium in which the change in the electrical potential between the cornea and the fundus is recorded during successive periods of dark and light adaptation.

# HISTORY

- Emil du Bois-Reymond (1848) observed that the cornea of the eye is electrically positive relative to the back of the eye.

- Elwin Marg named the electrooculogram in 1951 and Geoffrey Arden (Arden et al. 1962) developed the first clinical application

- The eye has a standing electrical potential between front and back, sometimes called the corneo-fundal potential. The potential is mainly derived from the retinal pigment epithelium (RPE), and it changes in response to retinal illumination

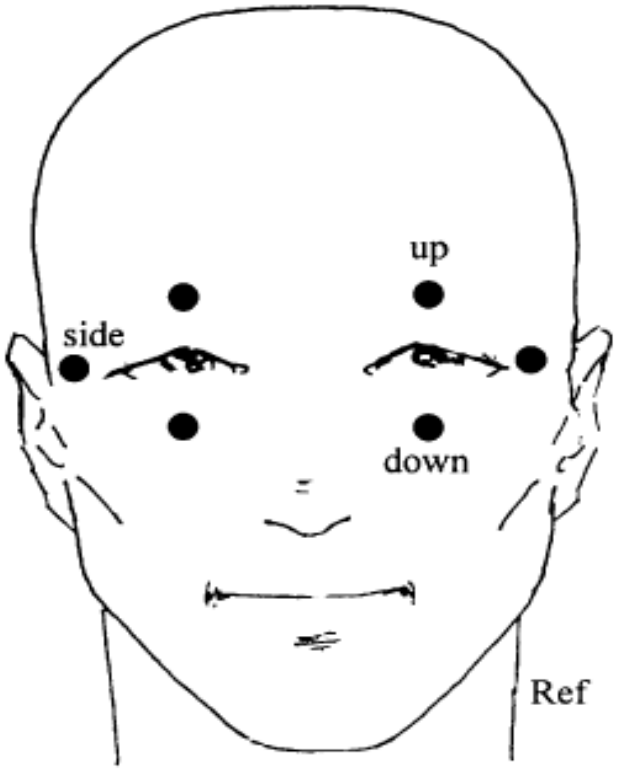
- The potential decreases for 8–10 min in darkness. Subsequent retinal illumination causes an initial fall in the standing potential over 60–75 s (the fast oscillation (FO)), followed by a slow rise for 7–14 min (the light response). These phenomena arise from ion permeability changes across the basal RPE membrane.

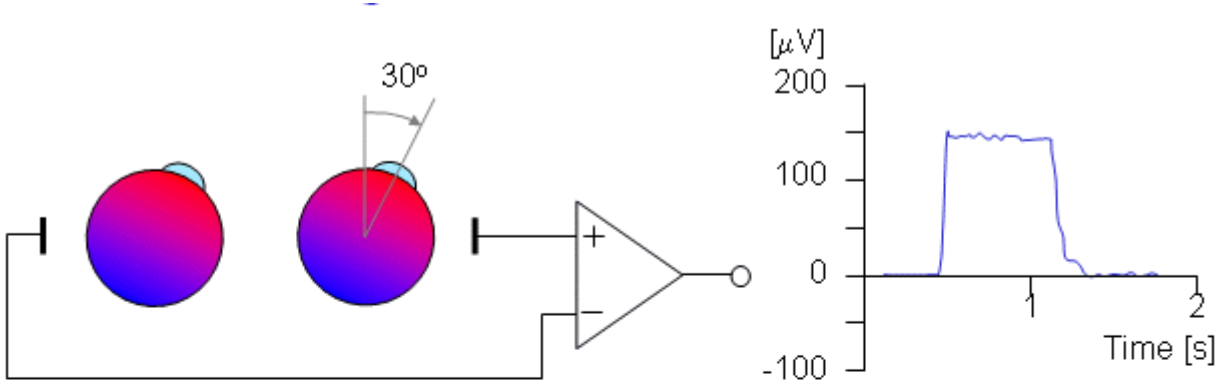
- The clinical electro-oculogram (EOG) makes an indirect measurement of the minimum amplitude of the standing potential in the dark and then again at its peak after the light rise. This is usually expressed as a ratio of ‘light peak to dark trough’ and referred to as the Arden ratio.

# Measurement of the clinical EOG

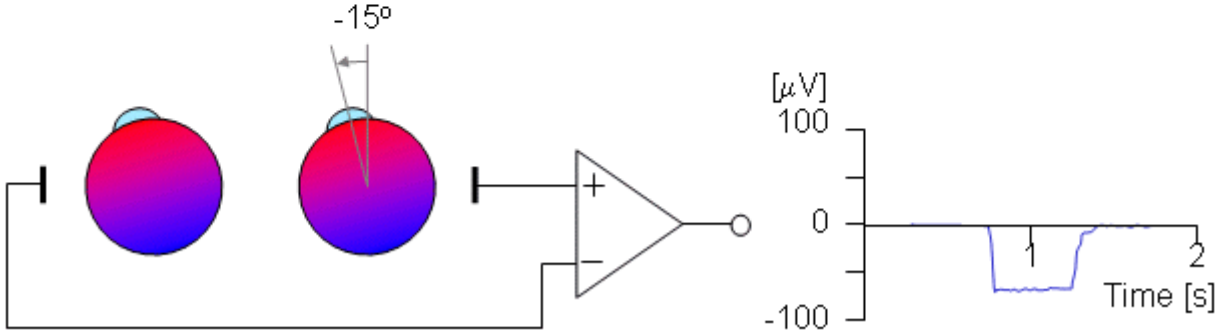
- The calibration of the signal may be achieved by having the patient look consecutively at two different fixation points located a known angle apart and recording the concomitant EOGs .
- By attaching skin electrodes on both sides of an eye the potential can be measured by having the subject move his or her eyes horizontally a set distance .
- Typical signal magnitudes range from 5-20 μV/°.

# Electrode Placement






Eyes moving 30º to the right




Eyes moving 15º to the left

- A ground electrode is attached usually to either the forehead or earlobe.
- Either inside a Ganzfeld, or on a screen in front of the patient, small red fixation lights are place 30 degrees apart .
- The distance the lights are separated is not critical for routine testing.

- The patient should be light adapted such as in an well-illuminated room, and their eyes dilated

- The patient keeps his or her head still while moving the eyes back and forth alternating between the two red lights.

- The movement of the eyes produces a voltage swing of approximately 5 milli volts between the electrodes on each side of the eye, which is charted on graph paper or stored in the memory of a computer.

## EOG eye movement recordings

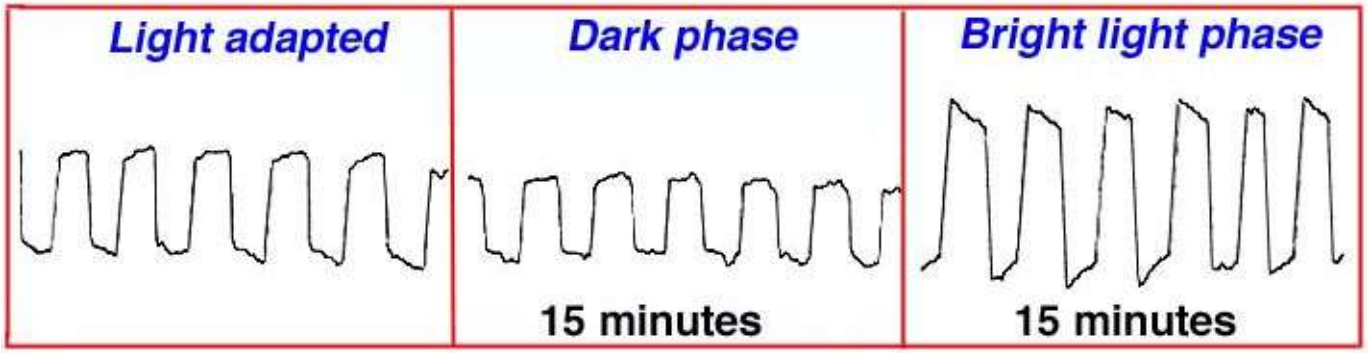



*Fig. 47. Light adapted pre-EOG, dark adaptation phase and light-rise phase.*

# The standard method

- After training the patient in the eye movements, the lights are turned off.
- About every minute a sample of eye movement is taken as the patient is asked to look back and forth between the two lights .
- After 15 minutes the lights are turned on and the patient is again asked about once a minute to move his or her eyes back and forth for about 10 seconds.

# EOG recording of a normal person

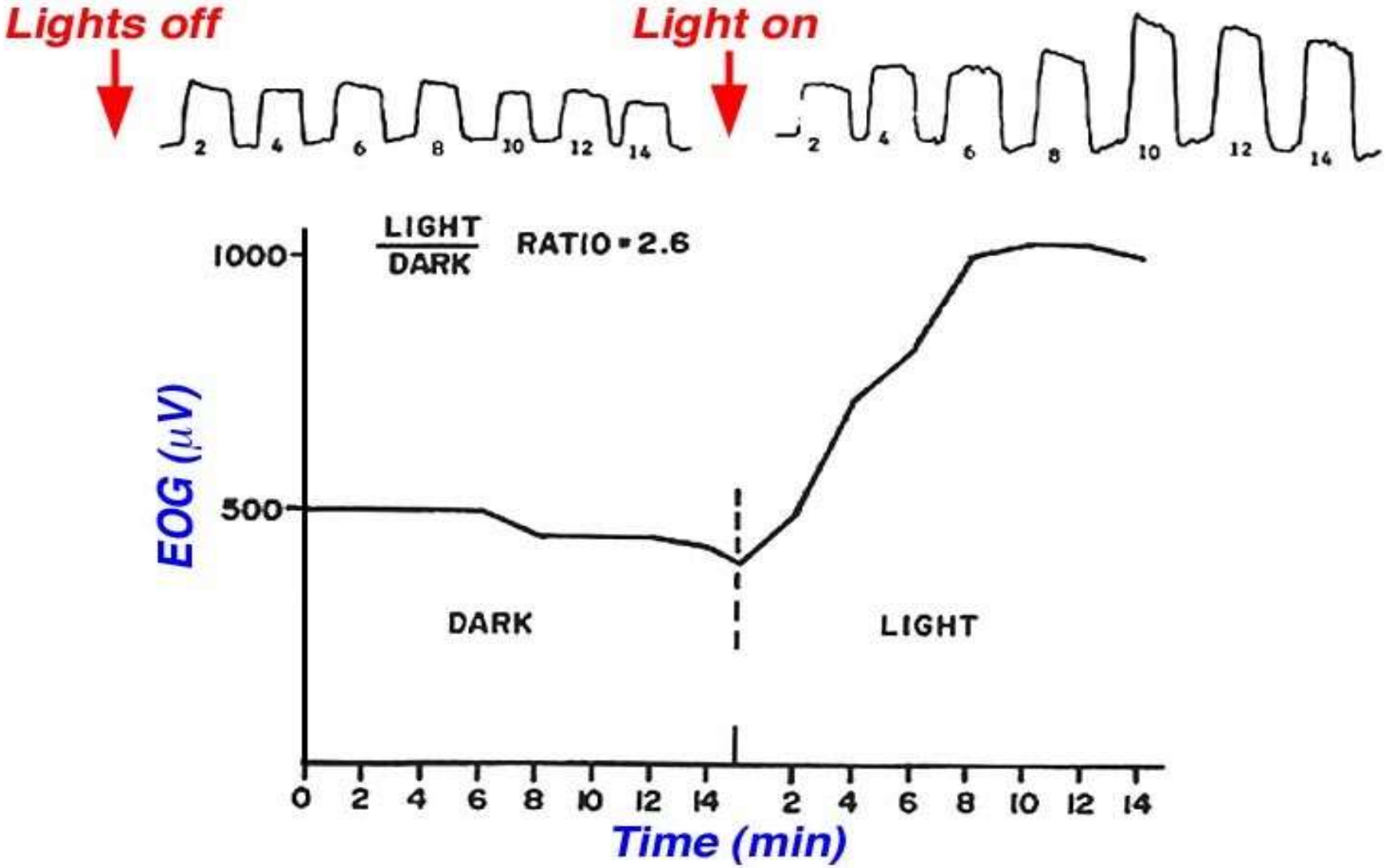



*Fig. 48. Normal EOG recording.*

# The standard method

- Typically the voltage becomes a little smaller in the dark reaching its lowest potential after about 8-12 minutes, the so-called “dark trough”.
- When the lights are turned on the potential rises, the light rise, reaching its peak in about 10 minutes.
- When the size of the "light peak" is compared to the "dark trough" the relative size should be about 2:1 or greater .
- A light/dark ratio of less than about 1.7 is considered abnormal.

# APPLICATIONS

- The light response is affected in:
  - diffuse disorders of the RPE and the photoreceptor layer of the retina including some characterized by rod dysfunction
  - chorio-retinal atrophic and inflammatory diseases

- In most of these there is correlation with the electroretinogram (ERG), except notably in the case of Best's vitelliform maculopathy, in which the clinical EOG is usually highly abnormal in the presence of a normal ERG

- May be an early indicator of Chloroquine toxicity

# Other diseases

- The curves of the EOG of the depressed patients have lower amplitude.
- The normalised mean EOG amplitudes obtained from a group of amblyopic eyes were significantly lower that the normalised mean amplitudes from the fellow eyes at all time points during the EOG recording
- ↓ed Amplitude of EOG seen with use of :

  Mannitol,Acetazolamide,Bicarbonate

# UNIT 2

# CHEMICAL ELECTRODES
# Arterial Blood Gases

## Equipment

**Blood Gas Analyzer**

- Electronic Circuitry
- Electrolyte Solution
- Electrodes

# Arterial Blood Gases

## Equipment

### Electronic circuitry

- Takes electrical current changes produced in the electrodes and provides a visual display

### Electrolyte Solution

- Helps to promote chemical reactions and electrical current

# Arterial Blood Gases

## Equipment

### Electrodes

- Utilized to measure values of ABG

**$pH$, $PCO_2$, $PO_2$**

**All other blood gas values are calculated**

# Arterial Blood Gases

## Equipment

### pH Electrode

- **Sanz Electrode**

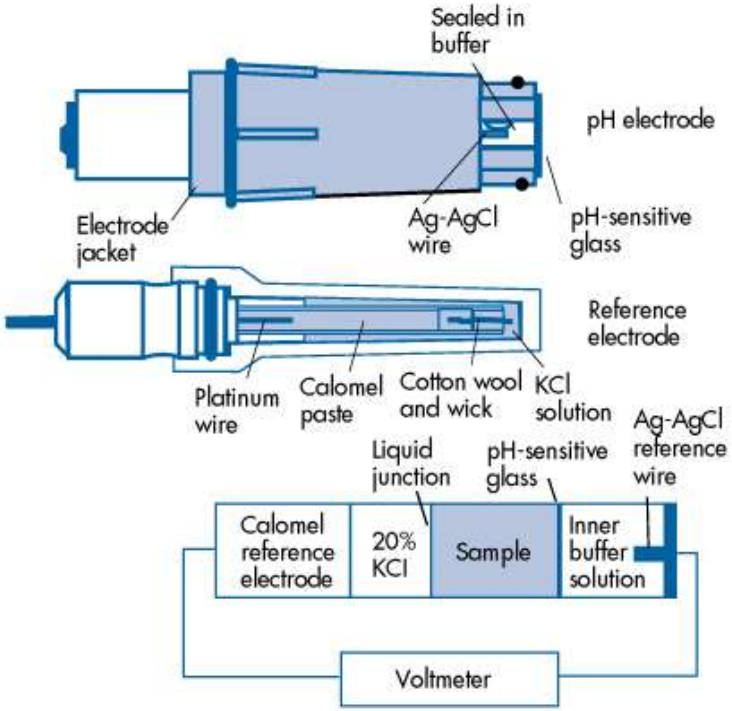
Consists of two electrodes:

- sampling/measuring electrode
- reference electrode and electrolyte solution

# Arterial Blood Gases

The pH electrode is a microelectrode, shown here with its plastic jacket. At the tip is a **silver-silver chloride** wire in a sealed-in buffer behind PH-sensitive quartz glass. The reference electrode contains a **platinum wire** in calomel paste that rests in a 20% **KCL solution**. The blood sample is introduced in such a way that it contacts the measuring electrode tip and the KCL. A voltmeter measure the potential difference across the sample, which is proportional to the pH

## Sanz Electrode (pH)



# Arterial Blood Gases

## Equipment

### $PCO_2$ Electrode

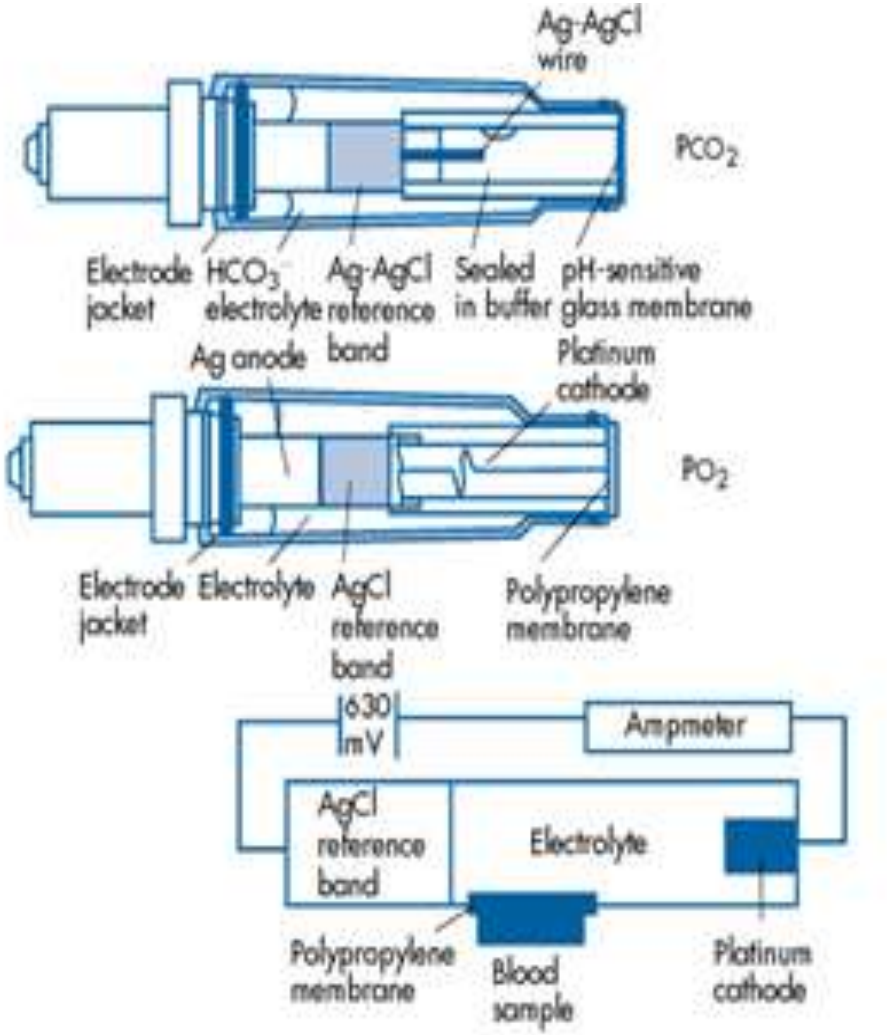
- **Severinghaus Electrode**

  - May also be referred to as a modified Sanz electrode

# Arterial Blood Gases

- The PCO2 electrode is a modified pH electrode.
- The electrode has a sealed-in buffer; an Ag-AgCl reference band is the other half-cell.
- The entire electrode is encased in **Lucite jacket** filled with bicarbonate electrolyte.
- The jacket is capped with a **Teflon membrane** that is permeable to CO2.
- **nylon mesh** covers the pH-sensitive glass, acting as a **spacer** to maintain contact with the electrolyte.
- CO2 diffuses through the Teflon membrane, combines with electrolyte, and alter the pH.
- The change in pH is displayed as partial pressure of CO2.

# Severinghaus Electrode (PCO2)



# Arterial Blood Gases

## Equipment

### PO2 Electrode

- **Clark Electrode**

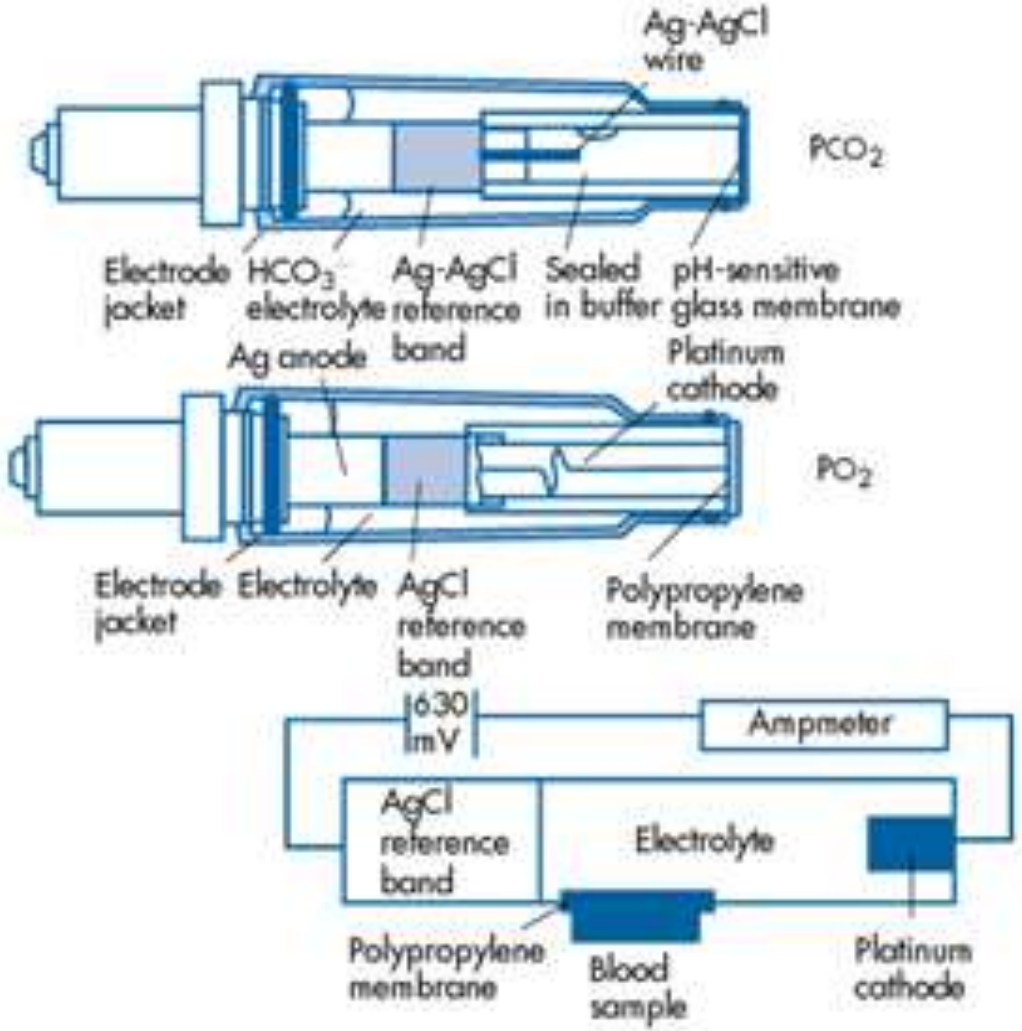
  - May also be referred to as a **polarographic** electrode

    - Periodic/routing cleaning of the tip with **pumice** is required because polypropylene attracts protein

# Arterial Blood Gases

- The PO2 electrode contains a **platinum cathode** and a **silver anode**.
- The electrode is polarized by applying a slightly negative voltage of approximately 630 mV.
- The tip is protected by a **polypropylene membrane** that allows O2 molecules to diffuse but prevents contamination of the platinum wire.
- O2 migrates to the cathode and is reduced, picking up free electrons that have come from the anode through a phosphate-potassium chloride electrolyte.
- Changes in the current flowing between the anode and cathode result from the amount of O2 reduced in the electrolyte and are proportional to partial pressure of O2.

# Clark Electrode (PO2)



# Arterial Blood Gases

## Calibration Procedures

To assure appropriate electronic function of the electrodes, calibration procedures are performed

- Performed automatically every 30 minutes by the ABG machine
- Performed on the pH, $PCO_2$, $PO_2$ electrodes
- Specific procedure for each electrode

# Arterial Blood Gases

## Calibration Procedures

- 2-Point Calibration
  - A “low” concentration and a “high” concentration is used at both ends of the physiological range to be measured
- Multiple-Point Calibration (3 or more points)
  - Verifies whether the gas analyzer is linear or not

# Arterial Blood Gases

## Calibration Procedures

### pH Electrode

- Uses two specific buffers with approximate values of:
  - 6.840 buffer
    - referred to as the zero point or low point buffer
  - 7.384 buffer
    - high point or slope point buffer

# Arterial Blood Gases

## Calibration Procedures

### pH Electrode

- Each buffer is injected into the sample chamber, one at a time
- The values of the buffer that is injected, should be displayed on the ABG machine within a specific SD (standard deviation)

# Arterial Blood Gases

## Calibration Procedures

### pH Electrode

- Standard deviation for pH is ± .005
- If value displayed is within the SD, machine is electronically calibrated
- If value displayed is outside of the SD, machine needs to be adjusted to assure electronic function

# Arterial Blood Gases

## Calibration Procedures

### $PO_2$ & $PCO_2$ Electrode

- Uses two specific concentration of gases for each electrode with approximate concentrations of $CO_2$ and $O_2$
- Uses two different tanks of gas to accomplish this

# Arterial Blood Gases

## Calibration Procedures

### $PO_2$ & $PCO_2$ Electrode

- **Tank One**
  - Low $CO_2$ (5%) - balance
  - High $O_2$ (12% or 20%)
  - Balance Nitrogen

- **Tank Two**
  - High $CO_2$ (10%) – slope
  - $O_2$ (0%)
  - Balance Nitrogen

# Arterial Blood Gases

## Calibration Procedures

### PO2 & PCO2 Electrode

- **Must convert tank concentration from % to mm Hg**

**($P_B - P_{H_2O}$) x tank concentration = mm Hg**

**(760 – 47) x 0.12 = 85.65 mm Hg**

# Arterial Blood Gases

## Calibration Procedures

### $PO_2$ & $PCO_2$ Electrode

- The values calculated for the $CO_2$ and $O_2$ concentration should be displayed on the ABG analyzer within a specific SD (standard deviation)

# Arterial Blood Gases

## Calibration Procedures

### PO2 & PCO2 Electrode

- Standard deviation for $PO_2$ and $CO_2$ is $\pm$ 0.5
- If values displayed are within the SD, machine is electronically calibrated
- If value displayed is outside of the SD, machine needs to be adjusted to assure electronic function

# Arterial Blood Gases

## Calibration Procedures

### Troubleshooting

- **If the ABG machine will not calibrate, check:**
  - The buffers
  - The mixed gases
  - The electrode's membrane
  - The electrode itself

# Arterial Blood Gases

## Quality Control

### Calibration vs. Quality Control

- Calibration is when the **equipment is adjusted or corrected** to match the control standards
- Quality Control testing must be performed on a regular basis to determine the **accuracy** and **precision** of the equipment against a known standard

# Arterial Blood Gases

## Quality Control

### Accuracy vs. Precision

- Accuracy refers to the mean (average) value of several measurements
- Precision refers to how consistently the same measurement will produce the same results

# Arterial Blood Gases

**Quality Control**

- Must be run every shift
- Utilize a known concentration of gases and buffers in a vial of liquid
- Run three levels of QC
  - Level 1 – Acidosis
  - Level 2 – Normal
  - Level 3 - Alkalosis

# Arterial Blood Gases

**Quality Control**

- When QC is run it must be recorded and maintained onsite; in the ABG laboratory

- Must be available for review by State agencies on demand

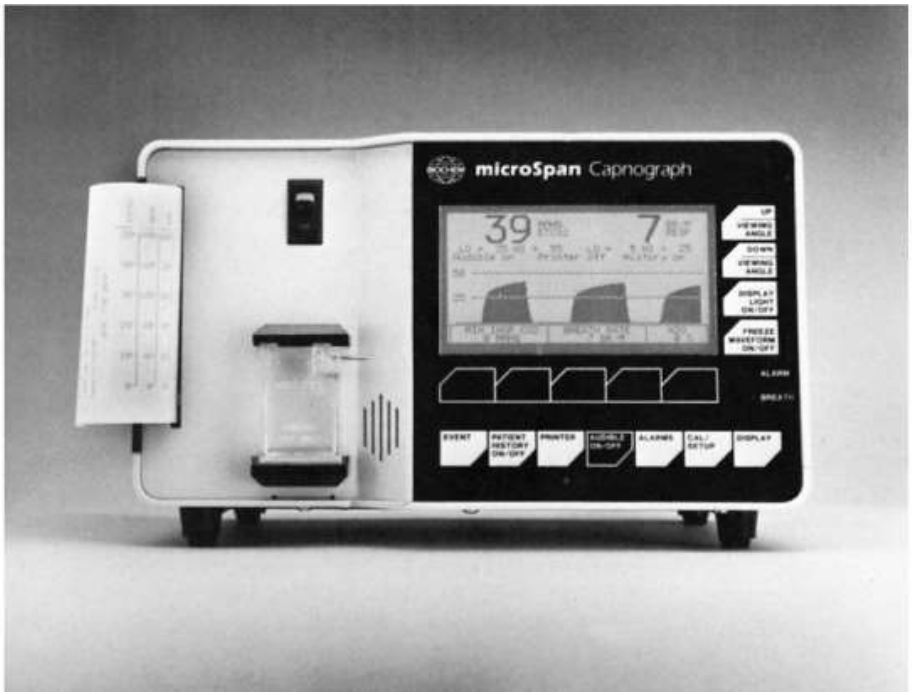
# Arterial Blood Gases

**Quality Control Plotting**

- In control
- Trend
- Random Error
- Out of Control

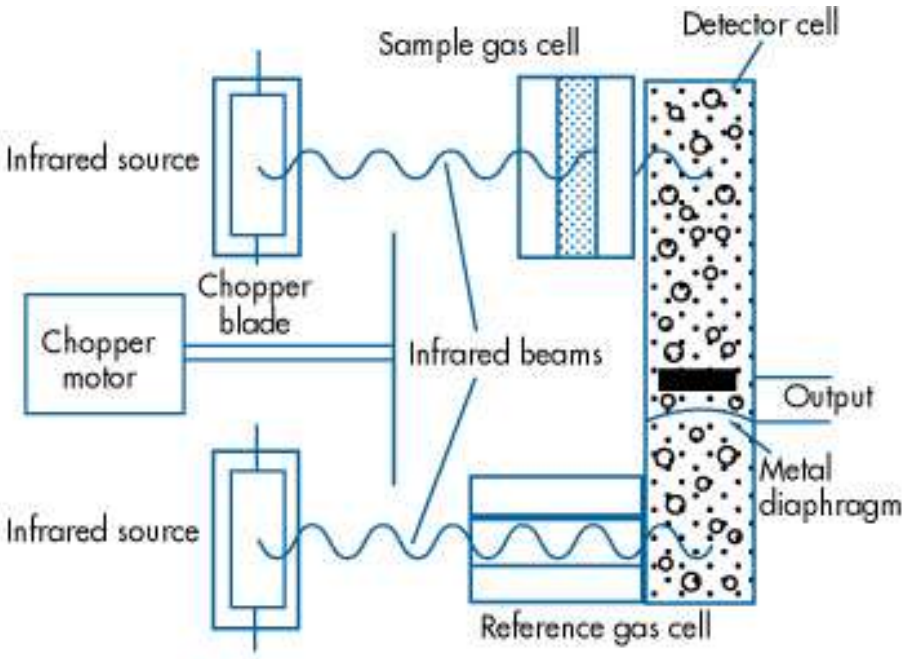
# Capnography

- **Capnography is the continuous, noninvasive monitoring of expired CO2 and analysis of the single-breath CO2 waveform**



# Capnography

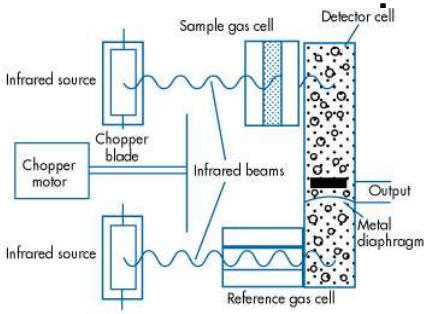
- **Capnography is performed utilizing:**
  - **Infrared analyzer**
    - **CO and CO2 absorb infrared radiation**



# Capnography

- **Capnography is performed utilizing:**
  - **Infrared analyzer**
    - **Requires accurate calibration**
      - **2 gas concentrations used**
        - **Room air**
        - **5% CO2 mixture**

    - **Inaccurate reading can occur when:**
      - **Condensation of water in sample tubing, connectors, or sample chamber**
      - **Flow changes after calibration**
      - **Saturation of a desiccant column**
      - **g sampling lines can cause waveform damping**



# ELECTROPHORESIS

# DEFINITIONS

## Electrophoresis

- Migration of charged solutes in a liquid medium under an electrical field
- Many biological molecules have ionisable groups eg. amino acids, proteins, nucleotides, nucleic acids
- Under an electric field -> charged particles migrate to anode (+) or cathode (-)

# Zone Electrophoresis

- Migration of charged molecules
- Support medium
  - porous eg. CA or agarose
  - can be dried & kept
- Same pH & field strength thru'out
- Separation based on electrophoretic mobility
- Separates macromolecular colloids eg. proteins in serum, urine, CSF, erythrocytes; nucleic acids

# Isotachophoresis

- Migration of small ions
- Discontinuous electrolyte system
  - leading electrolyte ($L^-$ ions) &
  - trailing electrolyte ($T^-$ ions)
- Apply sample solution at interphase of L & T
- Apply electric field -> each type of ion arrange between L and T ions -> discrete zones
- Separates small anions, cations, organic & amino acids, peptides, nucleotides, nucleosides, proteins

# THEORY of ELECTROPHORESIS

- Many biological molecules exist as
  (a) cations or (b) anions

- Solution with pH < pI
  -> ampholyte/zwitterion has overall +ve charge

- Solution with pH > pI
  -> ampholyte has overall –ve charge

- Under an electric field
  -> cations/overall +ve migrate to cathode
  -> anions/overall -ve migrate to anode

# THEORY of ELECTROPHORESIS

- Rate of migration depends on:
  - Net electrical charge of molecule
  - Size & shape of molecule
  - Electric field strength
  - Properties of supporting medium
  - Temperature of operation

# ELECTROPHORETIC TECHNIQUE

Instrumentation & Reagents

- Buffer boxes with buffer plates -> holds buffer
- Platinum or carbon electrode -> connected to power supply
- Electrophoresis support -> with wicks to contact buffer
- Cover -> minimize evaporation (Fig 7-1)

## Power Supplies

- Power pack: supply current between electrodes
- Flow of current -> Heat produced
  - increase in migration rate -> broadening of separated samples
  - formation of convection currents -> mixing of separated samples
  - thermal instability of heat sensitive samples
  - water loss -> concn of ions -> decrease of buffer viscosity -> decrease in resistance
- To minimize problems: use constant-current power supply

## Buffers

- To carry applied current & to fix the pH
  => determine electrical charge & extent of ionization => which electrode to migrate
- Ionic strength of buffer
  - thickness of ionic cloud -> migration rate -> sharpness of electrophoretic zones
  - [ion] ↑ -> ionic cloud ↑ -> movement of molecules ↓
- Barbital buffers & Tris-boric acid-EDTA buffers

## Protein Stains

- To visualize/locate separated protein fractions
- Dyes: amount taken up depends on
  - Type of protein
  - Degree of denaturation of proteins by fixing agents

Types of stains:  Table 7-1

# GENERAL PROCEDURES

Separation

- Place support material in EP chamber
- Blot excess buffer from support material
- Place support in contact with buffer in electrode chamber
- Apply sample to support

- Separate component using constant voltage or constant current for length of time

- Remove support, then
  -> dry or place in fixative
  -> treat with dye-fixative
  -> wash excess dye
  -> dry (agarose) or put in clearing agent (CA membs)

## Detection & Quantitation

- Express as
  - % of each fraction present or
  - absolute concn

- By densitometry
  - electrophoretic strip moved past an optical system
  - absorbance of each fraction displayed on recorder chart

# TYPES OF ELECTROPHORESIS

a. Agarose Gel Electrophoresis
b. Cellulose Acetate Electrophoresis
c. Polyacrylamide Gel Electrophoresis
d. Isoelectric Focusing
e. Two-dimensional Electrophoresis

# Agarose Gel Electrophoresis (AGE)

- Use agarose as medium
  - low concns -> large pore size
  - higher concns -> small pore size
- Serum proteins, Hb variants, lactate dehydrogenase, CK isoenzymes, LP fractions
- Pure agarose - does not have ionizable groups -> no endosmosis

- Advantages:
  - low affinity for proteins
  - shows clear fractions after drying
  - low melting temp -> reliquify at 65$^{o}$C

- Disadvantage:
  - poor elasticity

    -> not for gel rod system

    -> horizontal slab gels

# Cellulose Acetate Electrophoresis (CAE)

- Cellulose + acetic anhydride -> CA
- Has 80% air space -> fill with liquid when soaked in buffer
- Can be made transparent for densitometry
- Advantages:
  - speed of separation
  - able to store transparent membranes
- Disadvantages:
  - presoaking before use
  - clearing for densitometry

- Method:
  - wet CA in EP buffer
  - load sample about 1/3 way along strip
  - stretch CA in strips across a bridge
  - place bridge in EP chamber -> strips dip directly into buffer
  - after EP, stain, destain, visualise proteins

- For diagnosis of diseases
  - change in serum protein profile

# Polyacrylamide Gel Electrophoresis (PAGE)

- Tubular-shaped EP cell
  -> pour small-pore separation gel
  -> large-pore spacer gel cast on top
  -> large-pore monomer solution + ~3ul sample
  on top of spacer gel

- Electrophoresis
  -> all protein ions migrate thru large-pore gels
  -> concentrate on separation gel
  -> separation due to retardation of some
  proteins

- Average pore size in 7.7% PAGE separation gel about 5nm
  -> allow most serum proteins to migrate
  -> impedes migration of large proteins eg
  fibrinogen, $\beta_1$-lipoprotein, $\alpha_2$-macroglobulin
- Advantages:
  - thermostable, transparent, strong, chemically inert
  - wide range of pore sizes
  - uncharged -> no endosmosis
- Disadvantages:
  - carcinogenic

# Isoelectric Focusing

- To separate amphoteric cpds eg. proteins
- Proteins moves to zone where:

  pH medium = pI protein => charge = 0

- pI of protein confined in narrow pH range -> sharp protein zones
- Method:
  - use horizontal gels on glass/plastic sheets
  - introduce ampholytes into gel -> create pH gradient

- apply a potential difference across gel
- anode -> area with lowest pH
- cathode -> area with highest pH
- proteins migrate until it arrives at pH = pI
- wash with fixing solution to remove ampholytes
- stain, destain, visualise

- Separations of proteins with 0.01 to 0.02pH unit differences (Fig 7-4)

# Two-Dimensional (2D) EP (ISO-DALT)

- 1st D using IEF EP -> in large-pore medium
  -> ampholytes to yield pH gradient
- 2nd D using molecular weight-dependent EP
  -> in polyacrylamide -> linear or gradient
- O'Farrell method:
  - use β-mercaptoethanol (1st D) & SDS (2nd D)
- Detect proteins using Coomassie dyes, silver stain, radiography, fluorography
- Separates 1100 spots (autoradiography)

# AUTO ANALYSER

# Purpose of Autoanalyzer

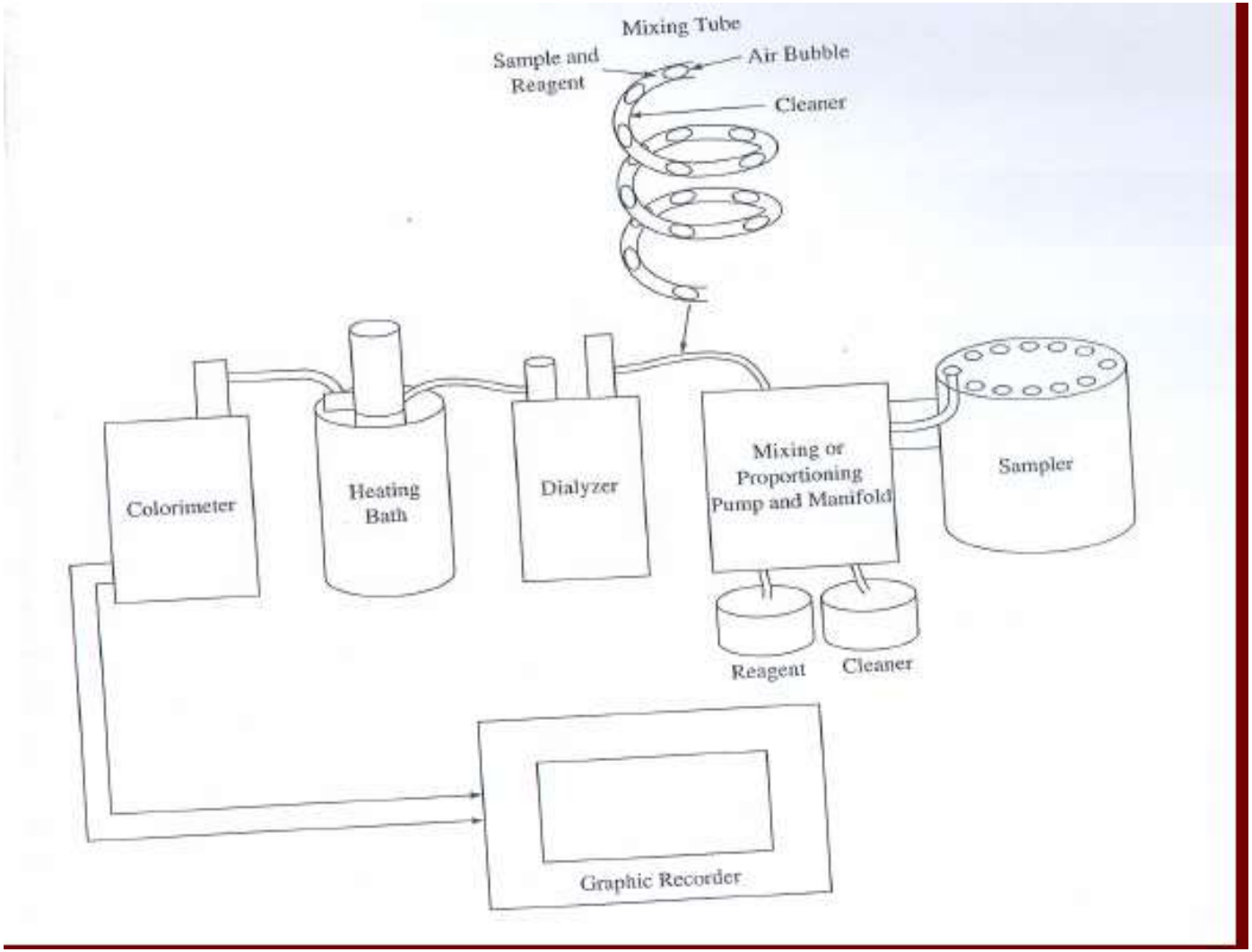
- The autoanalyzer is sequentially measures blood chemistry and displays this on a graphic readout
- This is accomplished by

– Mixing
– reagent
– Reaction
– Colorimetric measurement in continuous stream

# Elements of Autoanalyzer

- Sampler
- Proportioning pump and manifold
- Dialyzer
- Heating bath
- Colorimeter
- Record

# Schematic


Mixing Tube
Sample and Reagent
Air Bubble
Cleaner
Colorimeter
Heating Bath
Dialyzer
Mixing or Proportioning Pump and Manifold
Sampler
Reagent
Cleaner
Graphic Recorder

# Sampler

- Aspirates samples, standards, and wash solutions to the auto analyzer system.

# Proportioning pump

- Introduces samples with reagents to effect the proper chemical color reaction to be read by the colorimeter.
- Pumps fluids at precise flow rates to other modules, as proper color development depends on reaction time and temperature

# Dialyzer

- Separates interfacing substances from the sample material by permitting selective passage of sample components through a Semi-permeable membrane

# Heating bath

- Heats fluids continuously to exact temperature (37 degree).

# Colorimeter

- Monitors the changes in optical density of the fluid stream flowing through a tubular flow cell.
- Color intensities proportional to substance concentrations
- Colorimeter convert the color intensity to equivalent electrical voltages

# Recorder

- Converts the electrical signal from the colorimeter into a graphic display on moving chart

# Problems

- Identification of samples
- Sterilization for sample and glassware and equipment parts

# Maintenance

- Calibration and adjustment
- Mechanical
  - Tubing
  - Moving pump parts
- Electrical
  - Switches
  - Motors
- Electronic failures are few

# Note

- A patient’ s life may hinge on accurate measurement obtained by clinical instrumentation.
- Biomedical equipment technician must complete the manufacturer’s schools.

# CARDIAC OUTPUT

# Cardiac Output, Venous Return and their Regulation

- Cardiac output is controlled to maintain the proper amount of flow to tissues and to prevent undue stress on the heart.

# Cardiac Output

- Generally proportional to body surface area.
- Cardiac Index (CI): Approximately 3 liters/min/$m^2$ of body surface area.
- CI varies with age, peaking at around 8 years.

# Frank-Starling Law

- What goes into the heart comes out.

- Increased heart volume stretches muscles and causes stronger contraction.

- Stretch increases heart rate as well.
- Direct effect on sino-atrial node
- Bainbridge reflex (through the brain)

# Cardiac Output

- Depends on venous return, which, in turn, depends on the rate of flow to the tissues.

- Rate of flow to tissues depends on tissue needs (i.e. it depends on Total Peripheral Resistance). Therefore, cardiac output is proportional to the energy requirements of the tissues.

# Limit of Cardiac Output

- Normal CO – 5 L/min
- Plateau – 13 L/min
- Hypereffective heart plateau – 20 L/min
- Hypoeffective heart plateau – 5 L/min

# Hypereffective Heart

- Effected by:

1. Nervous excitation.
2. Cardiac Hypertrophy
   - Exercise – Marathon runners may get 30 to 40 L/min
   - Aortic Valve Stenosis

# Hypoeffective Heart

- Valvular disease
- Increased output pressure
- Congential heart disease
- Myocarditis
- Cardiac anoxia
- Toxicity

# Autonomic Nervous System

- Causes increased cardiac output when vessels become dilated (dinitrophenol).

- Causes venous constriction during exercise.

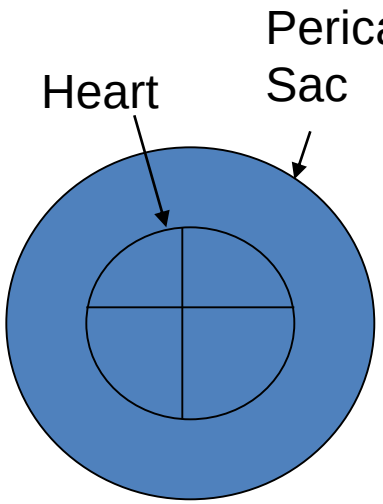
# Disease States Lowering Total Peripheral Resistance

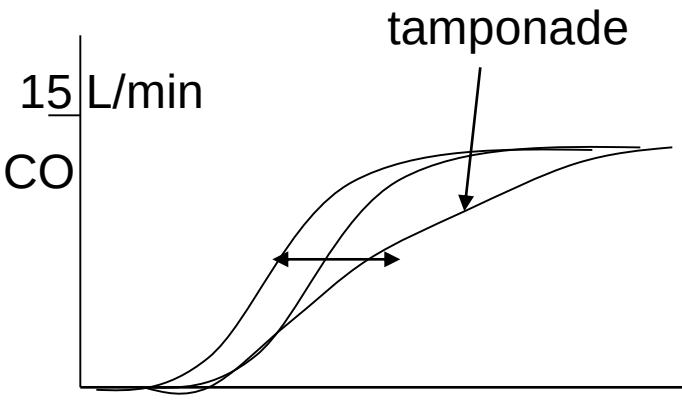
- Beriberi: insufficient thiamine – tissues starve because they cannot use nutrients.
- AV fistula: e.g. for dialysis.
- Hyperthyroidism: Reduced resistance caused by increased metabolism
- Anemia (lack of RBCs): effects viscosity and transport of $O_2$ to the tissues.

# Disease States Lowering Cardiac Output

- Heart attack, valvular disease, myocarditis, cardiac tamponade, shock.
- **Shock:** Nutritional deficiency of tissues.
- Decreased venous return caused by:
  - Reduced blood volume
  - Venous dilitation (increased circulatory volume)
  - Venous obstruction

# Changes in Intrapleural Pressure

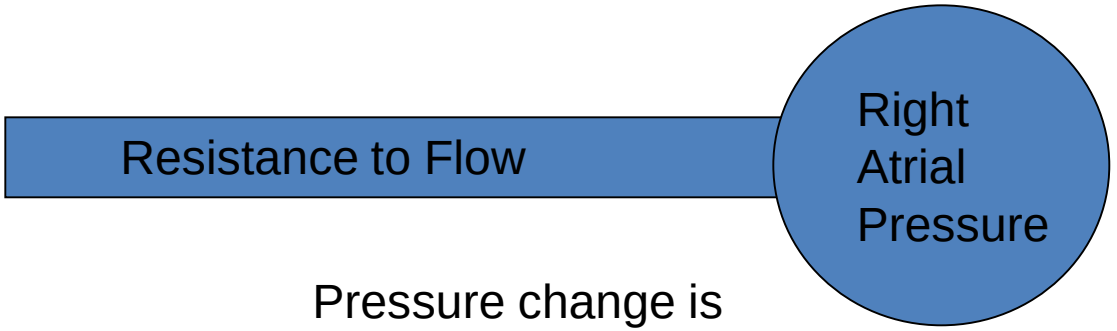



- Generally shift the cardiac output curve in proportion to pressure change (*breathing*, *Valsalva maneuver*).
- Cardiac Tamponade (filling of pericardial sac with fluid) lowers rate of change of CO with right atrial pressure

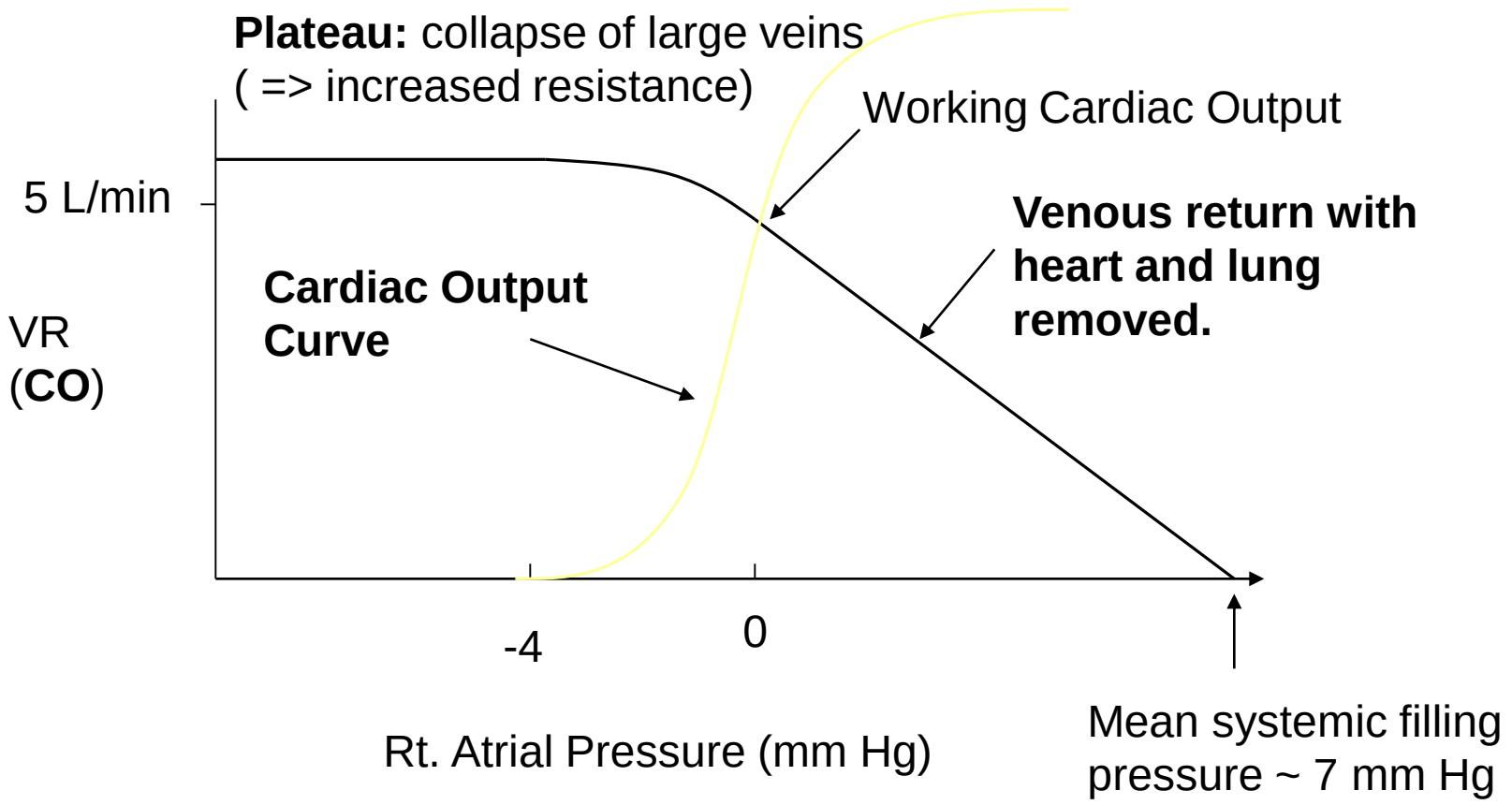
# Determinants of Venous Return

Mean systemic filling pressure




Pressure change is slight. Thus, small increase in RA Pressure causes dramatic reduction in venous return. (mean systemic filling pressure).

# Normal Venous Return Curve



# Filling Pressure

- Mean Circulatory: The pressure within the circulatory system when all flow is stopped (e.g. by stopping the heart).

- Mean Systemic: Pressure when flow is stopped by clamping large veins.

- The two are close numerically.

# Venous Return & Cardiac Output

- Cardiac output increases with atrial pressure.
- Normal atrial pressure is about 0 mm Hg.
- Venous return (with heart and lungs removed) decreases with atrial pressure.
- Working cardiac output is where venous return curve meets cardiac output curve.

# Compensation for Increased Blood Volume

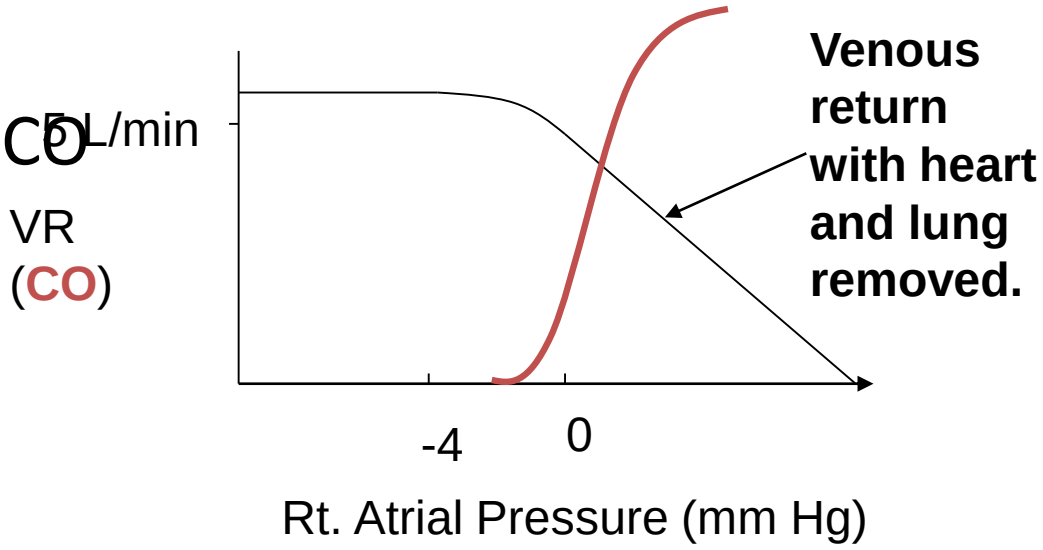
1. Increased CO increases capillary pressure, sending more fluid to tissues.
2. Vein volume increases
3. Pooling of blood in the liver and spleen
4. Increased peripheral resistance reduces cardiac output.

# Effects of Sympathetic Stimulation

- Increases contractility of the heart.
- Decreases volume by contracting the veins.
- Increases filling pressure
- Increases resistance

# Effects of Sympathetic Inhibition

- Shifts CO to the right
- Shifts venous return down and to the left
- - Reduced CO



# Effects of AV Fistula

1. Decreased VR resistance.
2. Slight increased CO because of reduced peripheral resistance.
3. After restoration of pressure (sympathetic)
4. Further CO increase.
5. Increased filling pressure.
6. Decreased kidney output (leads to higher fluid volume and more increase in CO).
7. Cardiac hypertrophy (caused by increased workload).

- Electromagnetic/ultrasonic (transit time) flow meter.
- **Oxygen Fick method:**
- $$CO = \frac{\text{(Rate of O2 absorbed by lungs)}}{[O2]_{la} - [O2]_{rv}}$$

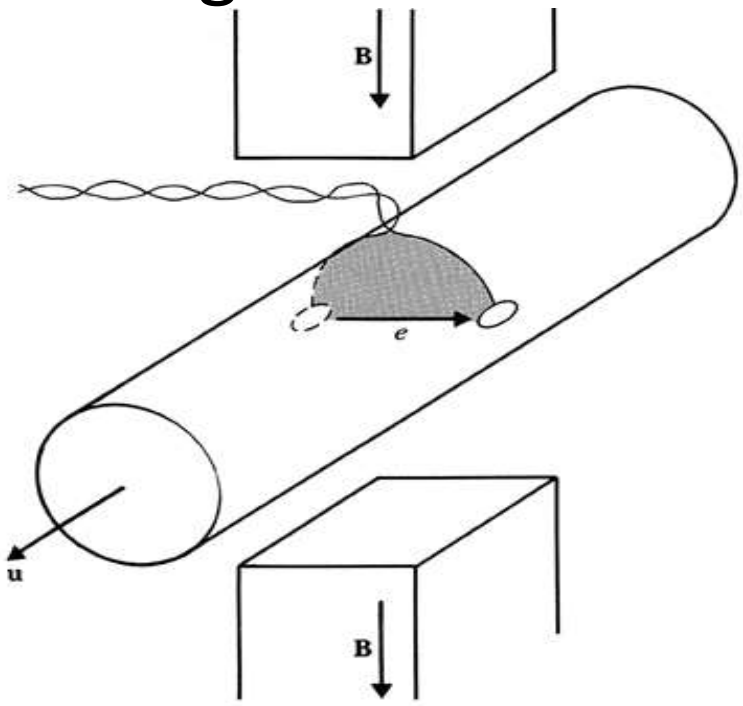
- **Indicator dilution method:**
- Inject cold saline (or dye) into RA, measure temperature (or concentration) in aorta.

# BLOOD FLOWMETER

# Electromagnetic Flowmeters

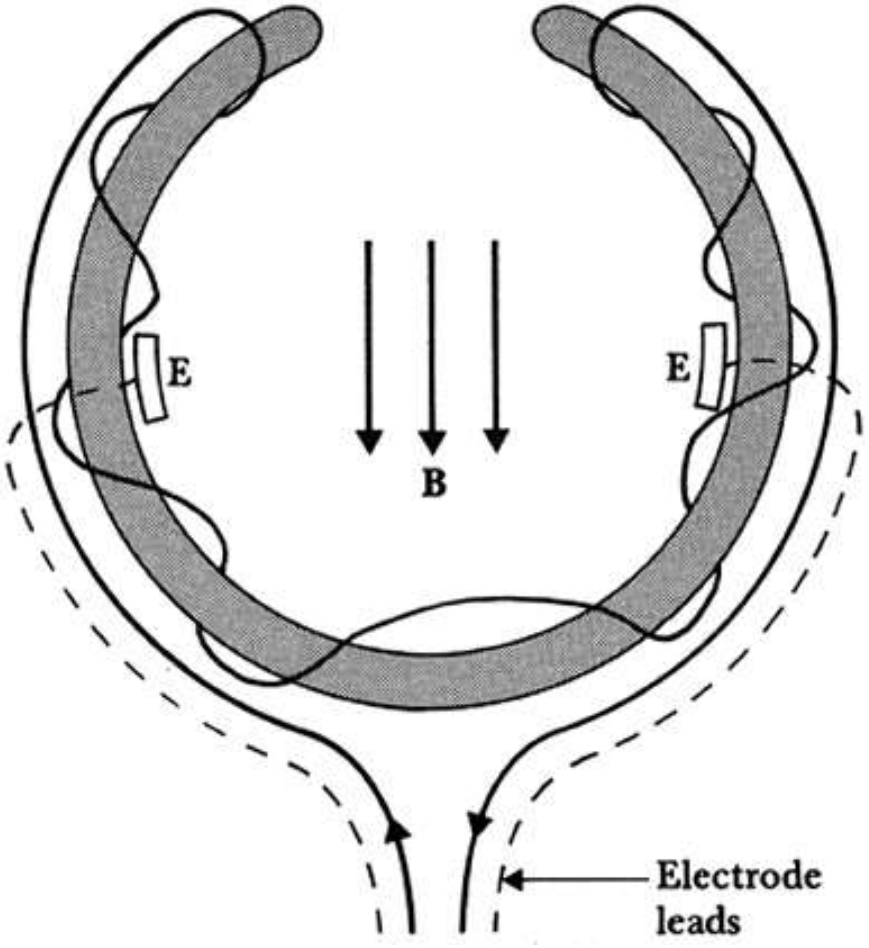
- Based on Faraday's law of induction that a conductor that moves through a uniform magnetic field, or a stationary conductor placed in a varying magnetic field generates *emf* on the conductor:

$$e = \int_0^L \mathbf{u} \times \mathbf{B} \cdot d\mathbf{L}$$




For uniform **B** and uniform velocity profile **u**, the induced emf is $e=BLu$. Flow can be obtained by multiplying the blood velocity $u$ with the vessel cross section $A$.

# Electromagnetic Flowmeter Probes



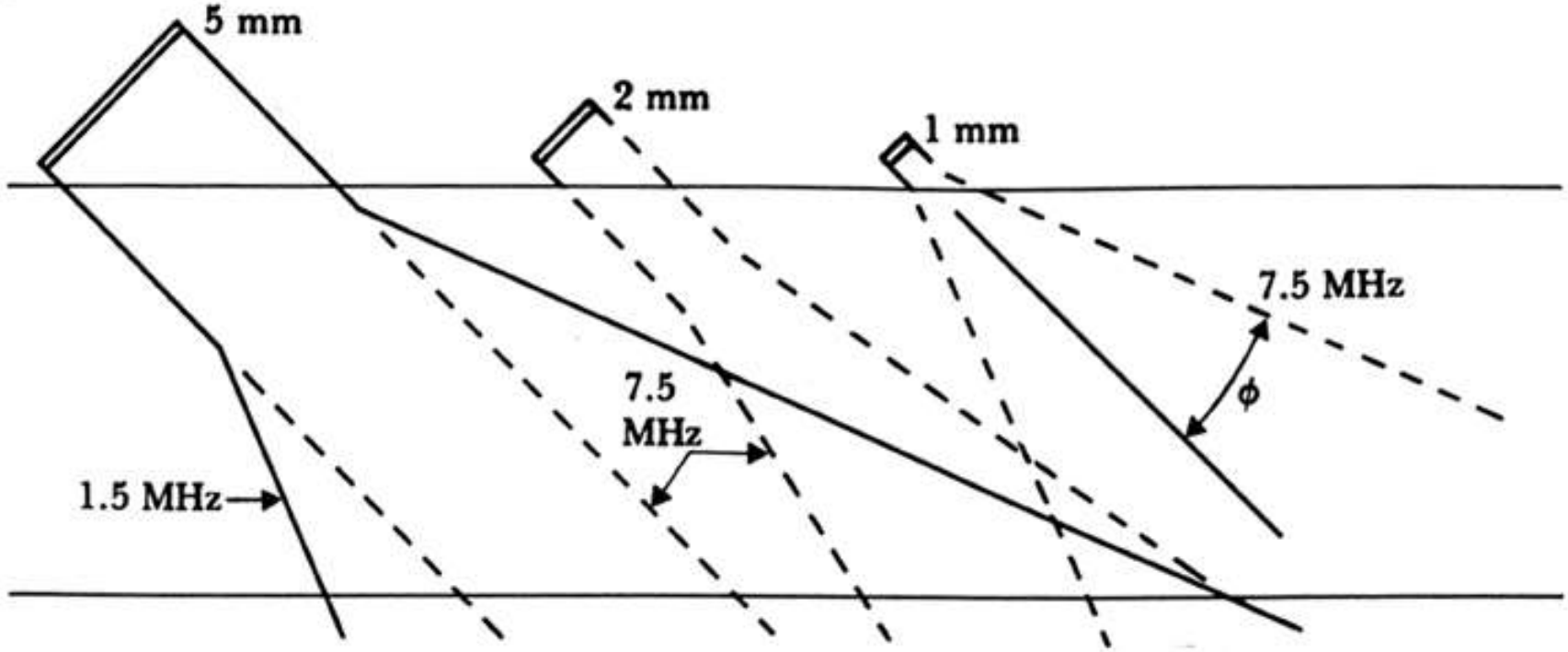

- Comes in 1 mm increments for 1 ~ 24 mm diameter blood vessels
- Individual probes cost $500 each
- Made to fit snuggly to the vessel during diastole
- Only used with arteries, not veins, as collapsed veins during diastole lose contact with the electrodes
- Needless to say, this is an INVASIVE measurement!!!
- A major advantage is that it can measure instantaneous blood flow, not just average flow

# Ultrasonic Flowmeters

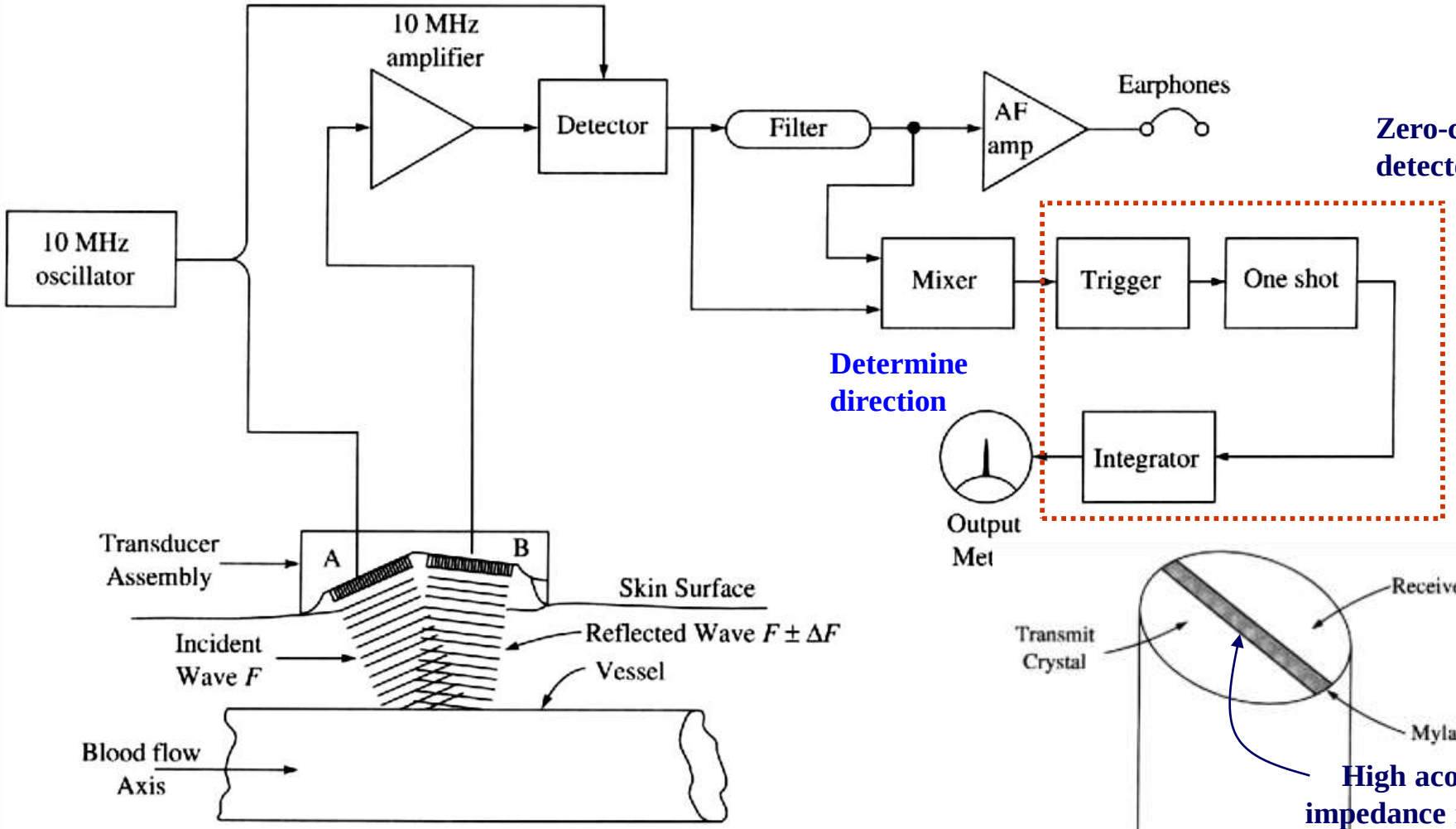
- Based on the principle of measuring the time it takes for an acoustic wave launched from a transducer to bounce off red blood cells and reflect back to the receiver.
- All UT transducers, whether used for flowmeter or other applications, invariably consists of a piezoelectric material, which generates an acoustic (mechanical) wave when excited by an electrical force (the converse is also true)
- UT transducers are typically used with a gel that fills the air gaps between the transducer and the object examined

# Near / Far Fields

- Due to finite diameters, UT transducers produce diffraction patterns, just like an aperture does in optics.
- This creates near and far fields of the UT transducer, in which the acoustic wave exhibit different properties
  - The near field extends about $d_{nf}=D^2/4\lambda$, where $D$ is the transducer diameter and λ is the wavelength. During this region, the beam is mostly cylindrical (with little spreading), however with nonuniform intensity.
  - In the far field, the beam diverges with an angle $\sin\theta=1.2\ \lambda/D$, but the intensity uniformly attenuates proportional to the square of the distance from the transducer


5 mm
2 mm
1 mm
7.5 MHz
ϕ
7.5
MHz
1.5 MHz

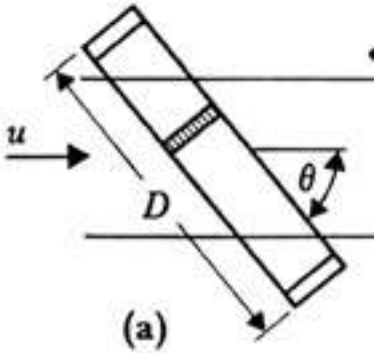
# UT Flowmeters



# Transit time flowmeters

Effective velocity of sound in blood: velocity of sound (c) + velocity of flow of blood averaged along the path of the ultrasound (û)

û=1.33ū for laminar flow, û=1.07ū for turbulent flow
ū: velocity of blood averaged over the cross sectional area, this is different than û because the UT path is along a single line not over an averaged of cross sectional area



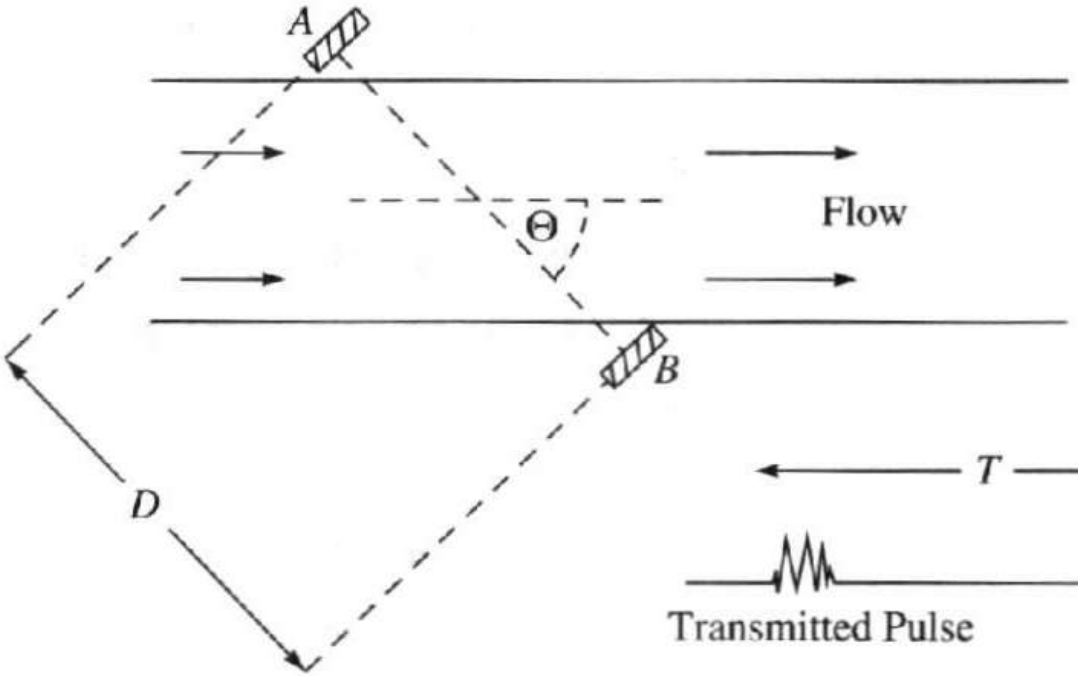

Transit time in up/down stream direction:

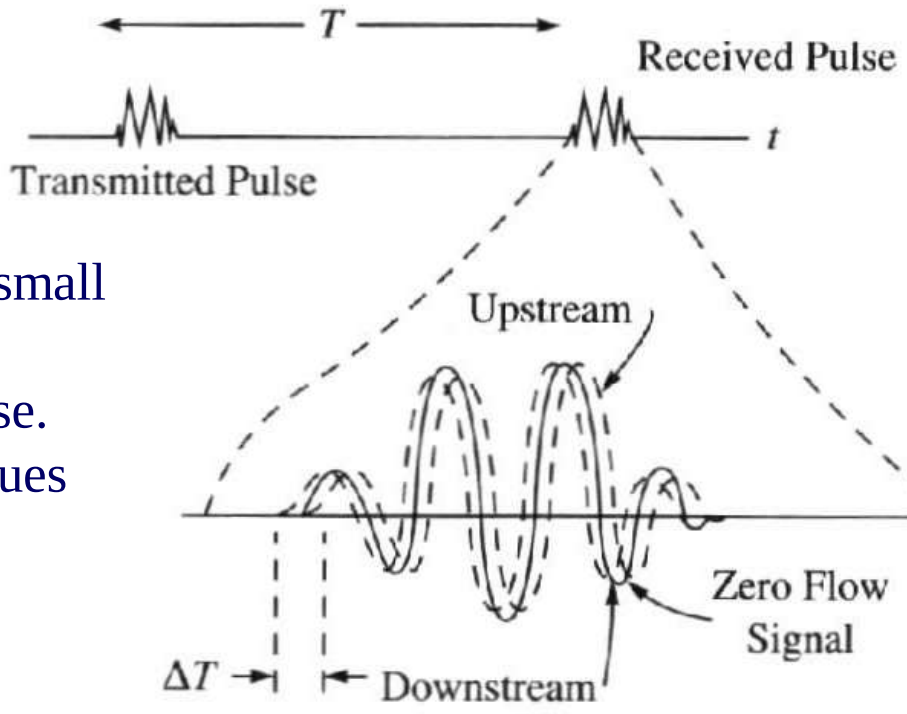
$$t = \frac{\text{distance}}{\text{conductionvelocity}} = \frac{D}{c \pm \hat{u}\cos\theta}$$

Difference between upstream and downstream directions

$$\Delta t = \frac{2D\hat{u}\cos\theta}{(c^2 - \hat{u}^2\cos^2\theta)} \cong \frac{2D\hat{u}\cos\theta}{c^2}$$

# Transit Time Flowmeters

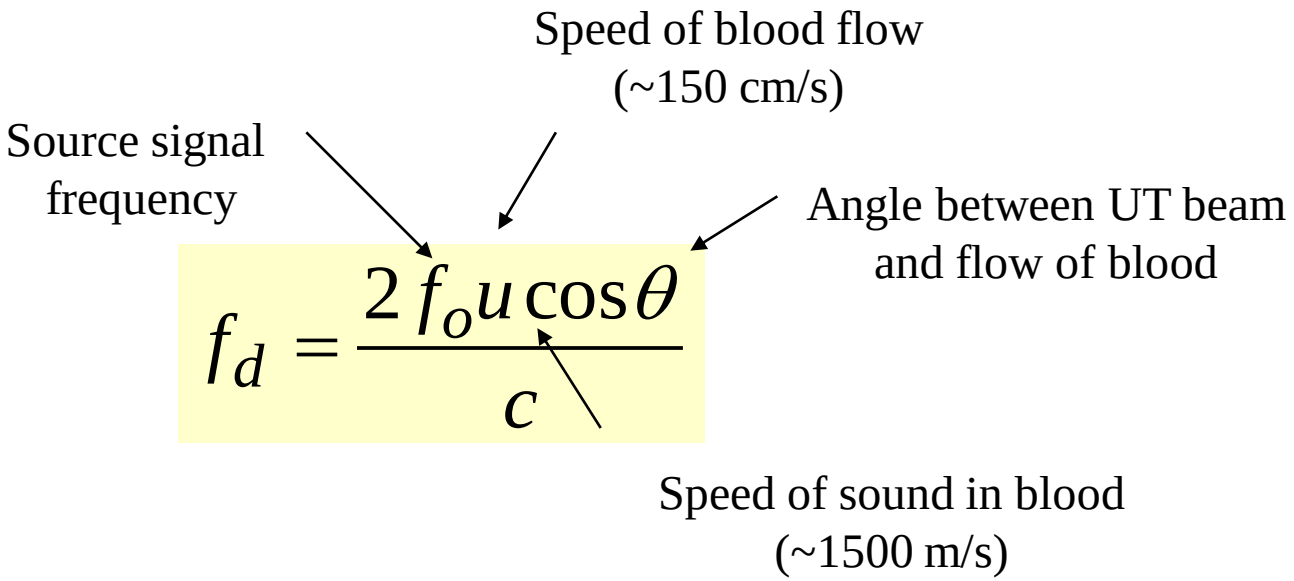


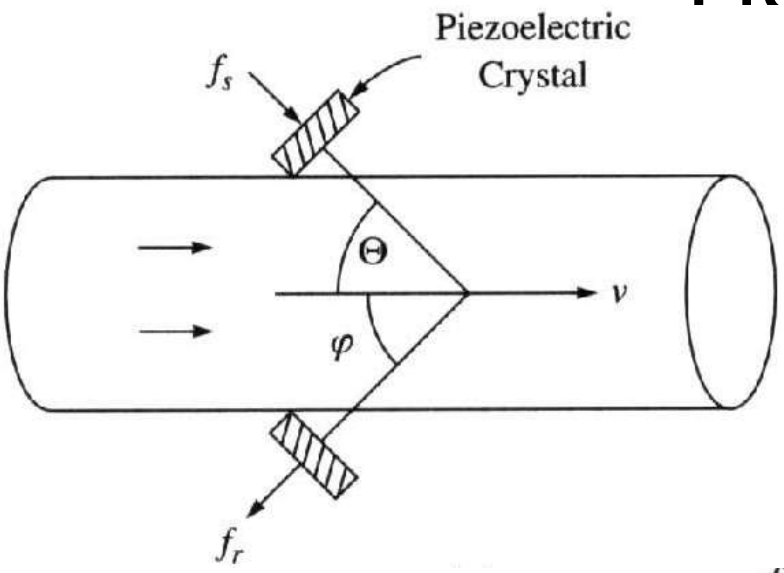

The quantity $\Delta T$ is typically very small and very difficult to measure, particularly in the presence of noise. Therefore phase detection techniques are usually employed rather then measuring actual timing.

# Doppler Flowmeters

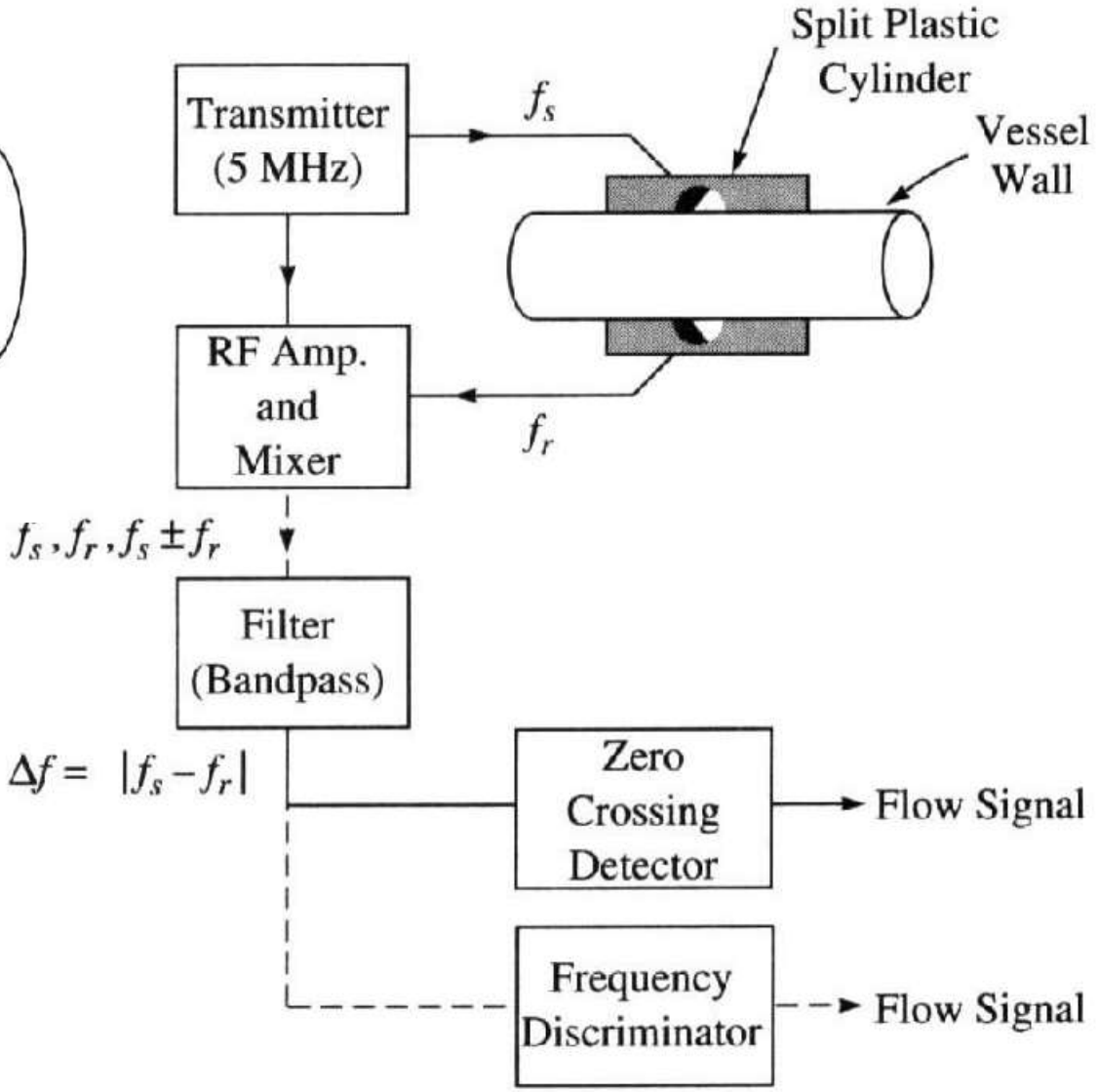
- The Doppler effect describes the change in the frequency of a received signal , with respect to that of the transmitted signal, when it is bounced off of a moving object.
  - Doppler frequency shift



# Doppler Flowmeters




$$\Delta F = \pm f_s(\cos\theta + \cos\phi)\frac{u}{c}$$



# Problems Associated with Doppler Flowmeters

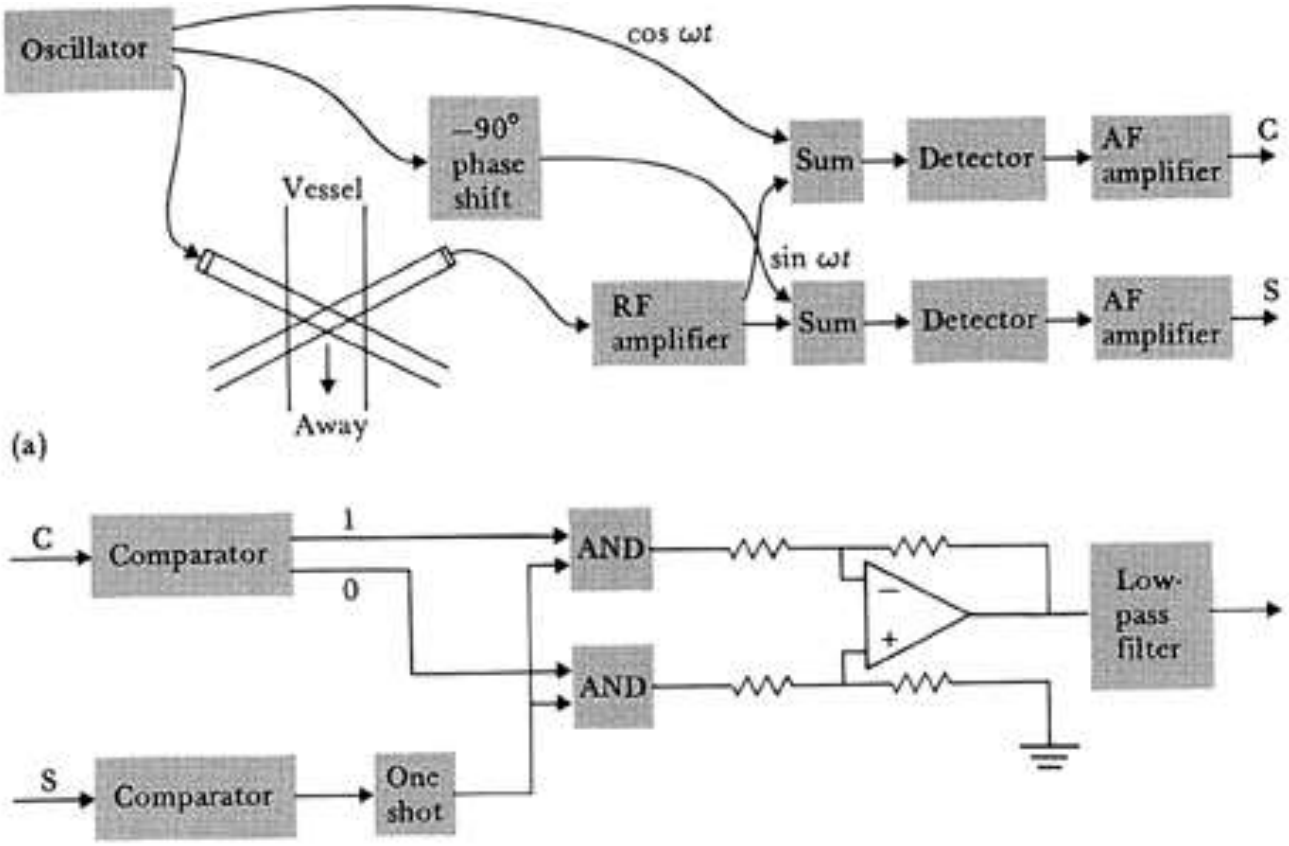
- There are two major issues with Doppler flowmeters
  - Unlike what the equations may suggest, obtaining direction information is not easy due to very small changes in frequency shift that when not in baseband, removing the carrier signal without affecting the shift frequency becomes very difficult

- Also unlike what the equation may suggest, the Doppler shift is not a single frequency, but rather a band of frequencies because
  - Not all cells are moving at the same velocity (velocity profile is not uniform)
  - A cell remains within the UT beam for a very short period of time; the obtained signal needs to be gated, creating side lobes in the frequency shift
  - Acoustic energy traveling within the beam, but at an angle from the bam axis create an effective $\Delta\theta$, causing variations in Doppler shift
  - Tumbling and collision of cells cause various Doppler shifts

# Directional Doppler

- Directional Doppler borrows the ***quadrature phase detector*** technique from radar in determining the speed and direction of an aircraft.
- Two carrier signals at $90^{o}$ phase shift are used instead of a single carrier. The +/- phase difference between these carriers after the signal is bounced off of the blood cells indicate the direction, whereas the change in frequency indicate the flowrate

# Directional Doppler




*(a) Quadrature-phase detector. Sine and cosine signals at the carrier frequency are summed with the RF output before detection. The output C from the cosine channel then leads (or lags) the output S from the sine channel if the flow is away from (or toward) the transducer. (b) Logic circuits route one-shot pulses through the top (or bottom) AND gate when the flow is away from (or toward) the transducer. The differential amplifier provides bi-directional output pulses that are then filtered.*

# BLOOD PRESSURE

# BLOOD PRESSURE

- The force at which blood is pumped against the walls of the arteries (mmHg)
- Two pressure measurements
  - Systolic pressure – measure of pressure when left ventricle contracts
  - Diastolic pressure
    - Measure of pressure when heart relaxes
    - Minimum pressure exerted against the artery walls at all times

# BLOOD PRESSURE

- **Systolic Pressure-**
  - Contraction of left ventricle
  - Top or first number
- **Diastolic Pressure**
  - Heart at rest
  - Bottom or second number

# BLOOD PRESSURE

**Hypertension**

- Low blood pressure
- Normal for some people
- Severely low blood pressure readings occur with:
  - Shock
  - Heart failure
  - Severe burns
  - Excessive bleeding

**Hypotension**

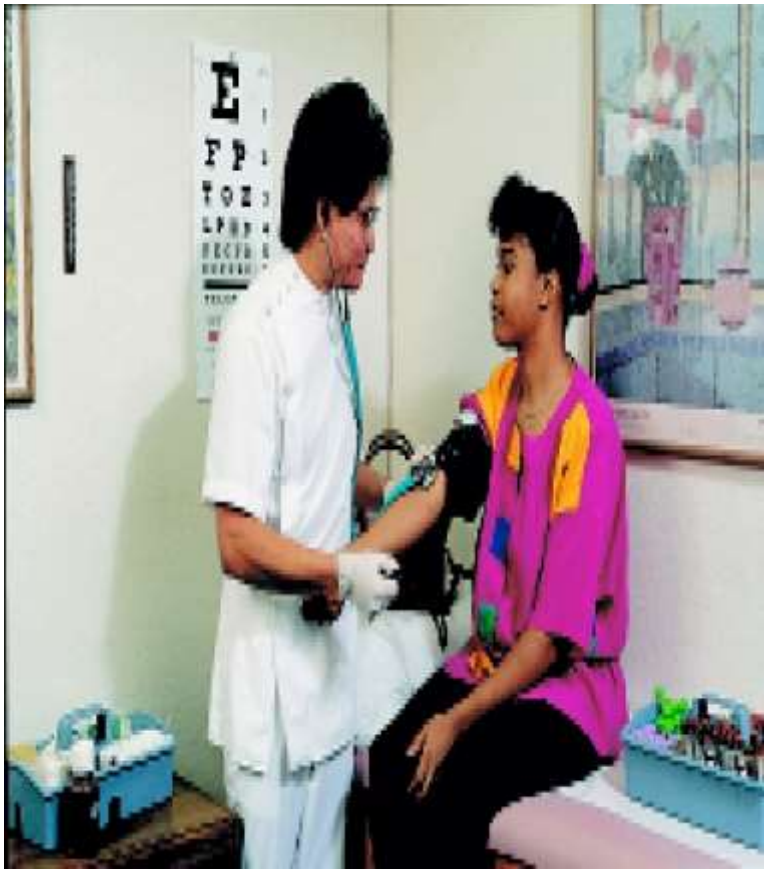
- High blood pressure readings
- Major contributor to heart attacks and strokes

# BLOOD PRESSURE

- Equipment
  - Sphygmomanometer
    - Inflatable cuff
    - Pressure bulb or other device for inflating cuff
    - Manometer
  - Types of sphygmomanometers
    - Aneroid
    - Electronic
    - Mercury

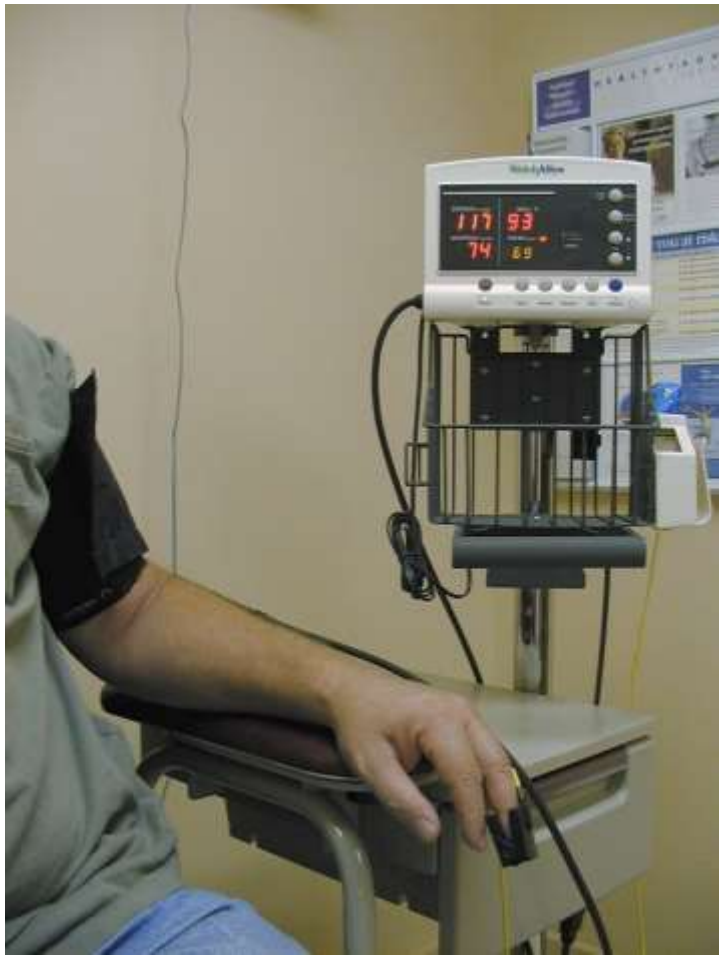
# BLOOD PRESSURE

- Aneroid sphygmomanometers
  - Circular gauge for registering pressure
  - Each line 2 mmHg
  - Very accurate
  - Must be checked, serviced, and calibrated every 3 to 6 months



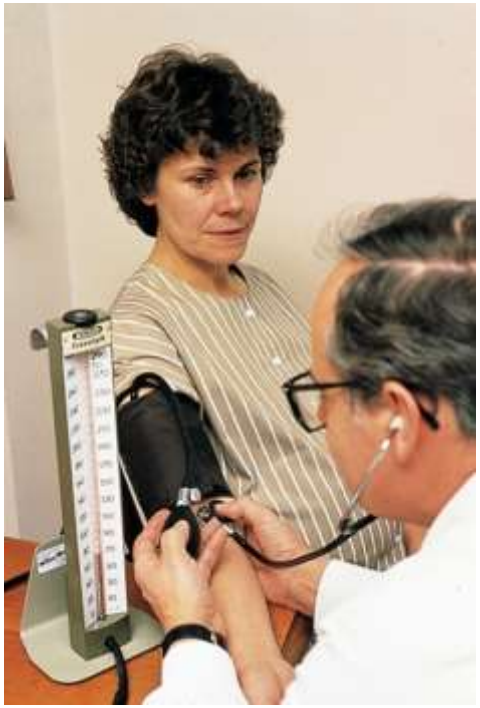
# BLOOD PRESSURE

- Electronic sphygmomanometers
  - Provides a digital readout of the blood pressure
  - No stethoscope is needed
  - Easy to use
  - Maintain equipment according to manufacturer's instructions



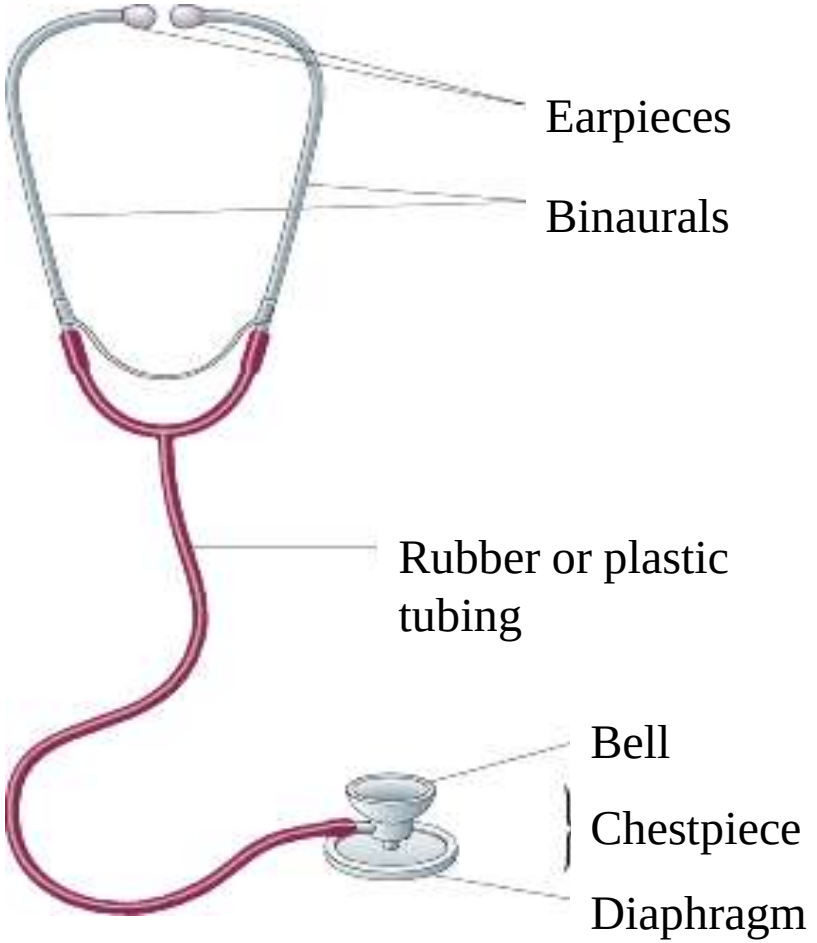
# BLOOD PRESSURE

- Mercury sphygmomanometers
  - A column of mercury rises with an increased pressure as the cuff is inflated
  - No longer available for purchase
  - If in use, must be checked, serviced, and calibrated every 6 to 12 months



# BLOOD PRESSURE

- Stethoscope
  - Amplifies body sounds
  - Earpieces
  - Binaurals and tubing
  - Chestpiece
    - Bell – low-pitched sounds
    - Diaphragm – high-pitched sounds



# BLOOD PRESSURE

- Measuring blood pressure
  - Place cuff on the upper arm above the brachial pulse site
  - Inflate cuff about 30 mmHg above palpatory result or approximately 180 mmHg to 200 mmHg
  - Release the air in cuff and listen for the first heartbeat (systolic pressure) and the last heartbeat (diastolic pressure)
  - Record results with systolic as the top number and diastolic as the bottom number (i.e., 120/76)

# BLOOD PRESSURE

- Special considerations in adults
  - Post exercise, ambulatory disabilities, obese, known blood pressure problems
  - Anxiety or stress
  - Avoid measurement in an arm
    - Injury or blocked artery is present
    - History of mastectomy on that side
    - Implanted device is under the skin
  - Proper cuff size – improper size results in inaccurate reading

# BLOOD PRESSURE

- Special considerations in children
  - Not routinely taken on each visit
  - Take before other tests or procedures
  - Cuff size important
  - Palpatory method not used with children
  - Heartbeat may be heard to zero; record diastolic when strong heartbeat becomes muffled

# BLOOD PRESSURE

- Orthostatic or postural hypotension
  - Blood pressure becomes low and pulse increases when the patient moves from lying to standing
  - Indicates fluid loss or malfunction of cardiovascular system
  - Vital signs are taken in different positions
  - Positive tilt test – increase in pulse > 10 bpm and a drop in BP > 20 mmHg

# BLOOD CELL COUNTERS

# Blood cell counter

- The blood cell counter count the number of RBC or WBC per unit of volume of blood using either of two method:
  - Electrical method called aperture impedance change
  - Optical method called flow cytometry

# Aperture impedance change

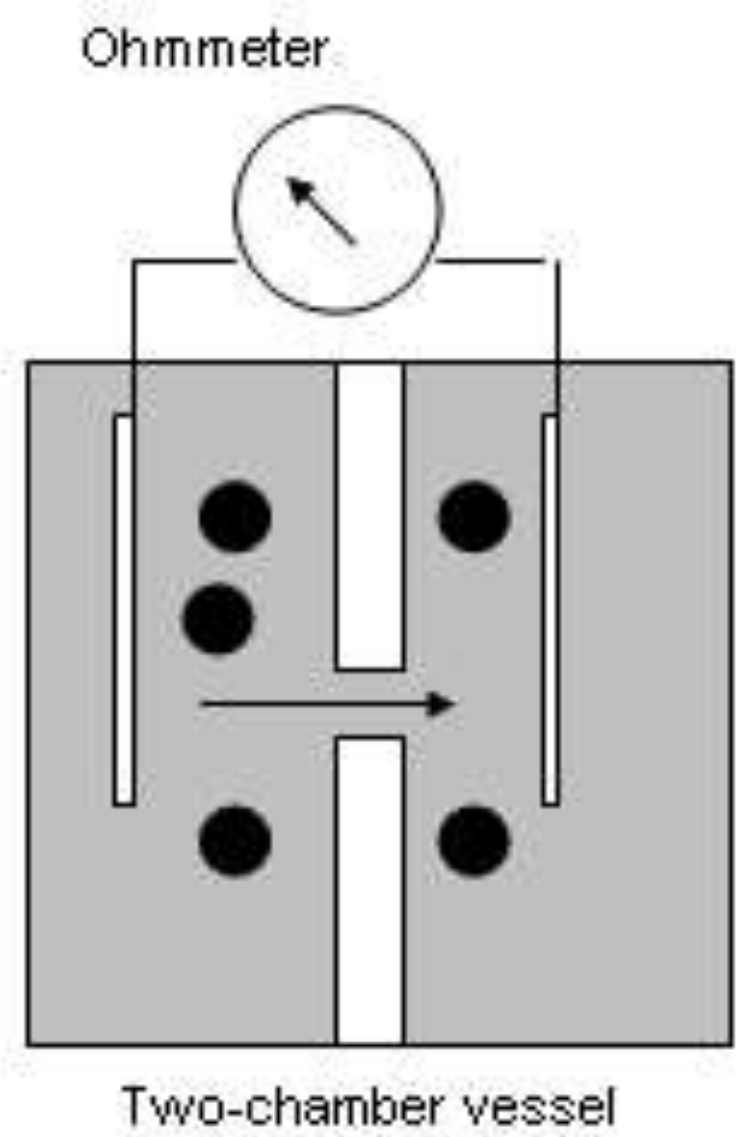
- When blood is diluted in the proper type of solution, the electrical resistivity of blood cells ($\rho_c$) is higher then the resistivity of the surrounding fluid ($\rho_f$)
- By contriving a situation in which these resistivities can be differentiated from each other, we can count cells

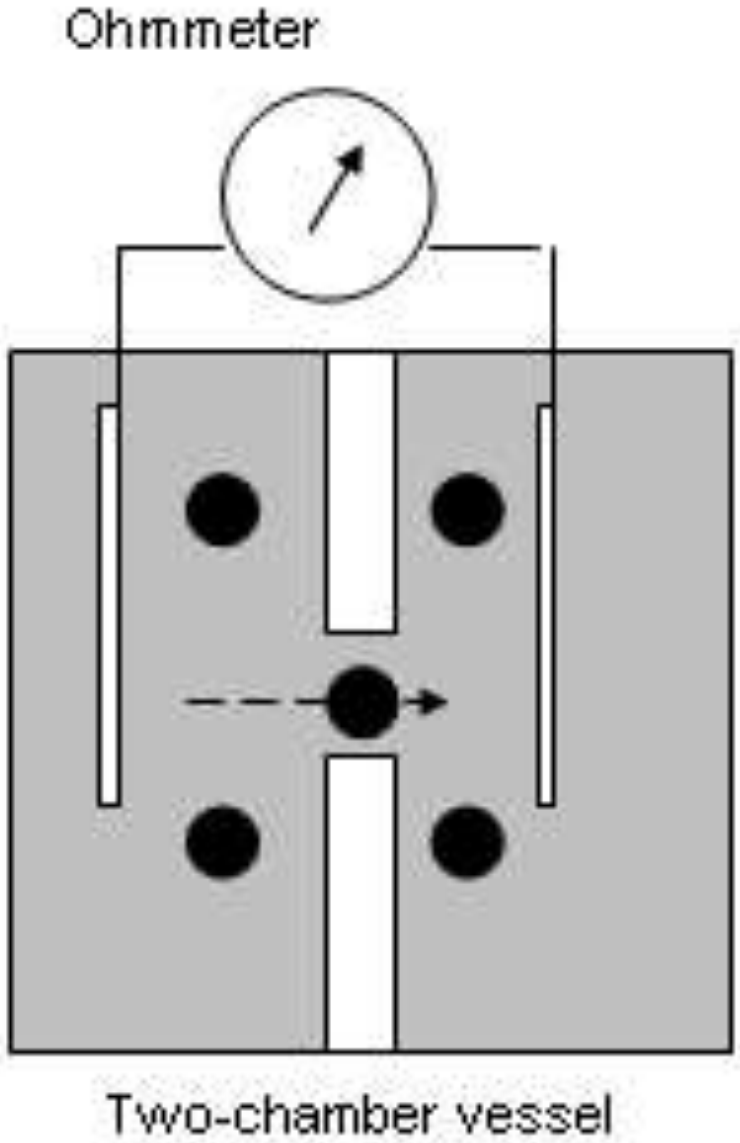
# Aperture impedance change

## *Blood cell sensing*

- **The sensor consist of a two-chamber vessel in which the dilute incoming blood is on one side of barrier, and the waste blood to be discarded is on the other**
- **A hole with a small diameter (50µm) is placed in the partition between the tow halves of the cell**
- **Ohmmeter measure the change on the resistance when the blood cell pass the aperture**

# Blood cell sensing

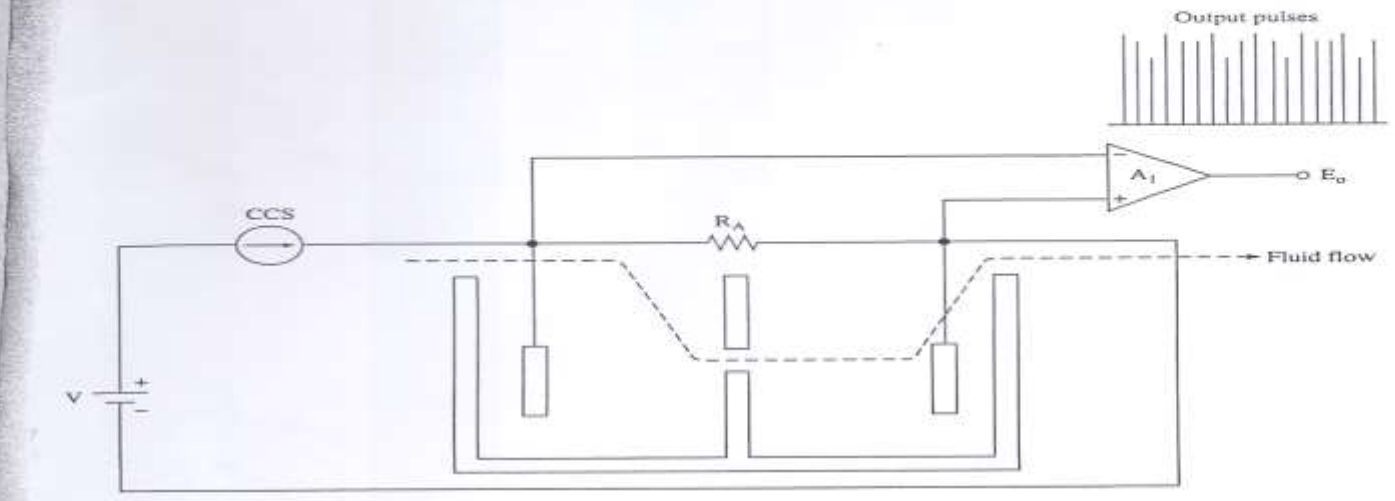


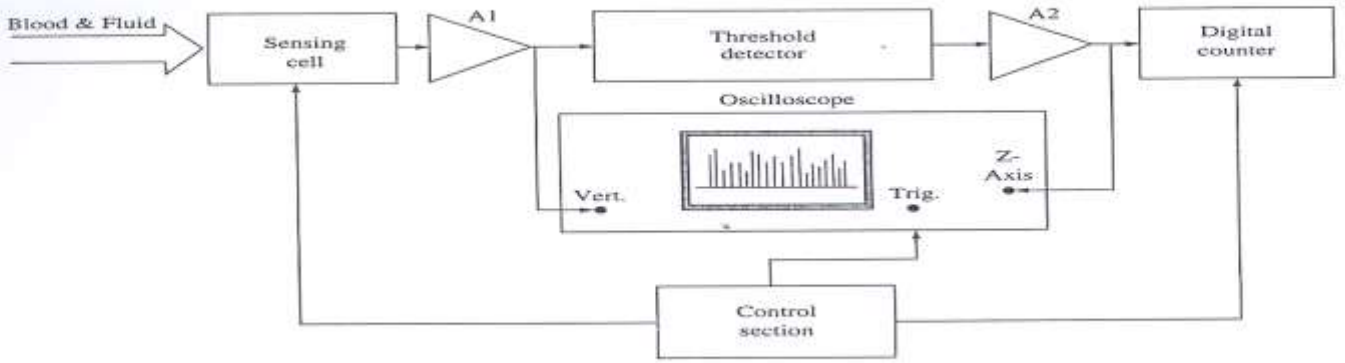
# Coulter Counter

- Constant current source (CCS) and voltage amplifier replace the ohmmeter
- $R_A$ is the resistance of the aperture and will be either high or low, depending on whether or not the blood cell is inside the aperture.
- Amplifier convert the current pulse to voltage pulse

# Schematic




Blood cell counters. *(a)* Coulter model F. *(b)* Coulter model senior.




Impedance aperture cell counter.

# Flow cytometry cell counters

## optical flow cytometry sensing

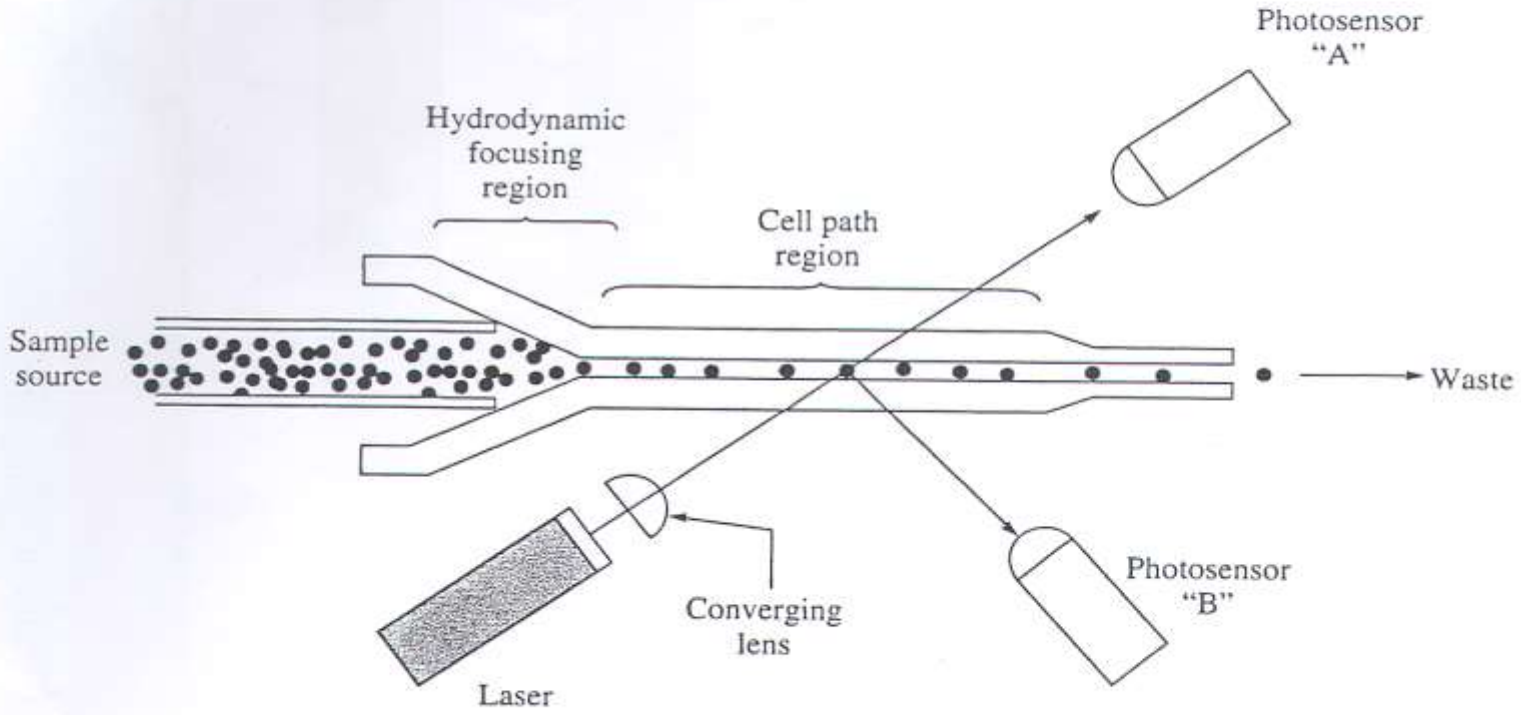
- The optical cytometry sensor consists of a quartz sensing sheath designed with a
  - hydrodynamic focusing region
  - cell path region that passes only a single cell at time.
- Focusing is done by decreasing the diameter of the aperture.
- Light source is (He-Ne) Laser

# Flow cytometry cell counters

## optical flow cytometry sensing

- Two Photodetectors (photosensors)
  - Photodetector A detects forward scatted light
  - Photodetector B detects orthogonal scatted light
- blood sample enters the analyzer
  - Optical counter → WBC count
  - Colorimeter → hemoglobin
  - Optical flow sensor → RBC count

# Schematic




Optical flow cytometry sensor.

# UNIT 3

# CARDIAC PACEMAKERS

# History

- First pacemaker implanted in 1958
- First ICD implanted in 1980
- Greater than 500,000 patients in the US population have pacemakers
- 115,000 implanted each year

# Pacemakers Today

- **Single or dual chamber**
- **Multiple programmable features**
- **Adaptive rate pacing**
- **Programmable lead configuration**

# Chronic AVHB

- **Especially if symptomatic**

  **Pacemaker most commonly indicated for:**
- **Type 2 2º**
  - **Block occurs within or below the Bundle of His**
- **3º Heart Block**
  - **No communication between atria and ventricles**

# Chronic Bifascicular and Trifascicular Block

- **Differentiation between uni, bi, and trifascicular block**
- **Syncope common in patients with bifascicular block**
- **Intermittent 3º heart block common**

# AVHB after Acute MI

- **Incidence of high grade AVHB higher**
- **Indications for pacemaker related to intraventricular conduction defects rather than symptoms**
- **Prognosis related to extent of heart damage**

# Sinus Node Dysfunction

- **Sinus bradycardia, sinus pause or arrest, or sinoatrial block, chronotropic incompetence**
- **Often associated with paroxysmal SVTs (bradycardia-tachycardia syndrome)**
- **May result from drug therapy**
- **Symptomatic?**
- **Often the primary indication for a pacemaker**

# Hypersensitive Carotid Sinus Syndrome

**Syncope or presyncope due to an exaggerated response to carotid sinus stimulation**

- **Defined as a systole greater than 3 sec due to sinus arrest or AVHB, an abrupt reduction of BP, or both**

# Neurally Mediated Syncope

- **10-40% of patients with syncope**
- **Triggering of a neural reflex**
- **Use of pacemakers is controversial since often bradycardia occurs after hypotension**

# Device Selection

- **Temporary pacing (invasive vs. noninvasive)**
- **Permanent pacemaker**

# Pacemaker Characteristics

**Adaptive-rate pacemakers**

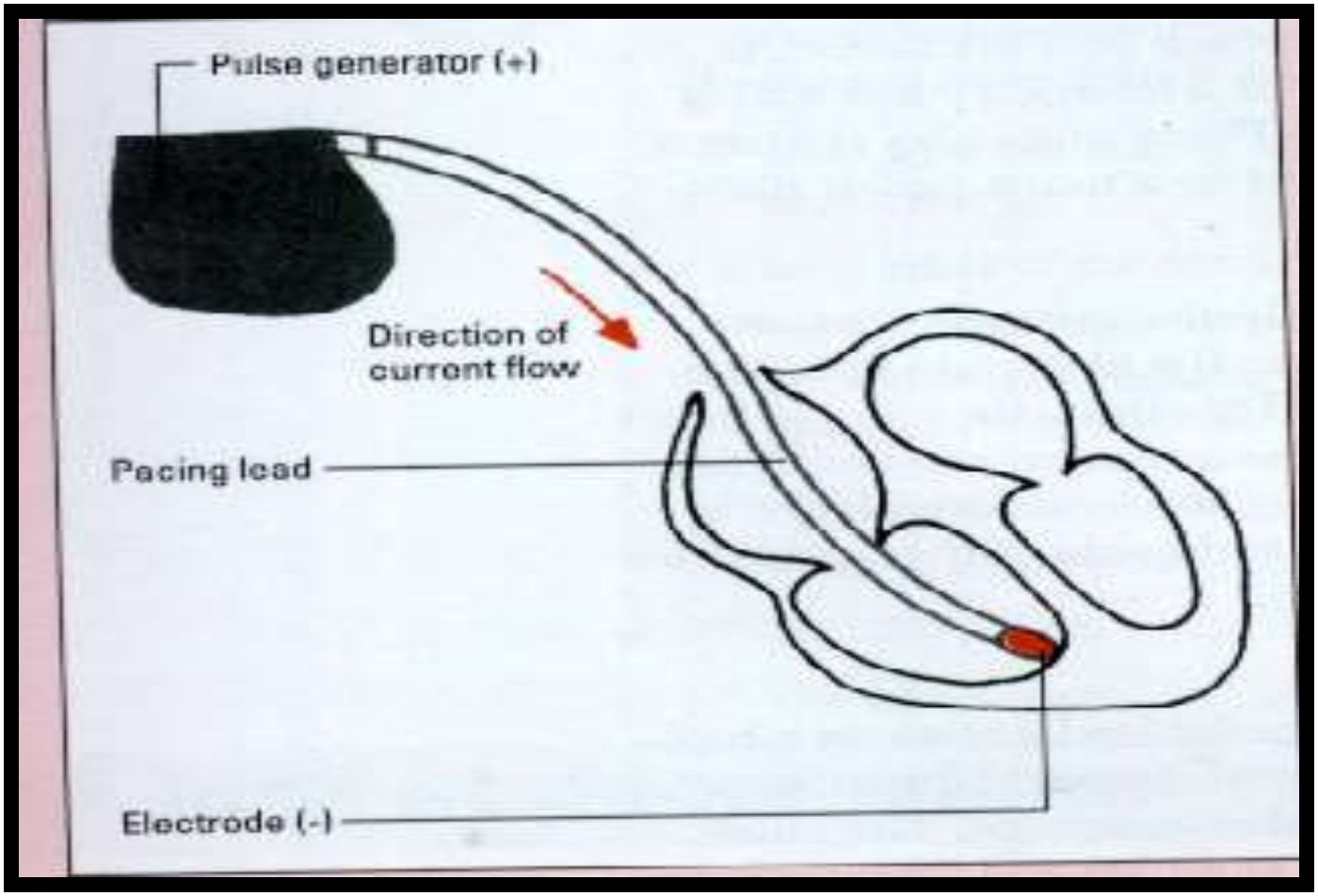
- **Single-pass lead Systems**
- **Programmable lead configuration**
- **Automatic Mode-Switching**
- **Unipolar vs. Bipolar electrode configuration**

# Mechanics

- Provide the rhythm heart cannot produce
- Either temporary or permanent
- Consists of external or internal power source and a lead to carry the current to the heart muscle
- Batteries provide the power source
- Pacing lead is a coiled wire spring encased in silicone to insulate it from body fluids

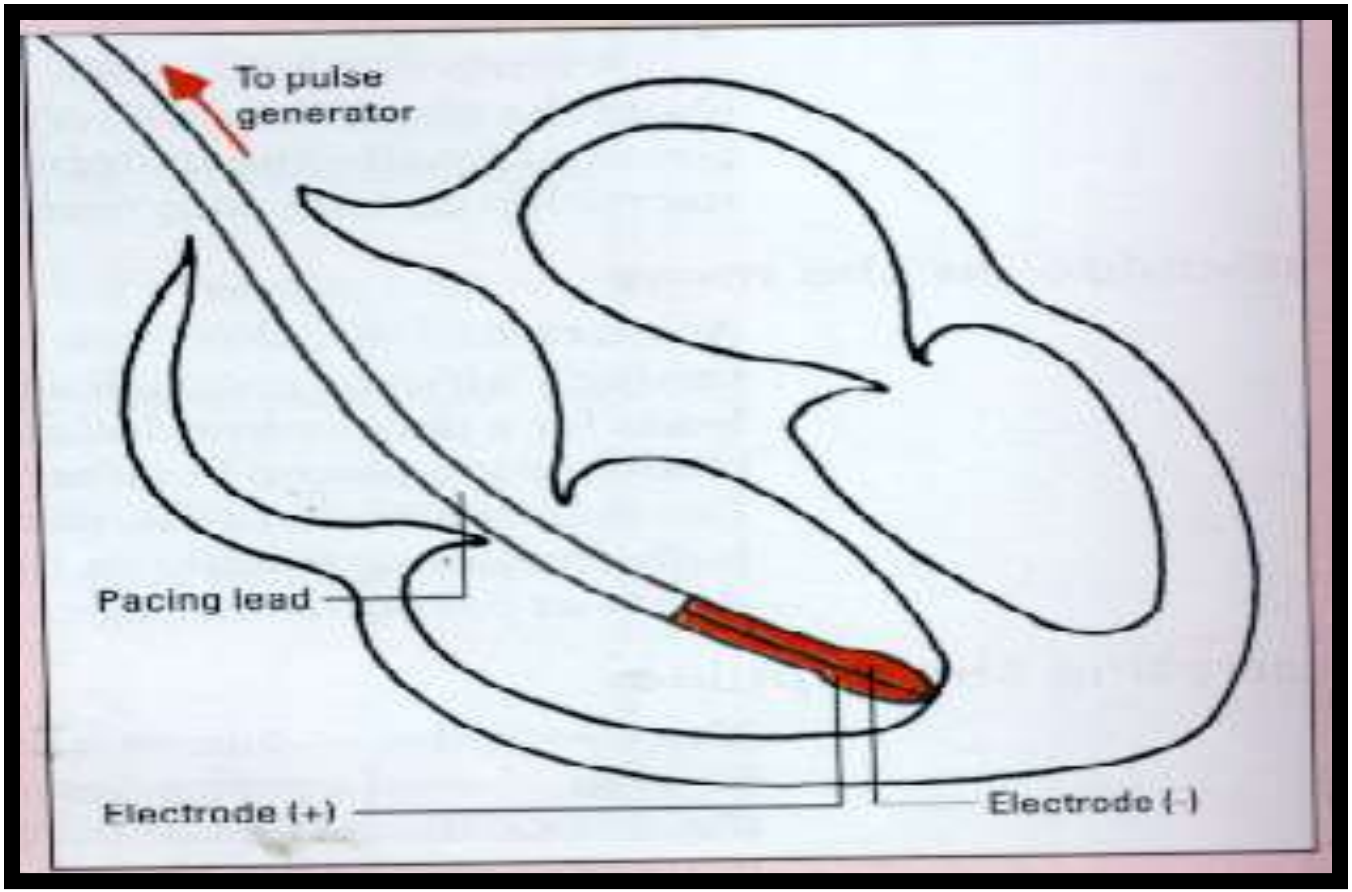
# Unipolar Pacemaker

- **Lead has only one electrode that contacts the heart at its tip (+) pole**
- **The power source is the (-) pole**
- **Patient serves as the grounding source**
- **Patient's body fluids provide the return pathway for the electrical signal**
- **Electromagnetic interference occurs more often in unipolar leads**


Pulse generator (+)
Direction of current flow
Pacing lead
Electrode (-)

# Bipolar Pacemaker

- **If bipolar, there are two wires to the heart or one wire with two electrodes at its tip**
- **Provides a built-in ground lead**
- **Circuit is completed within the heart**
- **Provides more contact with the endocardium; needs lower current to pace**
- **Less chance for cautery interference**


To pulse generator
Pacing lead
Electrode (+)
Electrode (-)

# Indications

1. Sick sinus syndrome (Tachy-brady syndrome)
2. Symptomatic bradycardia
3. Atrial fibrillation
4. Hypersensitive carotid sinus syndrome
5. Second-degree heart block/Mobitz II

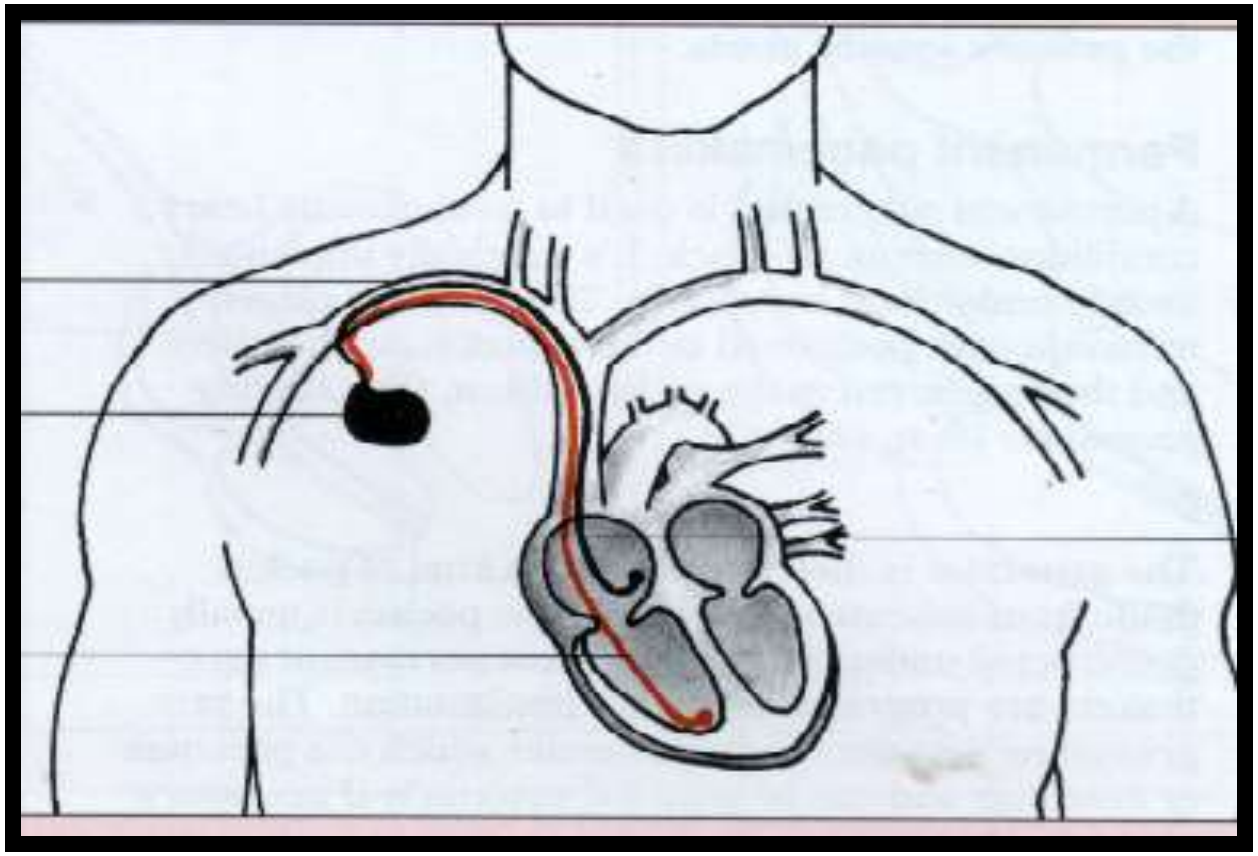
# Indications

6. **Complete heart block**
7. **Sinus arrest/block**
8. **Tachyarrhythmias**

   **Supraventricular, ventricular**

   **To overdrive the arrhythmia**

# Pacemaker Insertion



# Anesthesia for Insertion

**MAC**

- **To provide comfort**
- **To control dysrhythmias**
- **To check for proper function/capture**

**Have external pacer/Isuprel/Atropine ready**

**Continuous ECG and peripheral pulse**

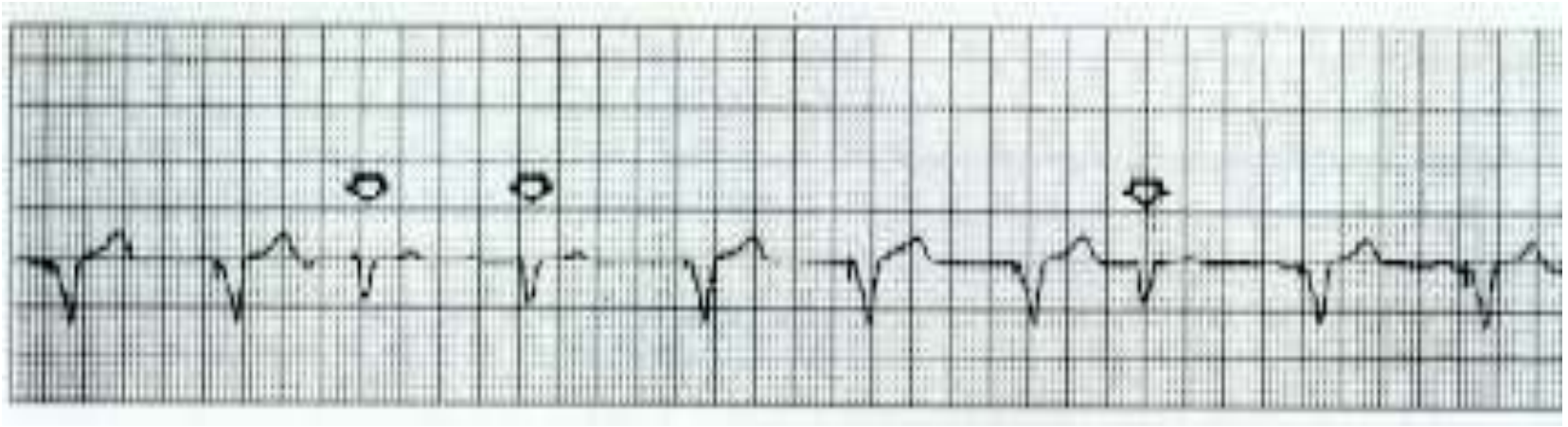
**Pulse ox with plethysmography to see perfusion of each complex**

- **(EKG may become unreadable)**

# Examples of Rhythms

**Sensing**

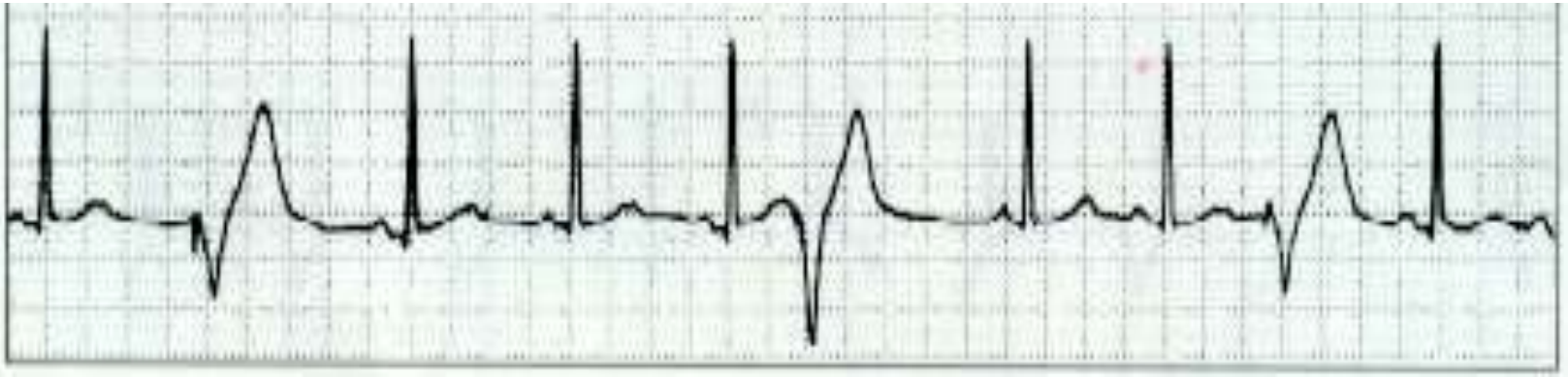
**Patient's own beat is sensed by pacemaker so does not fire**



# Examples of Rhythms

## Undersensing

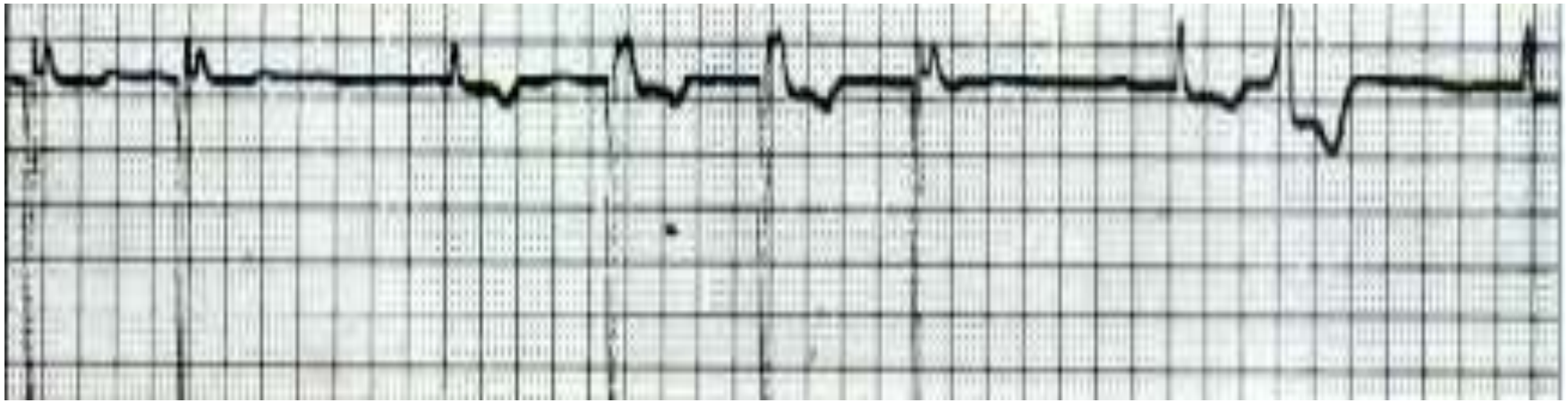
Pacemaker doesn't sense patient's own beat and fires (second last beat)



# Examples of Rhythms

## Oversensing

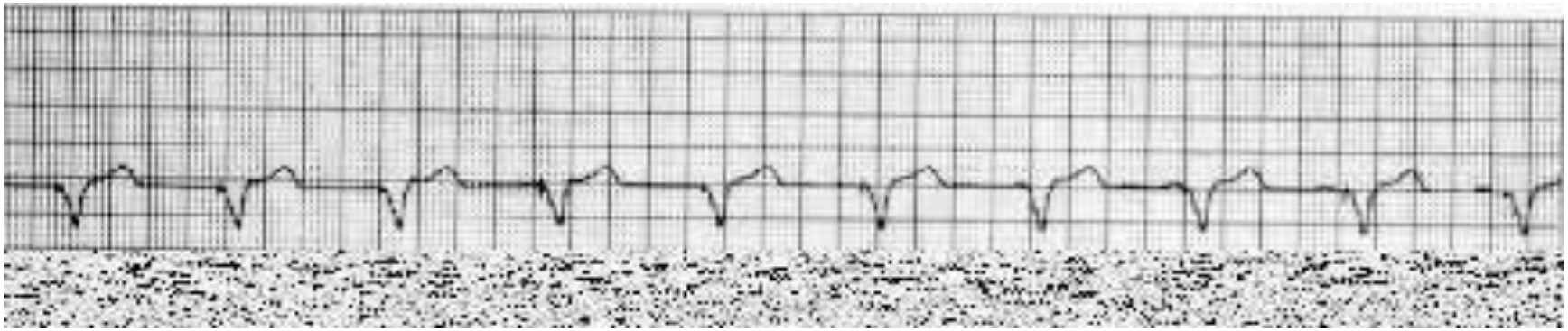
**Pacemaker senses heart beat even though it isn't beating. Note the long pauses.**



# Examples of Rhythms

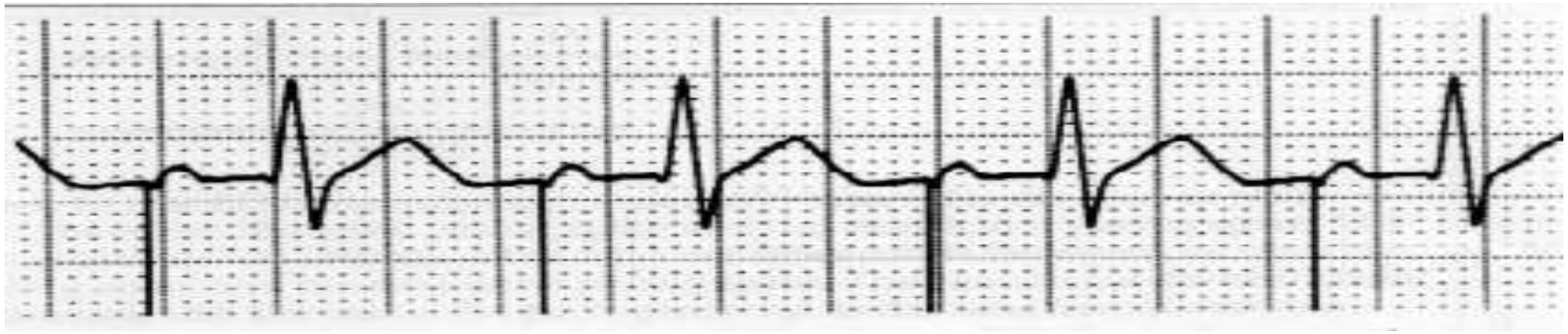
**Capture**

**Pacemaker output (spike) is followed by ventricular polarization (wide QRS).**



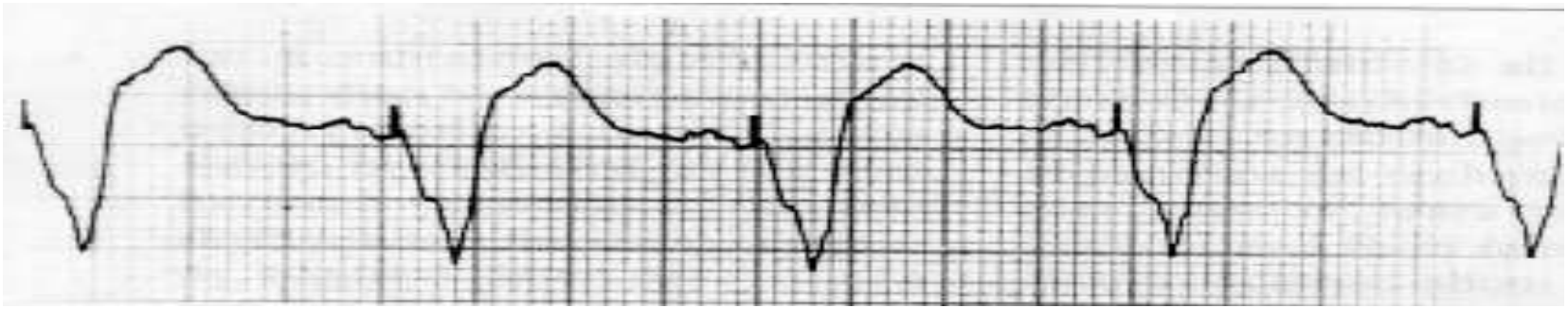
# Examples of Rhythms

**100 % Atrial Paced Rhythm with 100% Capture**



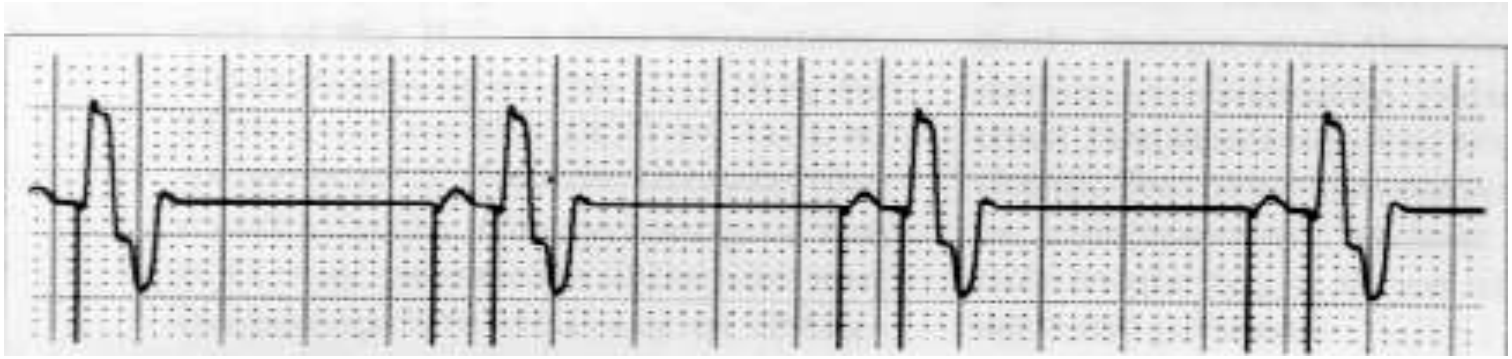
# Examples of Rhythms

**100% Ventricular Paced Rhythm with 100% Capture**



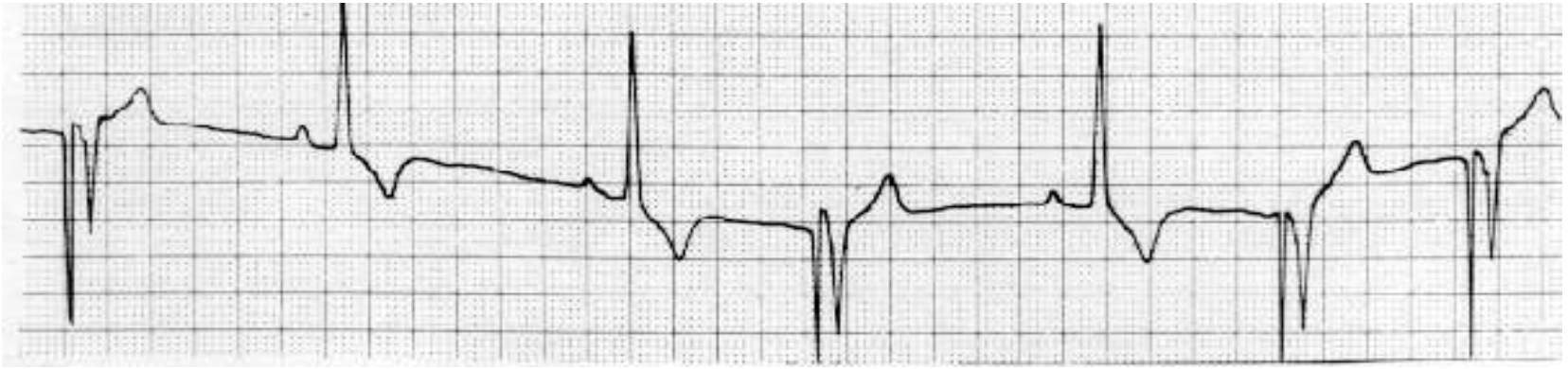
# Examples of Rhythms

## 100% Atrial and 100% Ventricular Paced Rhythm with 100% Capture



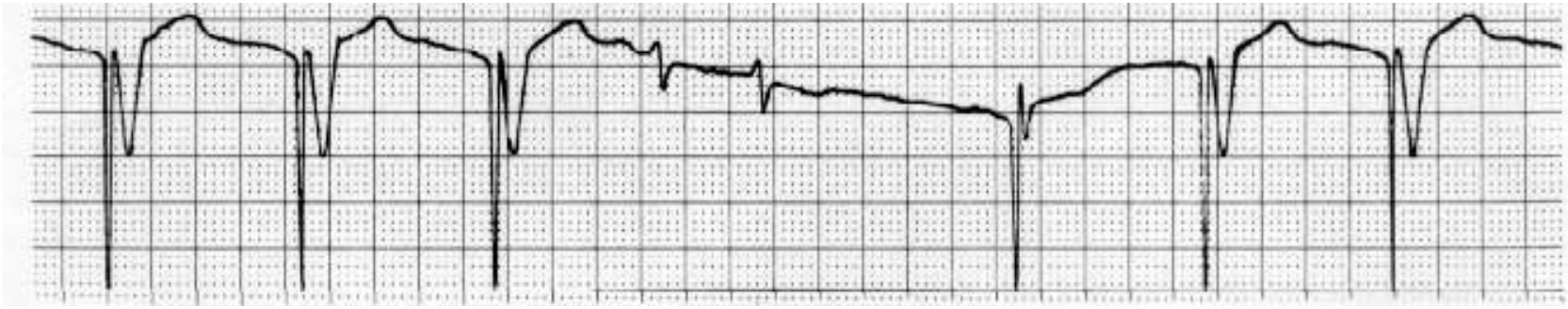
# Examples of Rhythms

**50% Ventricular Paced Rhythm with 100% Capture**



# Examples of Rhythms

**25% Ventricular Paced Rhythm with 100% Capture (Note the sensing that occurs. Pacer senses intrinsic HR and doesn't fire).**



# DEFIBRILLATOR

# Definition

- The *defibrillator* is an electrical device that delivers a pulse of therapeutic current intended to reverse a ventricular fibrillation (VF) or a life-threatening ventricular tachycardia (VT) in the heart of a patient.

- A current applied to the surface of the body in excess of 80 milliamps and less than 1 ampere such that it passes through the heart is apt to cause it to fibrillate.
  - The result is that the cardiac output falls to less than that required to sustain life.
    - This is electrocution.

- However, if the current exceeds 1 ampere, it carries enough energy to cause all of the cardiac muscle fibers to contract simultaneously and cause the heart to stop fibrillating.
  - The current pulse needs to be controlled very carefully.
    - If it is too small, it causes fibrillation, and
    - if it is too large, it can cause burn injuries.

# DEFIBRILLATOR PRINCIPLES

- The early clinical applications of defibrillation in 1956 by P. M. Zoll used an AC current pulse to defibrillate with some success.
  - However, the reliability was significantly improved in 1962 when B. Lown introduced a defibrillator that delivered a short DC pulse of current to the heart through the chest wall.

- Defibrillation occurs because the strong current stimulus causes simultaneous contraction of all of the muscles in the heart.
  - The first region to repolarize after the pulse is the sinoatrial (SA) node.
    - It, therefore, regains control of the pacing of the heart.

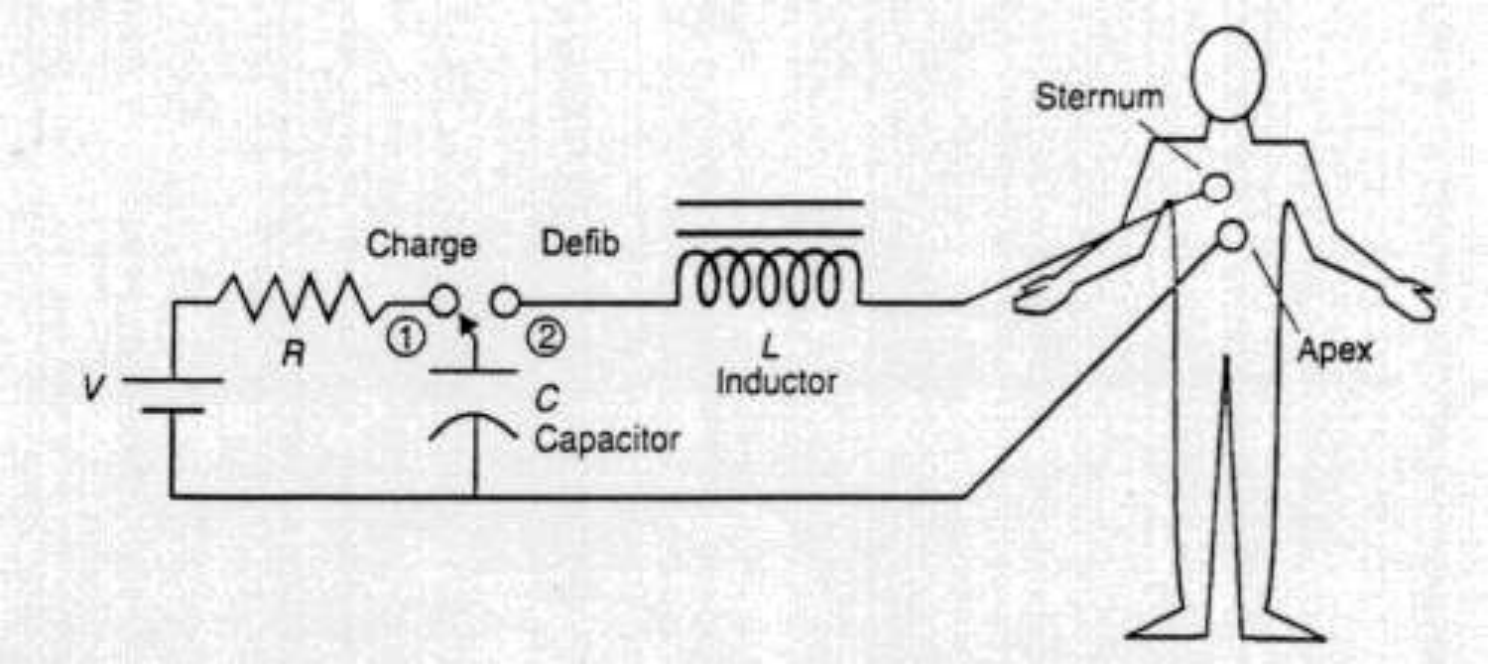
- The effective and safe use of the defibrillator depends upon the proper diagnosis of the symptoms of sudden cardiac death (SCD) and upon quick response.
  - Accurate diagnosis is crucial because the defibrillator pulse can induce fibrillation into a heart that is normally beating.
  - The need for quick response is necessary because the probability of reversing a fibrillation with a defibrillator declines rapidly after only one minute.

- Therefore, the effectiveness of the defibrillator has been improved by making self-diagnostic models available, especially to people with less medical training, such as
  - fire fighters,
  - paramedical professionals, and even
  - laypeople in the home of a cardiac patient.

- These people decrease the response time by their close availability to the victim of SCD who inherently has little or no warning.
  - In addition, implanted defibrillators are available to patients who have survived SCD and are susceptible to further attacks.

# Lown Defibrillator Circuit

- An electrical circuit introduced by Lown to deliver a short, high-current pulse to a patient.



- To prepare the defibrillator for external use, it is necessary to charge the capacitor up to between 1,000 and 6,000 volts.
  - This is done by putting the switch in the charge position, so that the battery voltage, stepped up to these high levels, can be applied to the capacitor.

- The capacitor consists of two pieces of metal separated by an insulating material.
  - If it is made to stand alone, the capacitor will hold its charge for a long time, minutes or even hours in some cases.

- That is, the capacitor stores energy, $W_A$, which develops a voltage, $V$, across its metal plates.
  - The amount of energy in units of joules is given by

$$W_A = C\frac{V^2}{2}$$

    - where $C$ is the value of the capacitance measured in units of farads and $V$ is the voltage across the capacitor.

- The energy stored in the capacitor is proportional to the square of the voltage between its plates.
  - The amount of energy typically stored in the capacitor of a defibrillator, so that it can be later delivered to the patient, ranges from 50 to 400 joules.

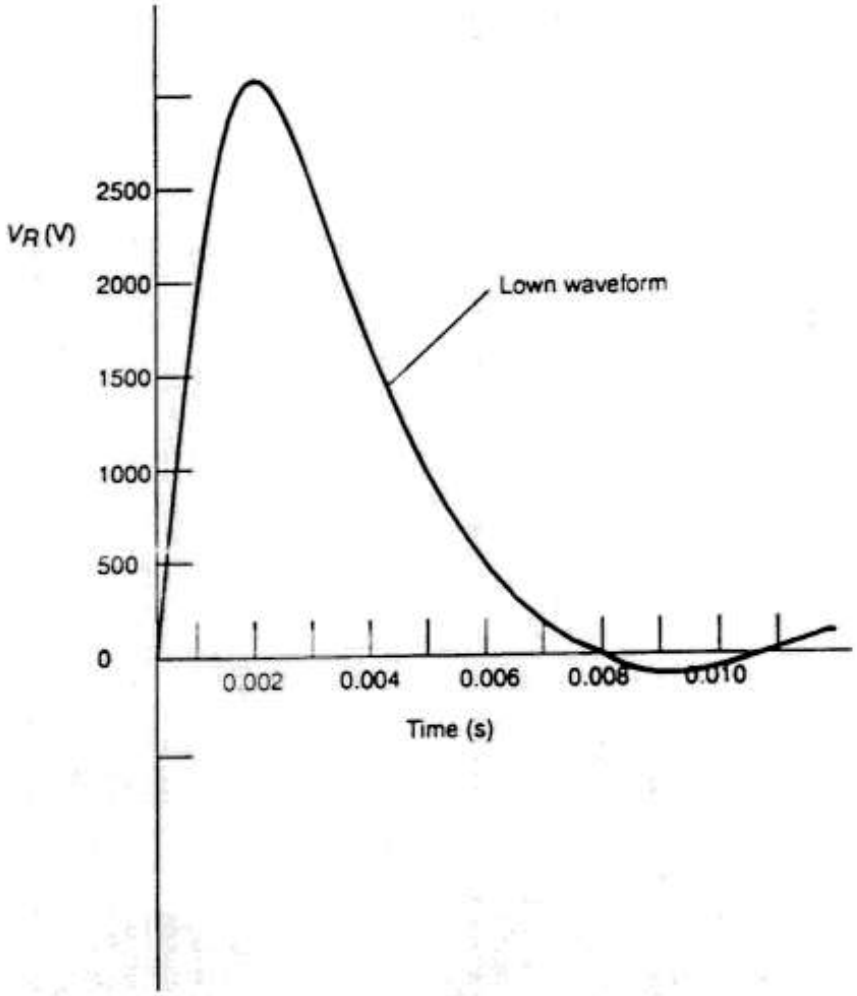
# Defibrillator Pulse Voltage and Energy

- It is important for the defibrillator user to understand the voltage pulse output because its shape is an indicator of proper defibrillator operation.
  - Early defibrillators had an erroneous waveform and were not reliable.

- An understanding of how the energy is distributed among the human—machine interface components determines whether the patient receives the appropriate therapy or whether an injury is inflicted.

- The defibrillator pulse is generated by the basic circuit.
  - After the capacitor has been charged with the switch in position 1, the defibrillator is ready to deliver a voltage pulse to the patient.
  - This delivery is made by putting the switch in the discharge position, 2.

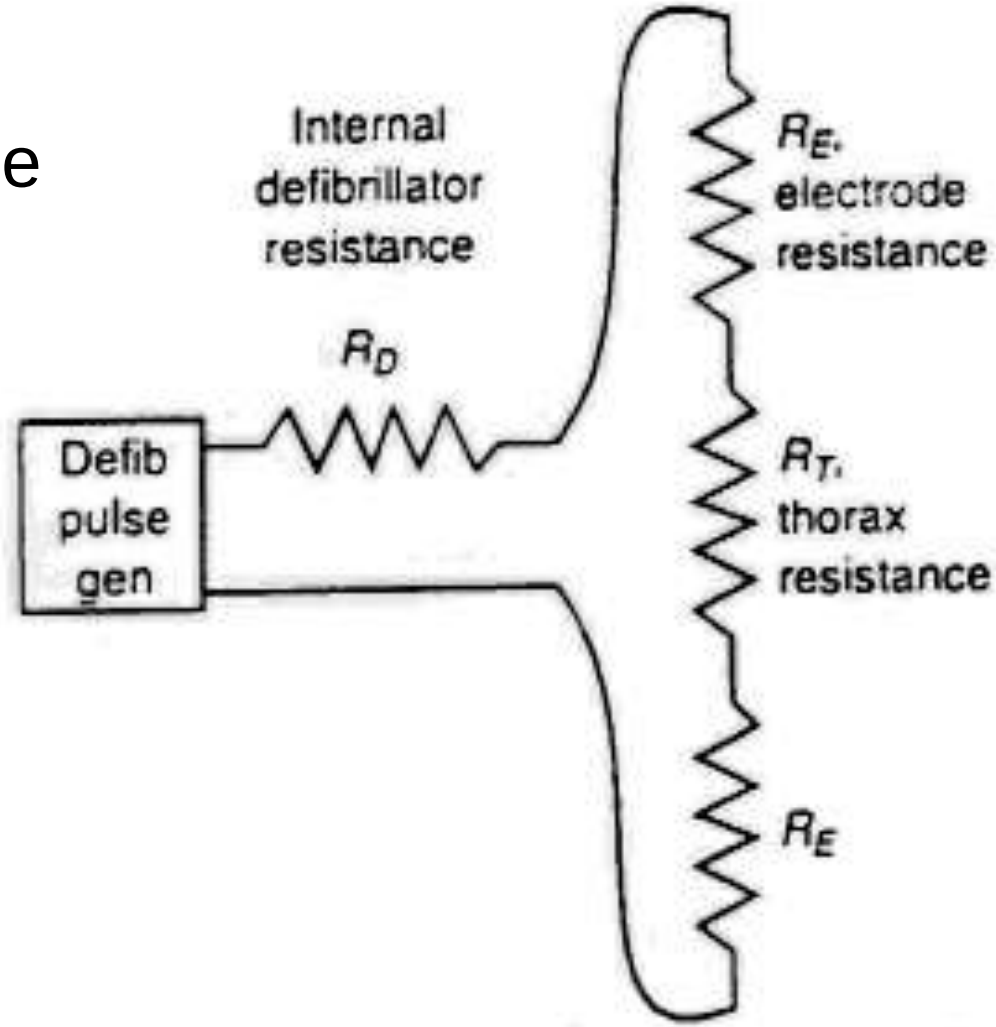
- A voltage waveform across the patient is developed.
  - The current is zero at the instant after the switch is thrown because the energy goes into building up a magnetic field around the inductor, *L.*
  - As that magnetic field builds up, the current, and therefore the voltage, increases in the paddle and patient resistances, causing the initial rise in voltage in the waveform.
  - After the energy stored in the capacitor becomes depleted, the current falls, causing the waveform to peak and then diminish to zero again.



- The oscillation of the energy between the capacitor and inductor after the initial pulse sometimes causes a small ripple to follow, but that should have no significant physiological effect.
  - The inductor and capacitor values are chosen to make a pulse to peak at about 2,600 volts and have a duration of approximately 7 milliseconds.

- All of this energy does not get into the patient.
  - Some is lost in the internal resistance of the defibrillator circuit, $R_D$ and some is wasted in the paddle—skin resistance, $R_E$ .

- To calculate how much of this energy gets to the patient, resistance $R_T$, consider the equivalent circuit.
  - The four resistors in this circuit are in series.



- Therefore, the current in each of them is the same.
  - And the energy absorbed by any one resistor is proportional to the total available energy, according to the voltage division principle.
    - The formula for the energy absorbed by the thorax, $W_T$ is

$$W_T = \frac{R_T}{R_D + 2R_E + R_T} W_D$$

# Diagnostic Defibrillator

- Ventricular fibrillation is a common initial rhythm in sudden cardiac death.
  - Early defibrillation is accepted as the most effective means of improving survival rates in ventricular fibrillation.

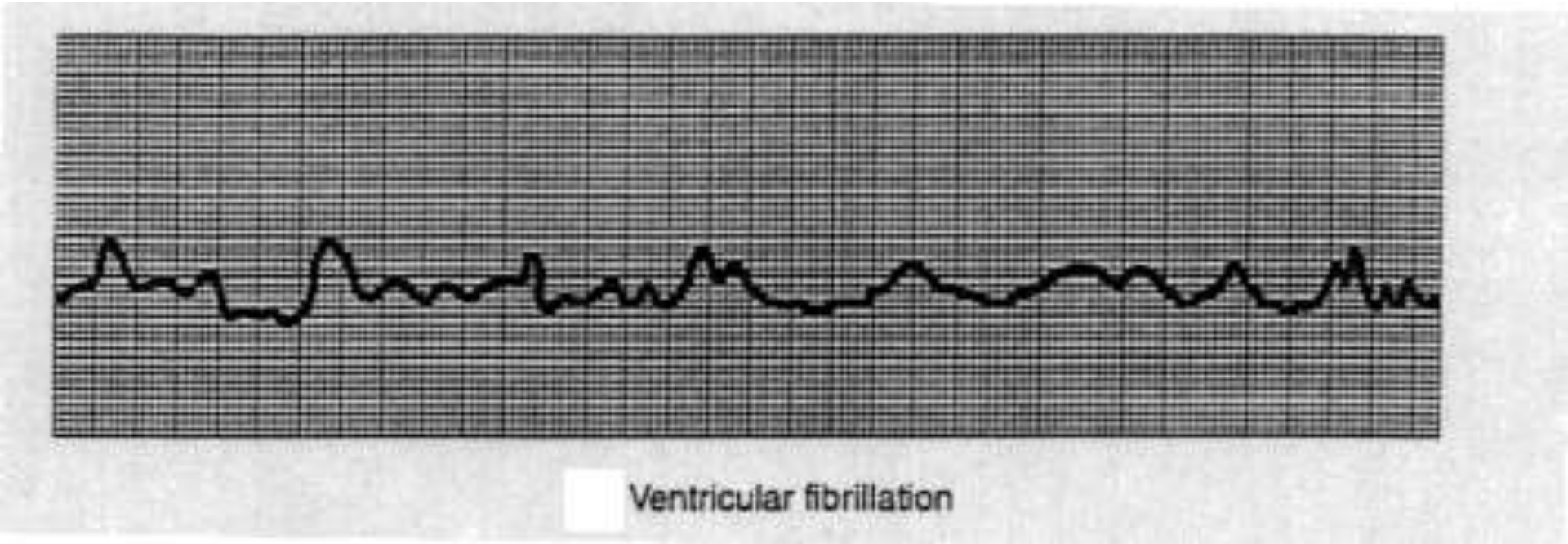
- The greatest impediment to early defibrillation is the fact that many cardiac arrests occur outside the hospital.
  - When communities added early prehospital defibrillation to their Advanced Cardiac Life Support (ACLS) protocols, survival rates improved.
    - Unfortunately, one of the major hazards in using a defibrillator is the misdiagnosis of a fibrillating heart.

- The major symptoms visible without the aid of diagnostic equipment are
  - A loss of consciousness,
  - Dilated pupils,
  - Lack of pulse, and
  - Apnea.

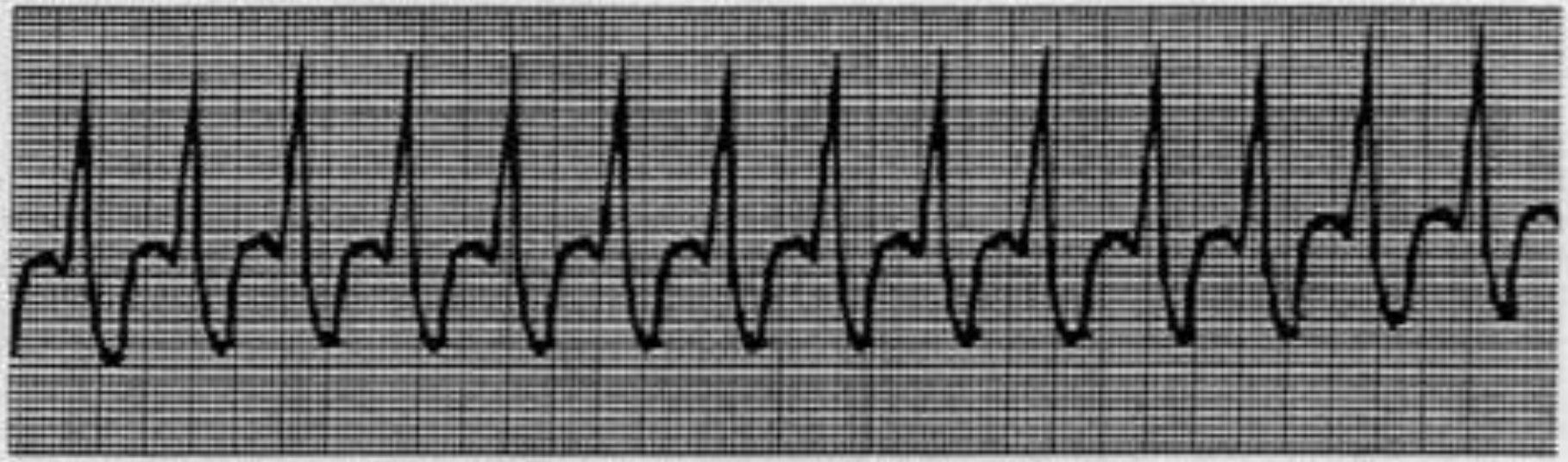
- These symptoms require skill and training to assess and can be misinterpreted.
  - If the defibrillating current is delivered to a normal heart, and if it hits during the *T* wave (when the heart is most vulnerable), it may cause the heart to fibrillate.

- Therefore, it is necessary to have positive evidence that the heart is fibrillating before the defibrillator is used.
  - This may be obtained from the EGG waveform.

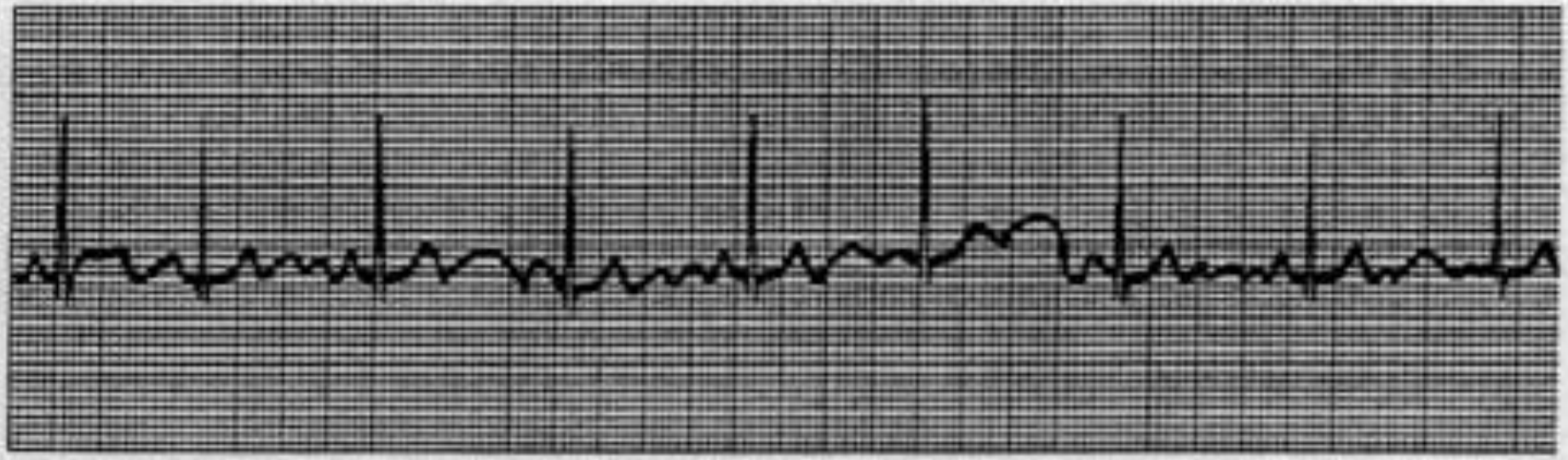
- The fibrillating EGG is characterized by a lack of *QRS* complexes and a visible component of approximately 150-cycle oscillations.



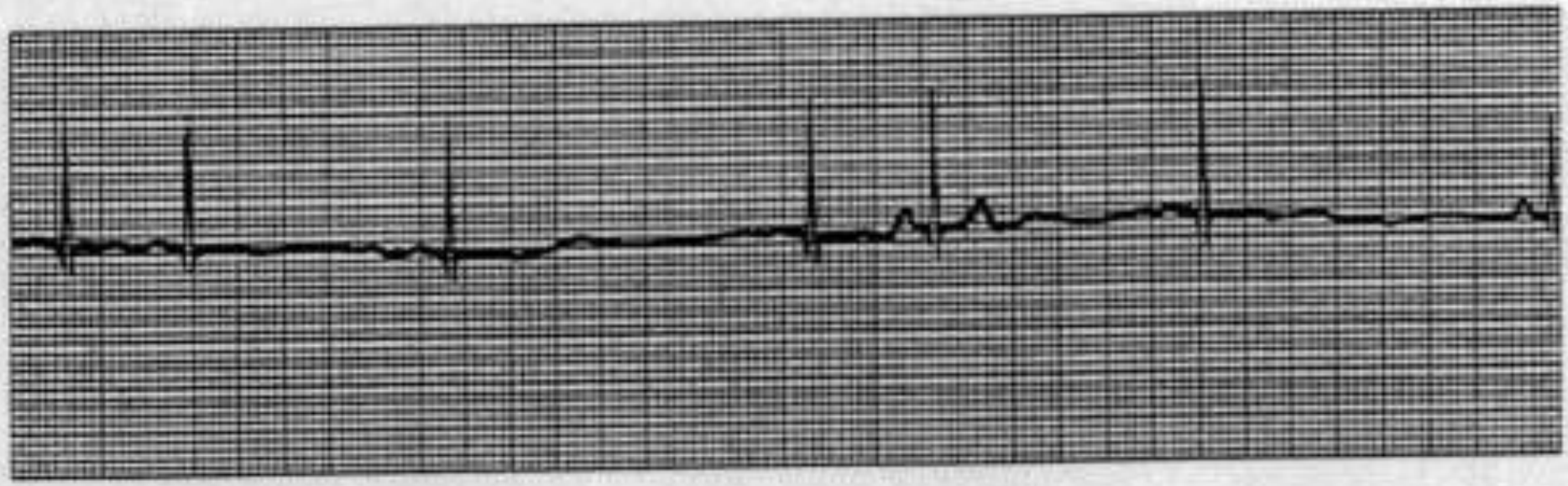
Ventricular fibrillation



Ventricular tachycardia



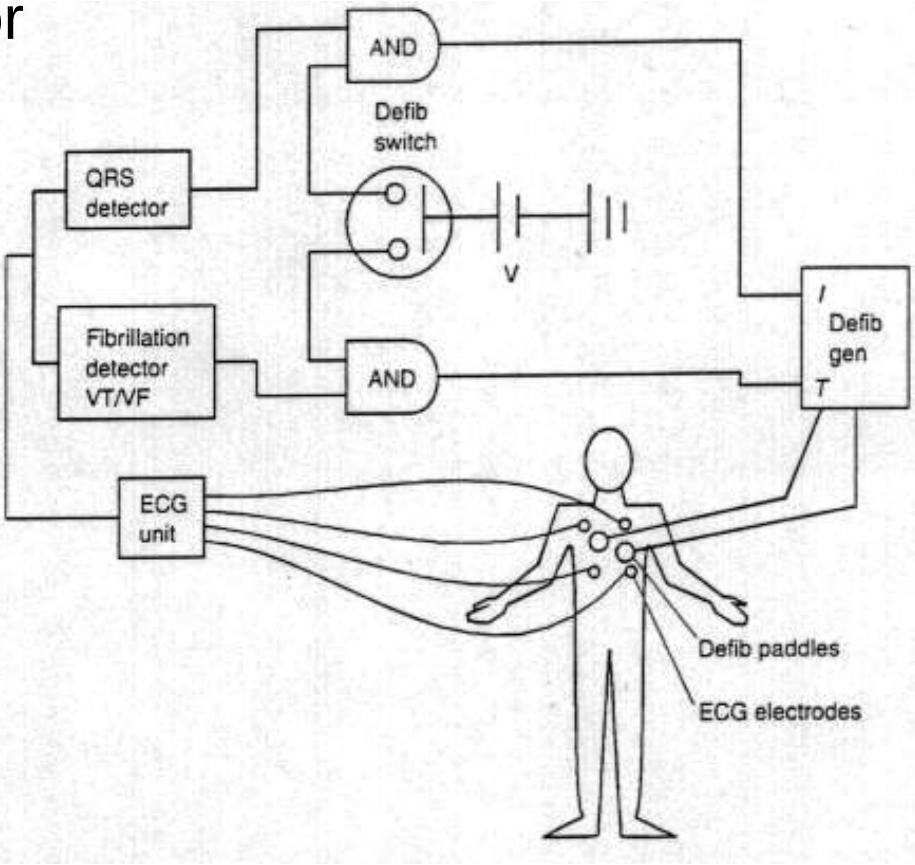
Atrial flutter



Atrial fibrillation

- In an attempt to provide early defibrillation to more of the population, a large number of emergency service people, such as firemen and policemen, who are not used to treating arrhythmias have been trained in the use of the simple automatic external or diagnostic defibrillator.

- The operation of this defibrillator is best explained by beginning with the patient who is wired with four ECG leads placed in the standard position.
  - The EGG waveform information is processed by the EGG unit to the lower left.
  - The output waveform is then applied to the *QRS* detector and the fibrillation detector.



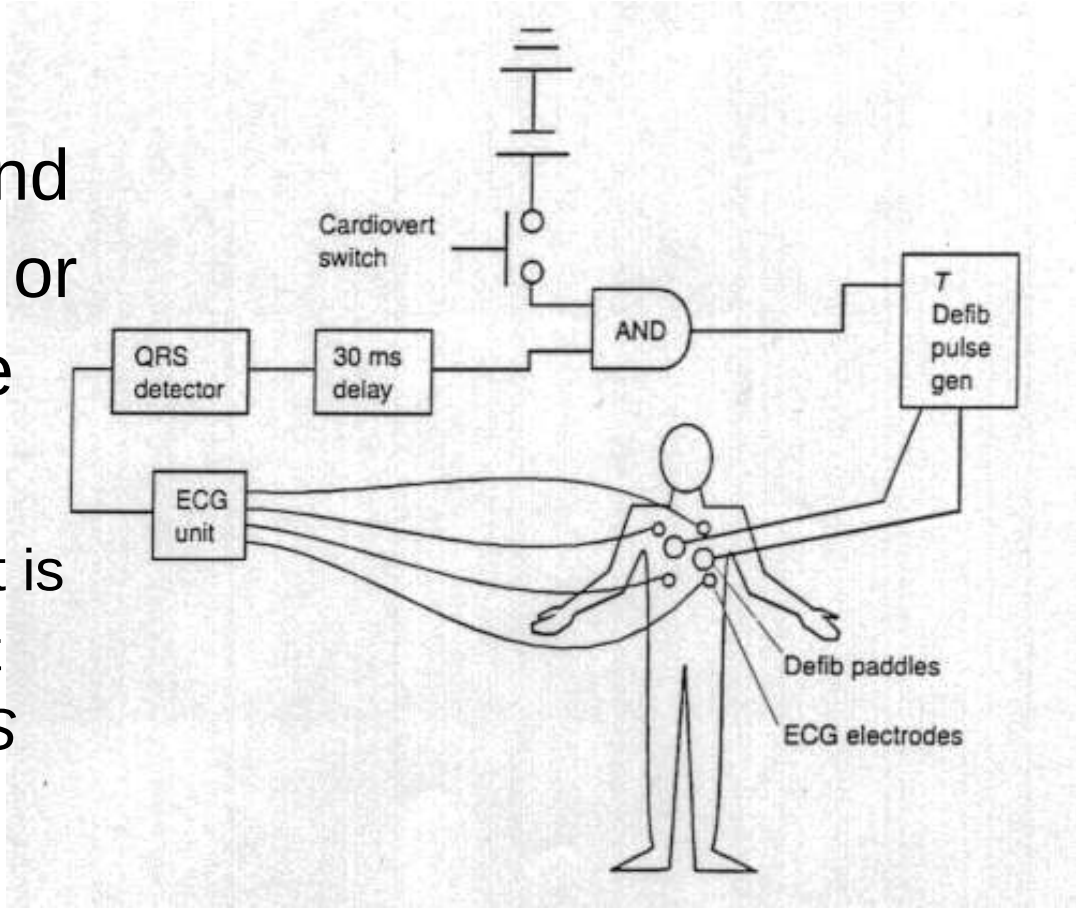
- If the *QRS* is present, a signal will be applied to the upper lead of the upper AND gate.
  - Then if the attendant pushes the *defib* switch, placing a signal on the lower lead also, the AND gate will deliver an inhibiting signal to the defibrillator pulse generator.
    - An AND gate generates an output signal only when stimulus is present on both the upper *and* the lower input terminals.

- If there is no *QRS* and the fibrillation detector delivers a stimulating pulse to the lower lead of the lower AND gate, then when the attendant activates the *defib* switch, a stimulus will be put on both terminals of that gate, and its output will trigger the defibrillator.
  - Thus, the defibrillator will deliver a therapeutic current pulse through the large electrodes on the sternum and apex to the patient's chest.

# Cardioverter

- When a physician diagnoses evidence of an abnormal supraventricular rhythm, such as an atrial flutter or a hemodynamically stable ventricular tachycardia, he or she may prescribe for the patient to be cardioverted.
  - A *cardioverter* delivers a defibrillating pulse to the heart synchronized on the *R* wave so that it does not accidentally cause ventricular fibrillation.

- Here, the leads are placed in the standard position on the chest, and the defibrillator paddles or adhesive electrodes are placed appropriately.
  - The EGG from the patient is amplified by the EGG unit and presented to the *QRS* detector.



- When the *QRS* is present, a signal from the output of the detector is passed through approximately 30 milliseconds of delay and then presented to the AND gate.
  - If the attendant is holding down the cardiovert switch, the AND gate will trigger the defibrillator pulse generator.
    - It then defibrillates the heart approximately 30 milliseconds after the *QRS.*

- This is the point in time that the heart normally depolarizes and delivering the defibrillation pulse at that time should not cause the heart to fibrillate.
  - The timing is important to keep the current pulse from hitting the heart during the *T wave*, when the ventricle may become partially depolarized and cause the heart to fibrillate.

# TELEMETRY

# Definition

**Telemetry : The process of making measurements on an object in the remote area and sending those measurements to a distant location for analysis**

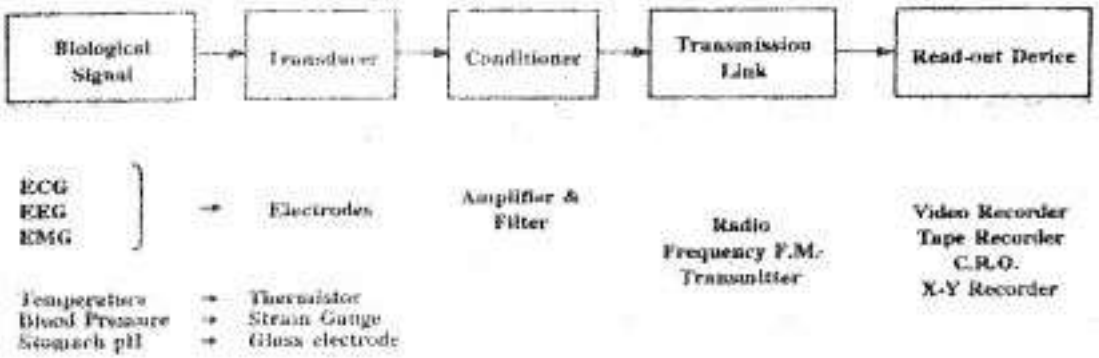
**Bio-Telemetry : The process of acquiring the biological information of a living organism along with their environment and sending those information to a distant location for analysis**

# DIFFERENT TYPES OF BIO TELEMETRY SYSTEM

# ELEMENTS OF BIOTELEMETRY SYSTEM

- The transducer converts the biolog9ical variable in to electrical
- Signal conditioner amplifies and modifies this signal for effective transmission
- Transmission link connects the signal input blocks to the read out devices by wire(or)wireless mean

# Block diagram of a bio-telemetry system



# Design of bio-telemetry system

The telemetry system should be selected to transmit the bio-electric signals with maximum fidelity and simplicity.

The size and weight of the telemetry system should be small.

It should have more stability and reliability

The power consumption should be very small.

# Radio telemetry systems

There are two types

1.single channel telemetry system

2.multichannel telemetry system

Single channel telemetry system:

A miniature battery operated radio transmitter is connected to the electrodes of the patients

Radio receiver which detects the radio signals and recovers the signals for further processing.

Receiving system can even be located in a room separate from the patien

few hundred kHz to about 300mHz

# Block diagram

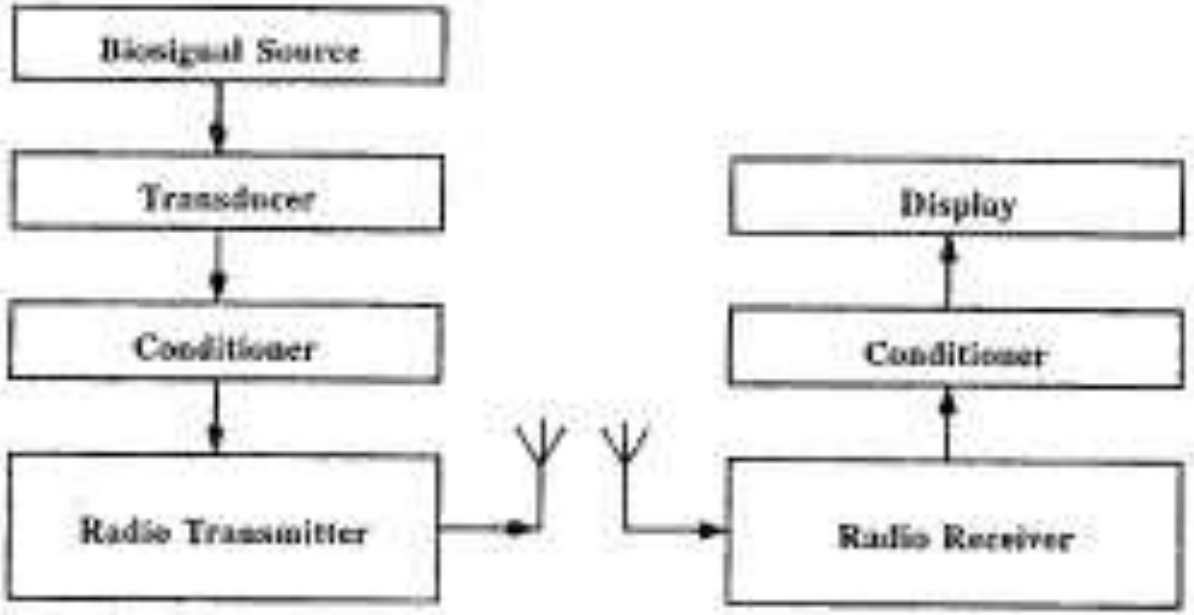



Fig.8.2. Block diagram of a typical single channel radio telemetry system

# Transmission of bio electric variables

- Active measurement:
- bioelectric variables like ECG,EMG and EEG are measured directly with out using any excitation voltage
- Passive measurement:
- Here the physiological variables like blood pressure,temperature,blood flow etc are measured indirectly using transducer and excitation voltage

# Tunnel diode fm transmitter

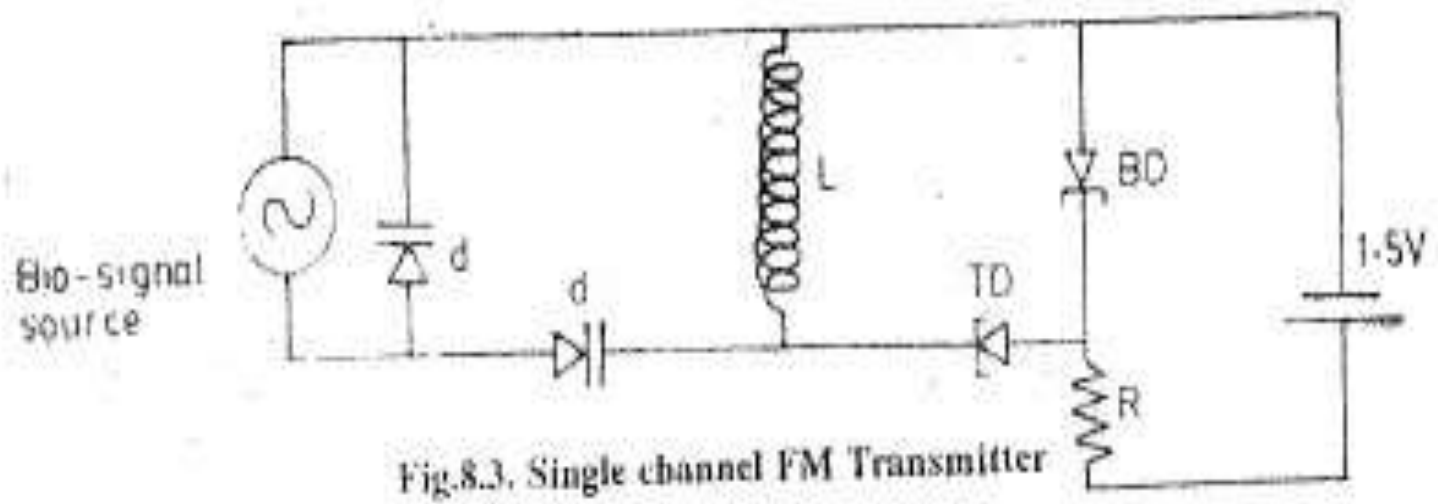



Fig.8.3. Single channel FM Transmitter

This circuit has higher fidelity an sensitivity

Total weight is about 1.44gm with battery

Radio frequency used - 100 to 250mhz

Frequency response - 0.01hz to 20khz

Input impedance - 300kilo ohms to mega ohms

Temperature stability for carrier freq -0.05%/c

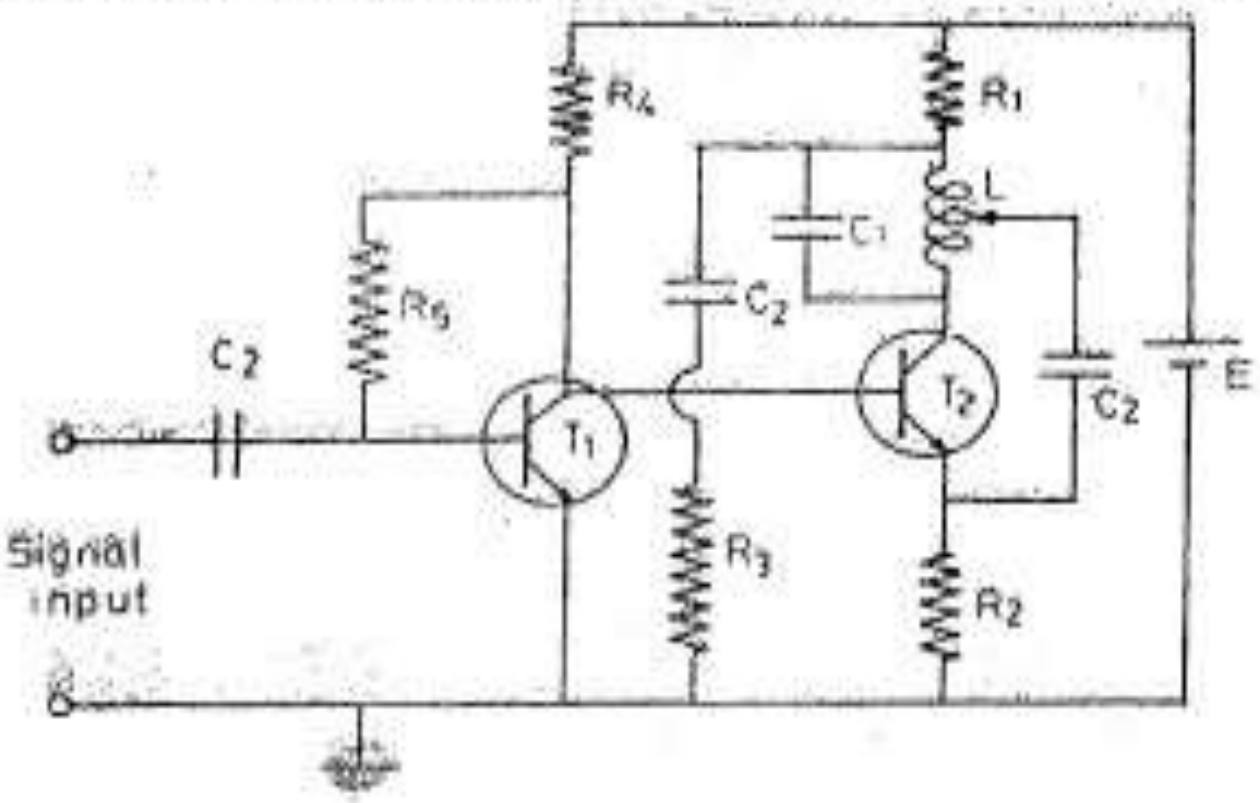
Varactor diodes d which are voltage sensitive semi conductor capacitors are used for freq modulation

The signal is transmitted through the inductor L

# Hartley type F.Mtransmitter

- In this circuit ,the capacitor c1 and inductor l1 form the tank circuit.
- Capacitor  c2 are coupling capacitors
- T1 is the driver amplifier capacitor and T2 is the oscillating transistor.
- Amplitude of i/p signal  varies from 10uv to several millivolts.
- Bandwidth of the signal is from 100hz to 1000hz.

b) Hartley type F.M. Transmitter (for the transmission of ECG, EEG & EMG)



# Radio telemetry with a sub-carrier

When the relative position of transmitter to the body or other conduction object changes,the carrier frequency and amplitude will change.

To avoid this loading effect,the subcarrier system is needed.

The signal is modulated on a subcarrier to convert the signal frequency to the neighbourhood of the subcarrier frequency.

At the receiver end,the receiver detects the R.F. and recovers the subcarrier carrying the signal.

All noise interference and loading effect can be separated by filters

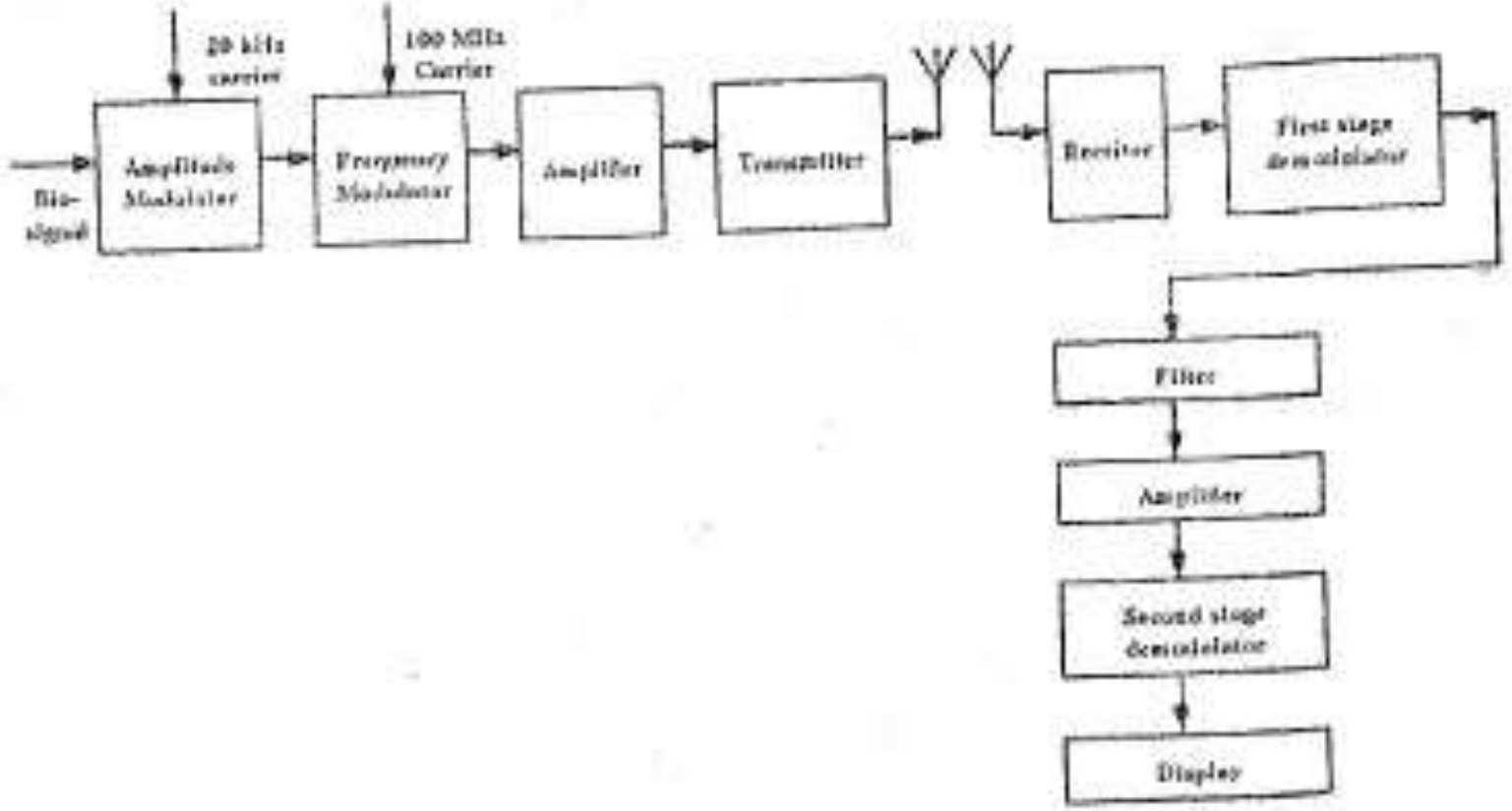



Fig.8.6. Biotelemetry system with a subcarrier

# Multiple channel telemetry system

There are two types :

1. Frequency division multiplex
2. Time division multiplex

## Frequency division multiplex system:

Each signal is frequency modulated on a subcarrier frequency

Then these modulated subcarrier frequencies are combined to modulated the main R.F. carrier.

The frequency of the subcarriers has to be carefully selected to avoid interference

The low pass filters are used to extract the signals without any noise.

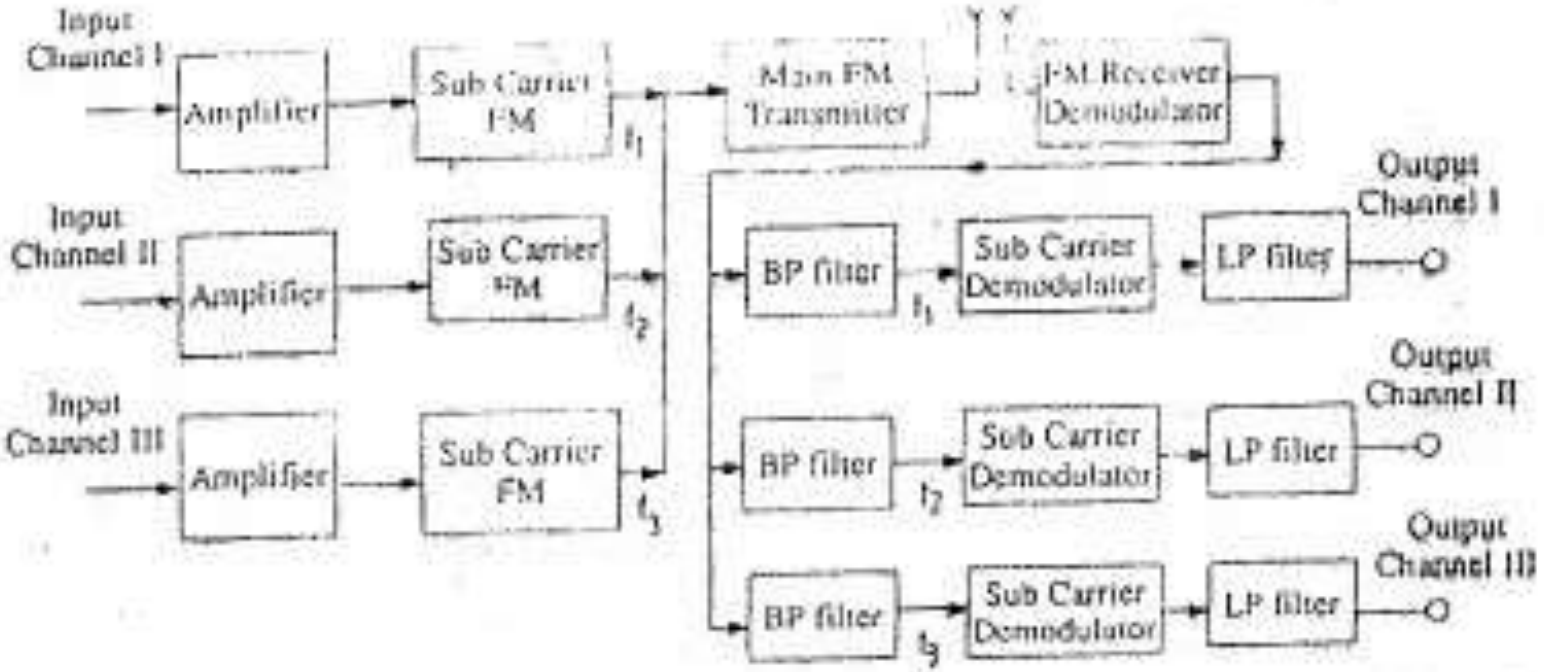



Fig.8.8 Frequency Division Multiplex System

# Time division multiplex telemetry system

- The transmission channel is connected to each signal-channel input for a short time to sample and transmit that signal
- When all the channels have been scanned once a cycle is completed and the next cycle will start
- At the reciever end,the process is reversed
- If the number of scanning cycles per second is large and if the transmitter and the reciever

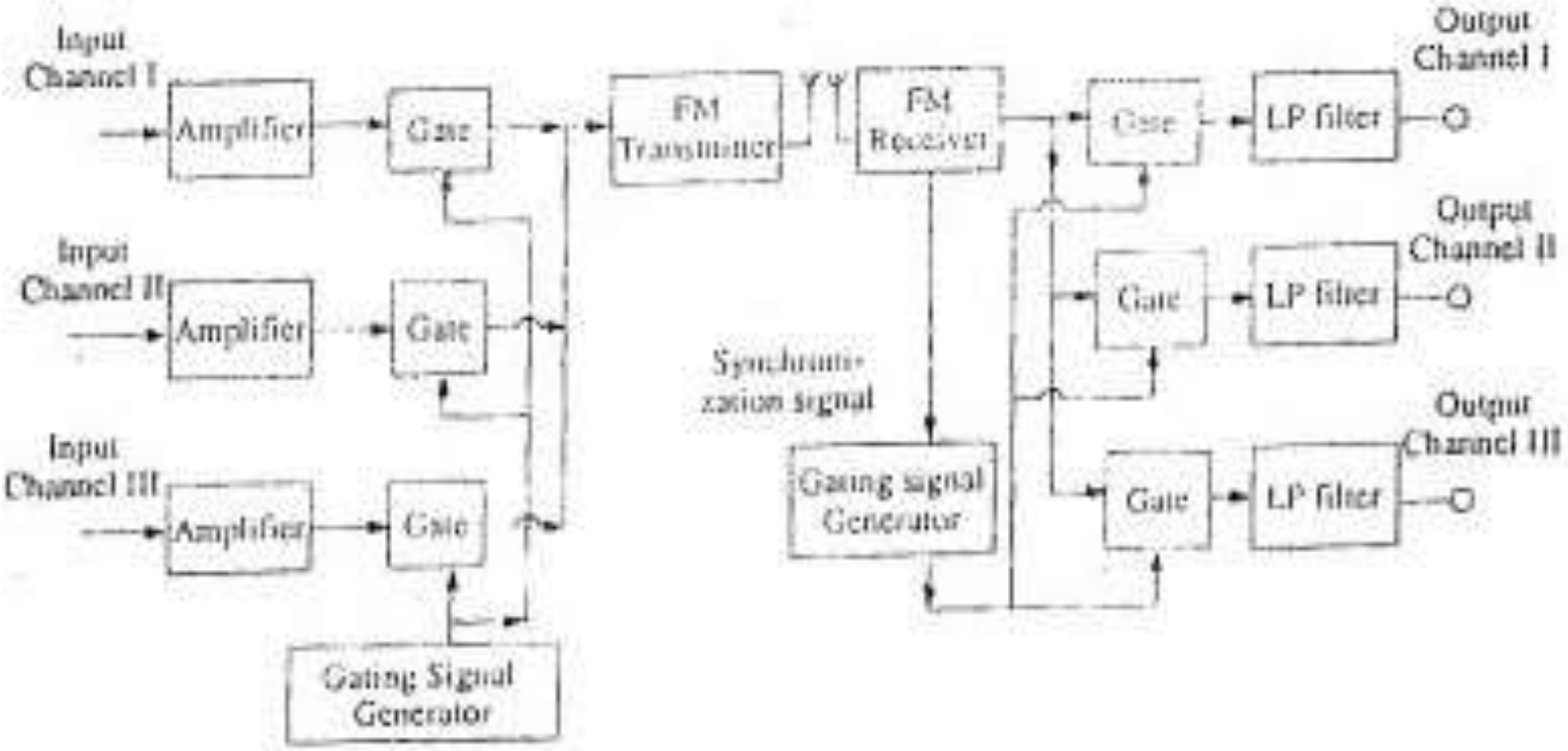



Fig.8.9 Time Division Multiplex System

# RADIO PILL

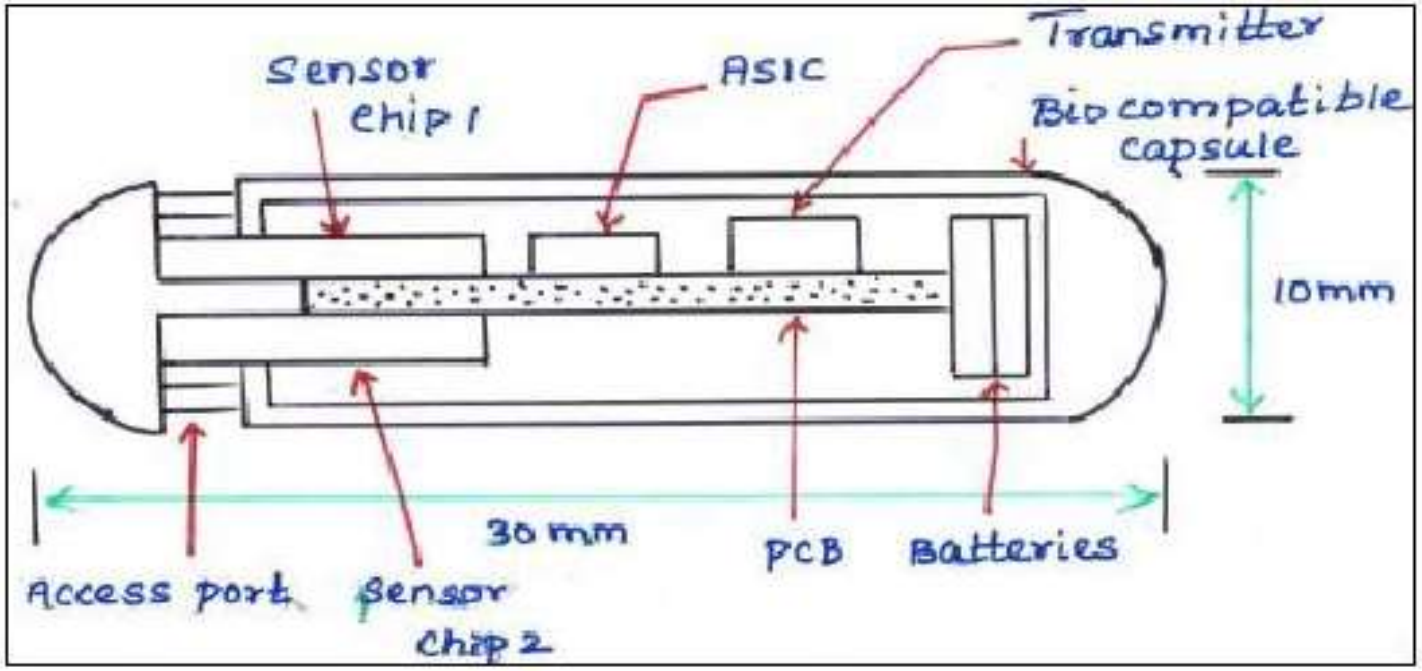
# Radio Pill

- Radio pill when swallowed, will travel the GI tract (Gastrointestinaltract) and simultaneously perform multiparameter in physiological analysis.
- After completing its mission it will come out of the human body by normalbowel movement.

# Radio Pill

- The pill is 10mm in diameter and 30mm long weighing around 5gmand records parameters like temperature, pH, conductivity and dissolved oxygen in real time.
- The pill comprises an outer biocompatible capsule encasing microsensors, a control chip, radio transmitter and two silver-oxide cells.

# Radio Pill


Sensor
Chip 1
ASIC
Transmitter
Bio compatible
capsule
10mm
30 mm
Access port
Sensor
Chip 2
PCB
Batteries

# Radio Pill

- The outer casing of the pill is made by machining chemically resistant polyetheterketone, which is biocompatible. It is made up of two halves, which are joined together by screwing.
- The pill houses a PCB chip carrier that acts as a common platform for attachment of sensors, application- specific integrated circuit (ASIC), radio transmitter and batteries

# TELESTIMULATION

- Telestimulation systems are described for chronic indirect muscle stimulation in caged rabbits and mice.
- Both systems use a 5 MHz carrier frequency transmission and consist of a transmitter and a receiver.
- The latter is fixed to the back of the animal.

# TELESTIMULATION

- The system for rabbits uses pulse width modulation for transmitting stimulation frequency and amplitude.
- Duration of the stimulation impulse is generated in the receiver.
- Clock batteries in the receiver generate impulse energy.

# TELESTIMULATION

- The impulse amplitude varies by only 1%.
- In the system used for mice, impulse energy is transmitted together with the stimulation frequency.
- This is achieved by a receiver containing two separate coils which are opposed to each other in an angle of 80 degrees C.

# TELESTIMULATION

- In contrast to the rabbit system, the duration of the stimulation impulse is generated by the impulse width of the 5 MHz carrier.
- The amplitude of the stimulation impulse depends on the amplitude of the carrier.
- Due to the geometry of induction coil and receiver, impulse intensity varies at maximum by only 10%.

# UNIT 4

# Definition of Radiation

- “Radiation is an energy in the form of electro-magnetic waves or particulate matter, traveling in the air.”

# Types of Radiation

- Radiation is classified into:
  - Ionizing radiation
  - Non-ionizing radiation

# Ionizing Versus Non-ionizing Radiation

- **Ionizing Radiation**
  - **Higher energy electromagnetic waves (gamma) or heavy particles (beta and alpha).**
  - **High enough energy to pull electron from orbit.**

- **Non-ionizing Radiation**
  - **Lower energy electromagnetic waves.**
  - **Not enough energy to pull electron from orbit, but can excite the electron.**

# Ionizing Radiation

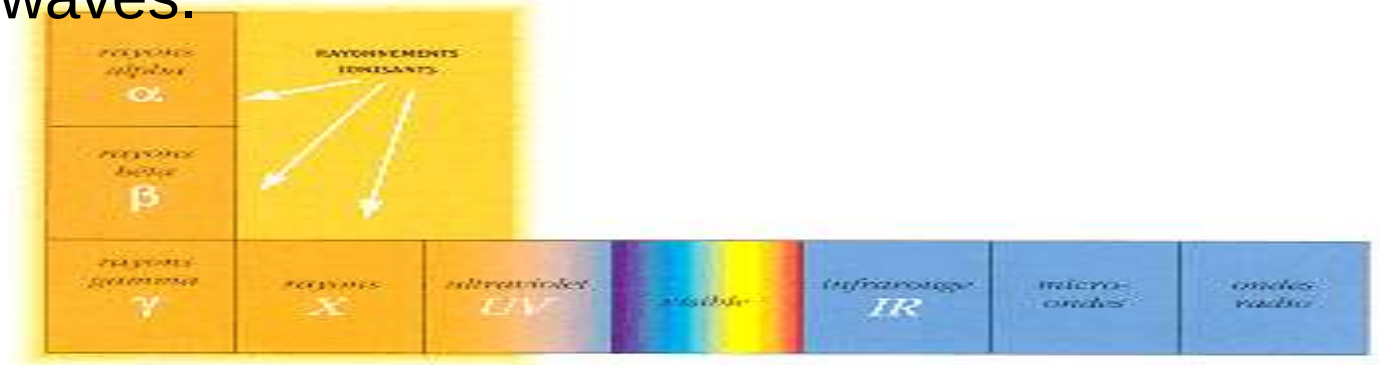
- Definition:

  “ It is a type of radiation that is able to disrupt atoms and molecules on which they pass through, giving rise to ions and free radicals”.

# Another Definition

## Ionizing radiation

A radiation is said to be ionizing when it has enough energy to eject one or more electrons from the atoms or molecules in the irradiated medium. This is the case of a and b radiations, as well as of electromagnetic radiations such as gamma radiations, X-rays and some ultra-violet rays. Visible or infrared light are not, nor are microwaves or radio waves.



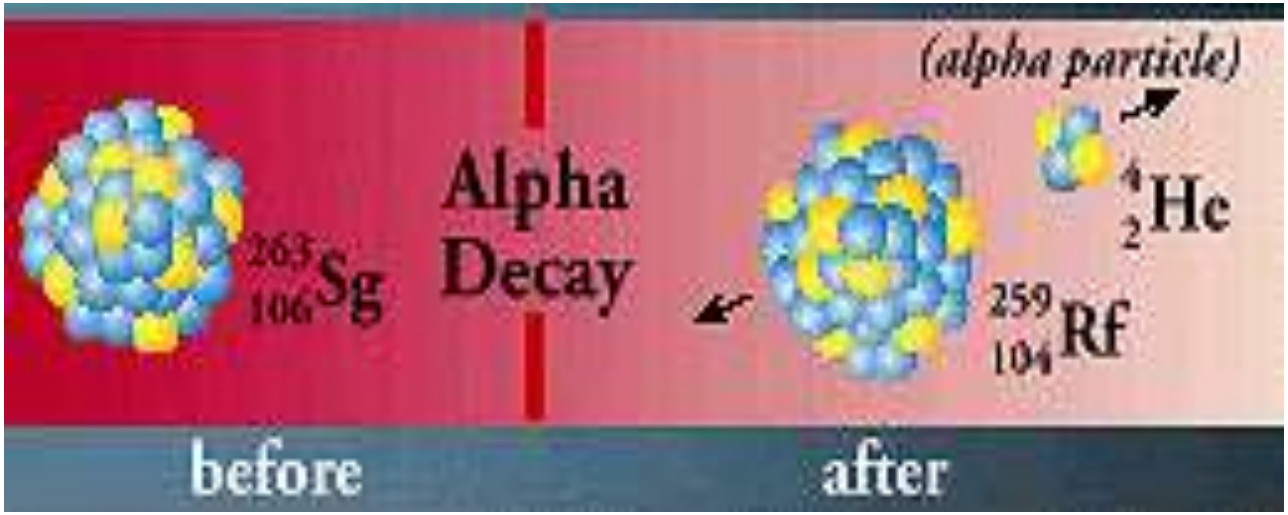
# Primary Types of Ionizing Radiation

- Alpha particles
- Beta particles
- Gamma rays (or photons)
- X-Rays (or photons)
- Neutrons

# Types and Characteristics of Ionizing Radiation

## Alpha Particles

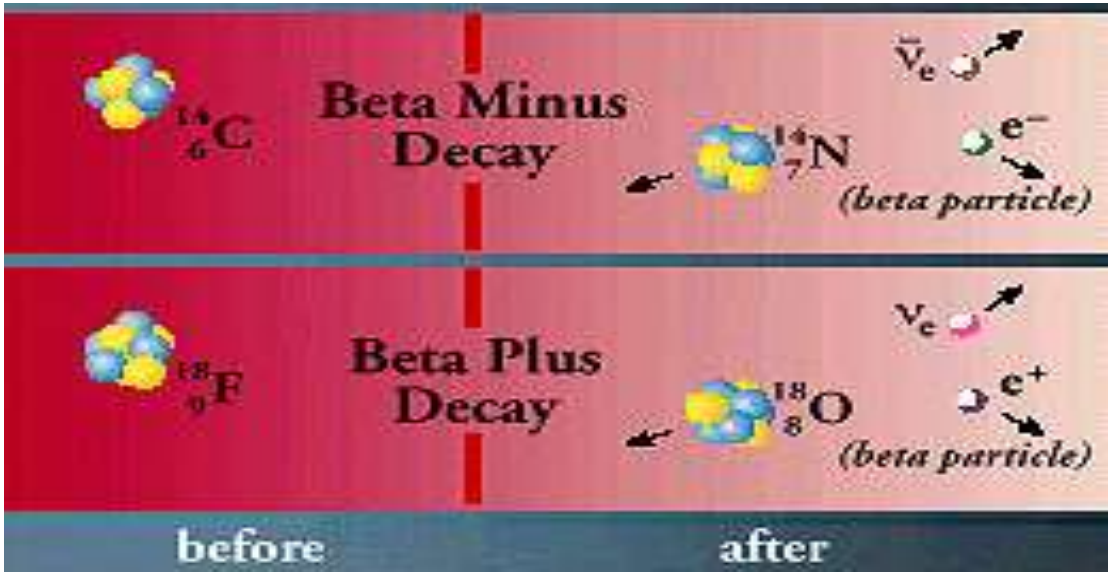
Alpha Particles: 2 neutrons and 2 protons
They travel short distances, have large mass
Only a hazard when inhaled



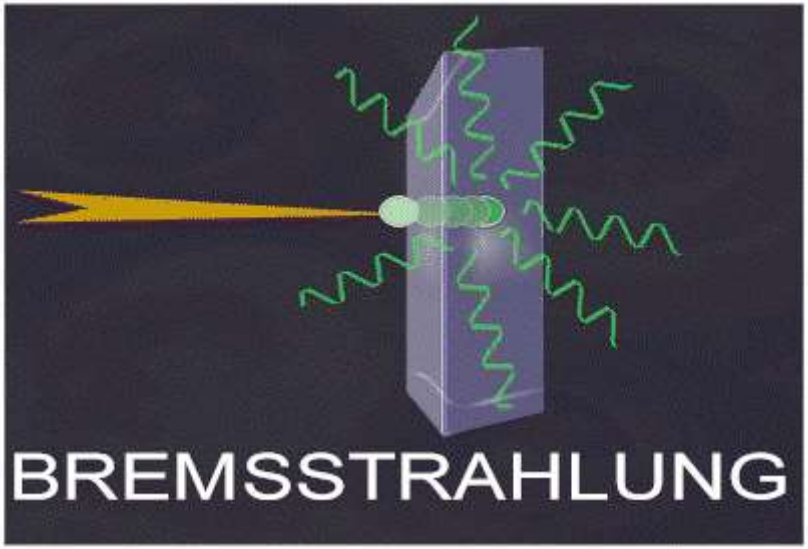
- ***Alpha Particles*** *(or Alpha Radiation)*: **Helium nucleus** (2 neutrons and 2 protons); +2 charge; heavy (4 AMU). Typical Energy = 4-8 MeV; **Limited range** (<10cm in air; 60µm in tissue); High LET (**QF=20**) causing **heavy damage** (4K-9K ion pairs/µm in tissue). **Easily shielded** (e.g., paper, skin) so an **internal radiation** hazard. Eventually lose too much energy to ionize; become He.

# Beta Particles

Beta Particles: Electrons or positrons having small mass and variable energy. Electrons form when a neutron transforms into a proton and an electron or:

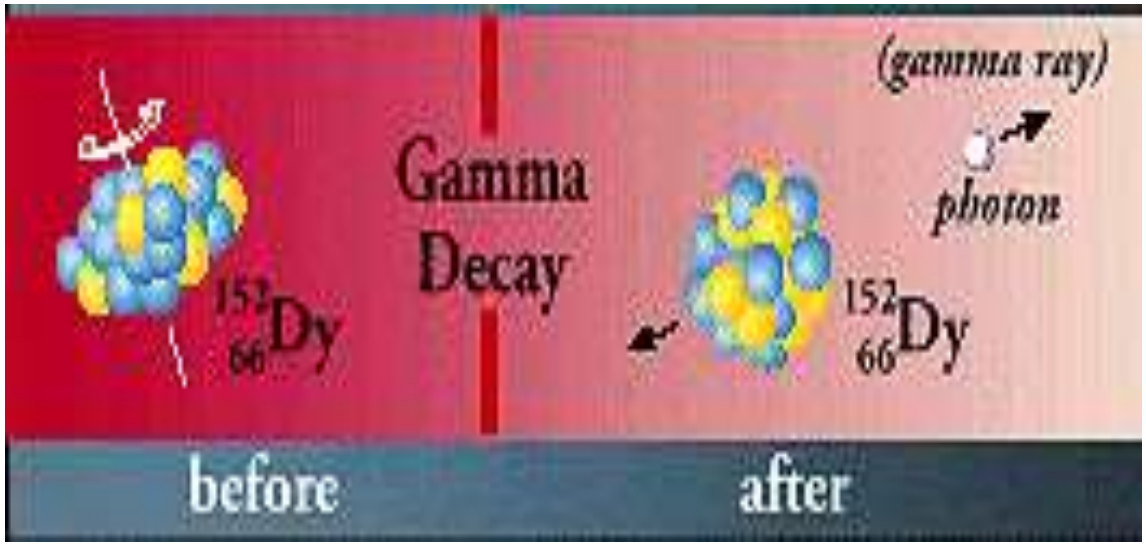


- ***Beta Particles***: High speed **electron ejected from nucleus**; -1 charge, light 0.00055 AMU; Typical Energy = several KeV to 5 MeV; Range approx. 12'/MeV in air, a few mm in tissue; Low LET (**QF=1**) causing **light damage** (6-8 ion pairs/μm in tissue). Primarily an internal hazard, but high beta can be an external hazard to skin. In addition, the high speed electrons may lose energy in the form of X-rays when they quickly decelerate upon striking a heavy material. This is called **Bremsstralung** (or Breaking) **Radiation.** Aluminum and other light (<14) materials are used for shielding.


BREMSSTRAHLUNG

# Gamma Rays

**Gamma Rays (or photons): Result when the nucleus releases energy, usually after an alpha, beta or positron transition**



# X-Rays

X-Rays:  Occur whenever an inner shell orbital electron is removed and rearrangement  of the atomic electrons results with the release of the elements characteristic X-Ray energy

- ***X-*** *and* ***Gamma Rays***: **X-rays** are photons (Electromagnetic radiations) emitted **from electron orbits**. **Gamma rays** are photons emitted **from the nucleus**, often as part of radioactive decay. Gamma rays typically have higher energy (Mev's) than X-rays (KeV's), but both are unlimited.

# Neutrons

Neutrons:  Have the same mass as protons but are uncharged

# Non-ionizing Radiation

- Definition:

“ They are electromagnetic waves incapable of producing ions while passing through matter, due to their lower energy.”

- All earth surface system components emit radiation---the sun and the earth are the components we are most interested in

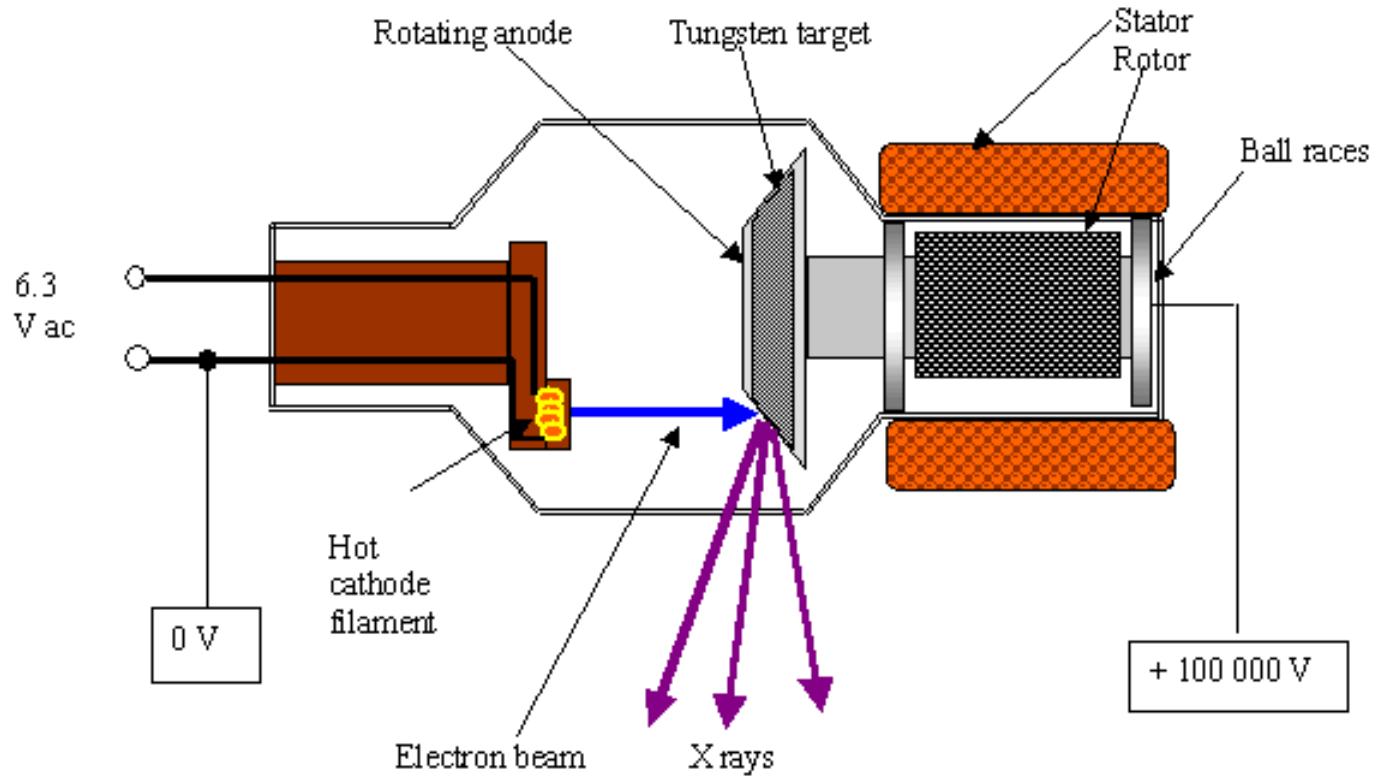
- The sun emits radiation composed of high energy infrared radiation, visible light, and ultraviolet radiation collectively known as shortwave radiation (SW)

- The earth emits radiation composed of lower energy infrared radiation collectively known as long-wave radiation (LW)

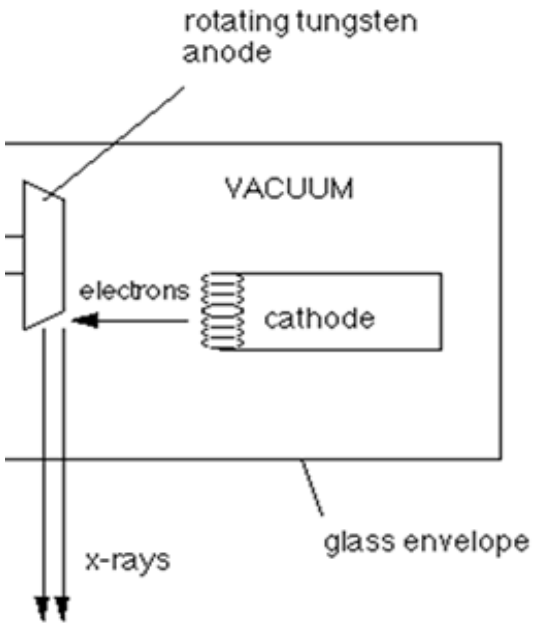
# Examples on Non-ionizing Radiation Sources

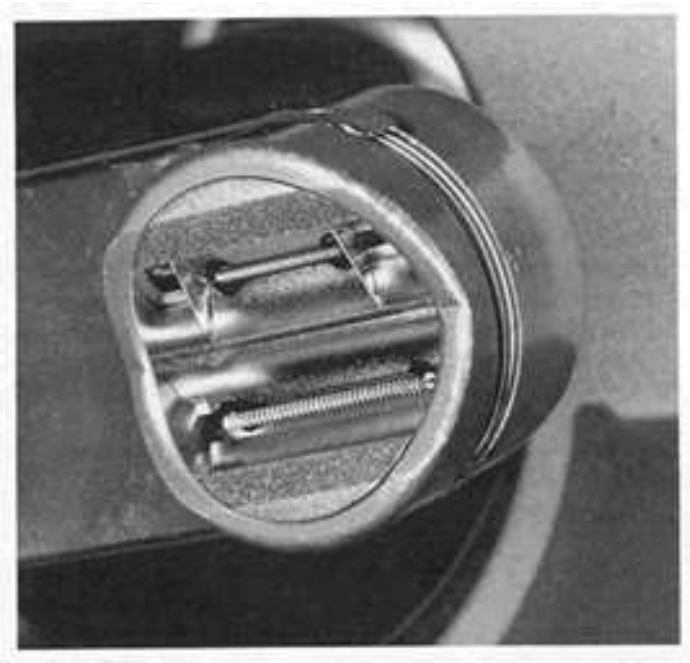
- Visible light
- Microwaves
- Radios
- Video Display Terminals
- Power lines
- Radiofrequency Diathermy (Physical Therapy)
- Lasers

# X-ray Production


Rotating anode
Tungsten target
Stator
Rotor
Ball races
6.3
V ac
Hot
cathode
filament
0 V
+ 100 000 V
Electron beam
X rays

# CATHODE



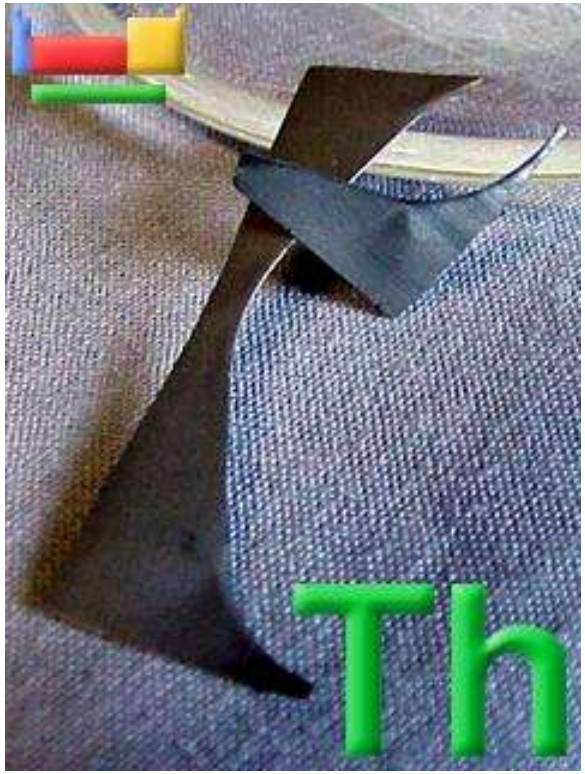



MADE OF TUNGSTEN + 1%-3% THORIUM

# TUNGSTEN

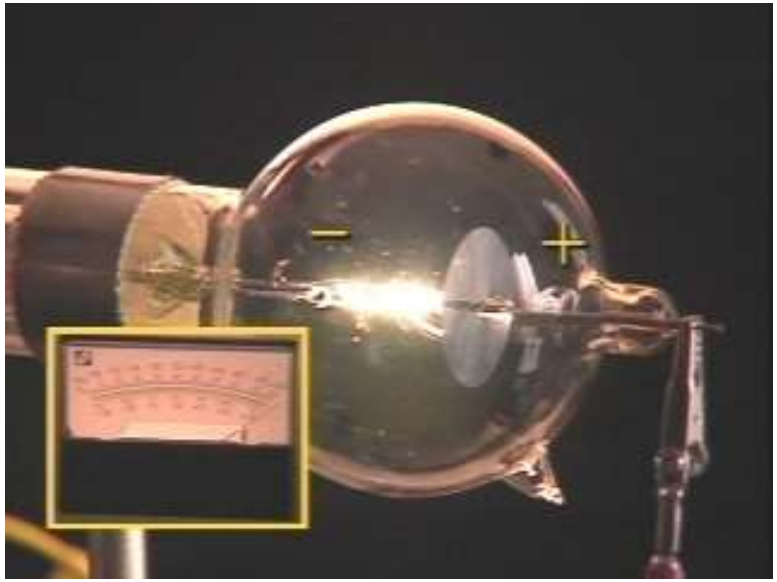

MELTING POINT- 3,410 DEG. CELSIUS

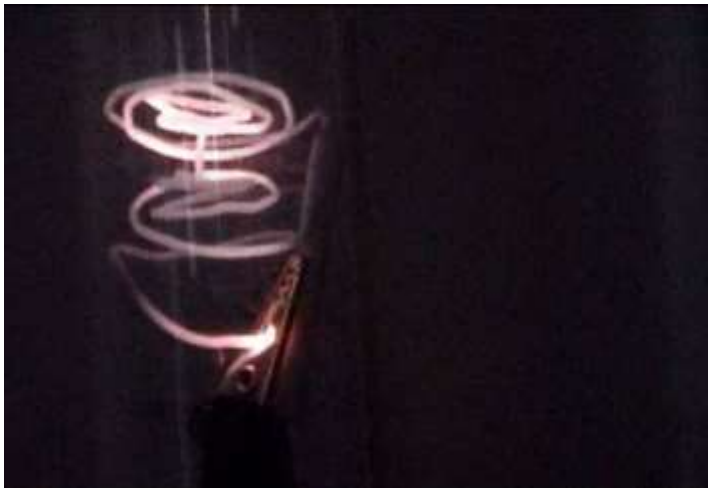
# THORIUM




Z # 90

# THERMIONIC EMISSION



CATHODE HEATED UP TO AT LEAST 2,200 DEG. CELSIUS

# ANODE +++++

TUNGSTEN TARGET

# TUNGTEN AS TARGET

HIGH Z# - 74------EFFICIENCY OF X-RAY PRODUCTION 

HIGH MELTING POINT –3,410 ° C– TARGET HEATED TO 2,000 ° C

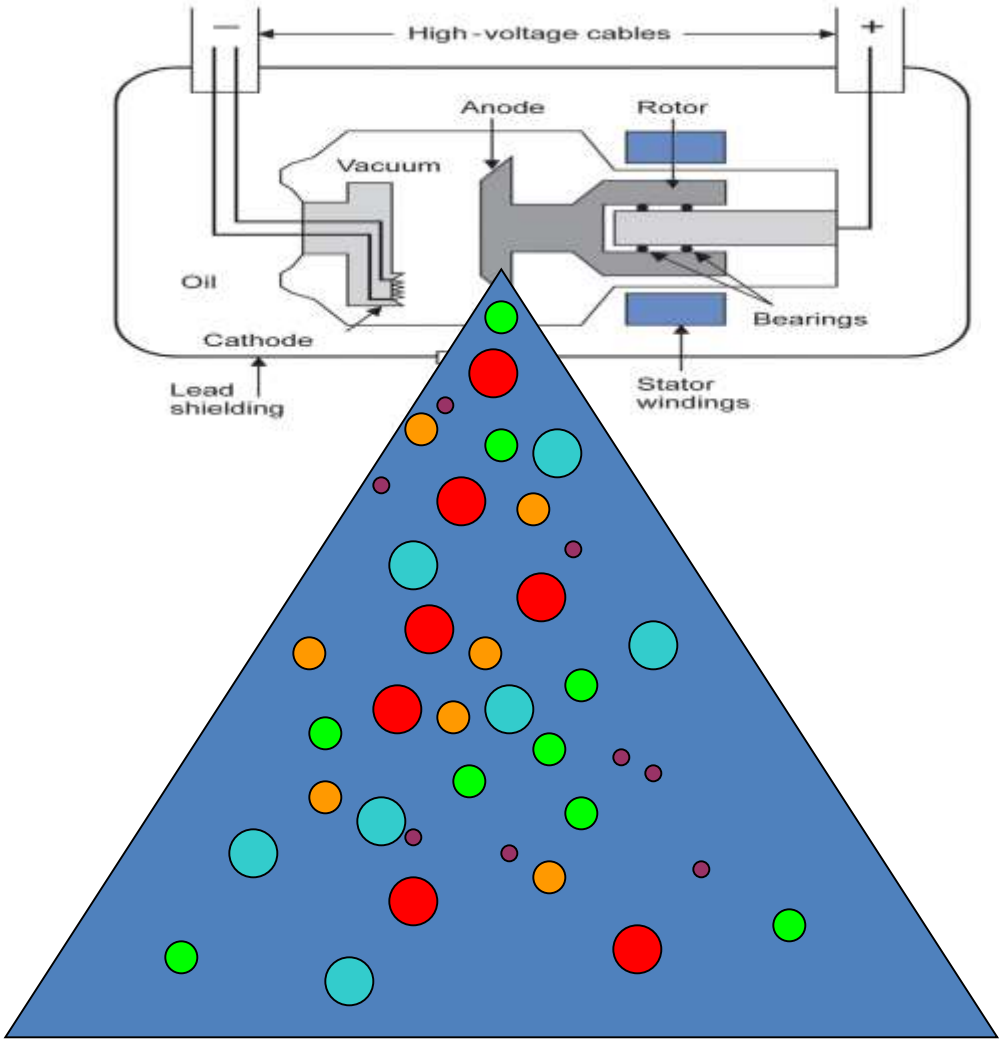
# X-RAY PRODUCTION

- BREMSSTRAHLUNG RADIATION
- CHARACTERISTIC RADIATION

# BREMSSTRAHLUNG RADIATION

If an incoming free electron gets close to the nucleus of a target atom, the strong electric field of the nucleus will attract the electron, thus changing direction and speed of the electron. The Electron  looses energy which will be emitted as an X-ray photon. The energy of this photon will depend on the degree of interaction between nucleus and electron, i.e. the passing distance. Several subsequent interactions between one and the same electron and different nuclei are possible. X-rays originating from this process are called bremsstrahlung. Bemsstrahlung is a German word directly describing the process: "Strahlung" means "radiation", and "Bremse" means "brake

# BREMS EMISSION-CONTINUOUS

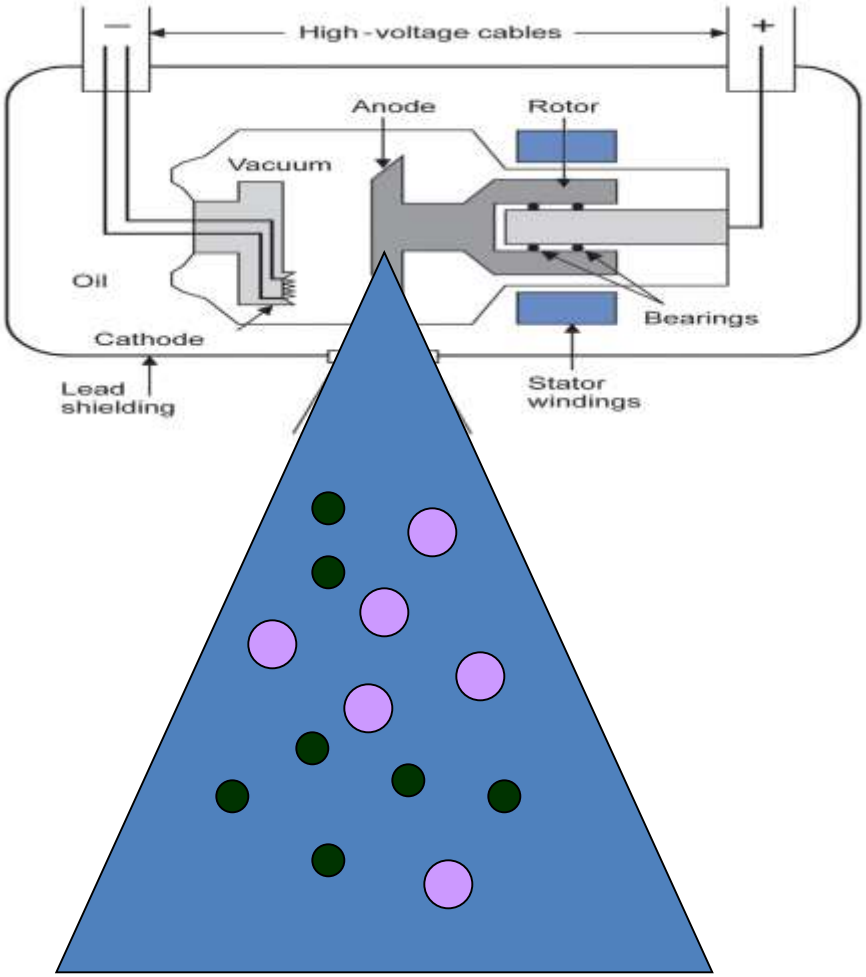


# Characteristic X-rays

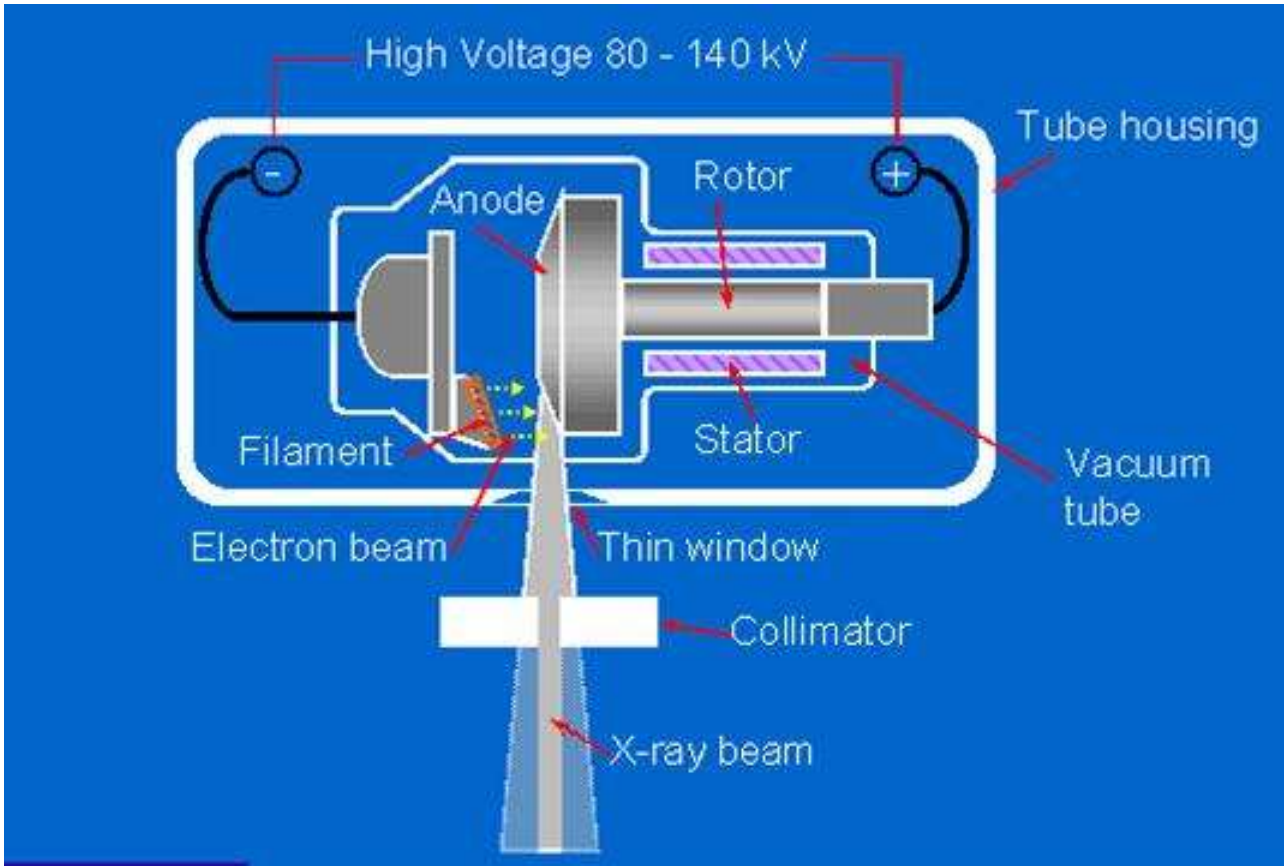
The high energy electron can also cause an electron close to the nucleus in a metal atom to be knocked out from its place. This vacancy is filled by an electron further out from the nucleus. The well defined difference in binding energy, characteristic of the material, is emitted as a monoenergetic photon. When detected this X-ray photon gives rise to a characteristic X-ray line in the energy spectrum.

# CHARACTERISTIC EMISSION-

# LESS POLYENERGETIC!

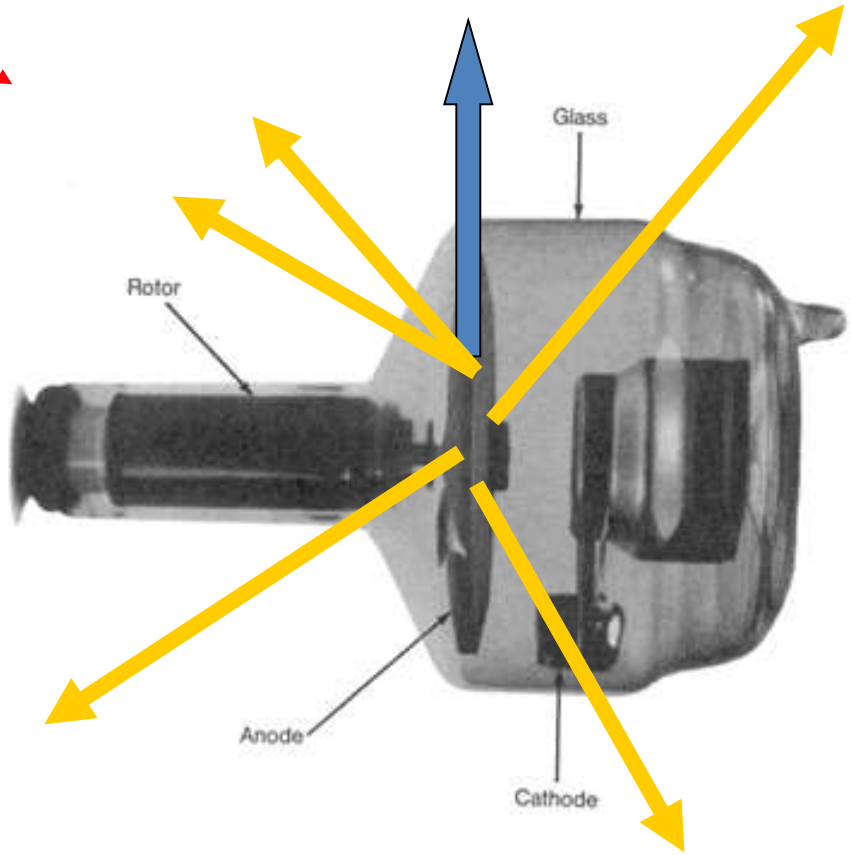


# USEFUL RADIATION – PROJECTED TOWARD THE PATIENT

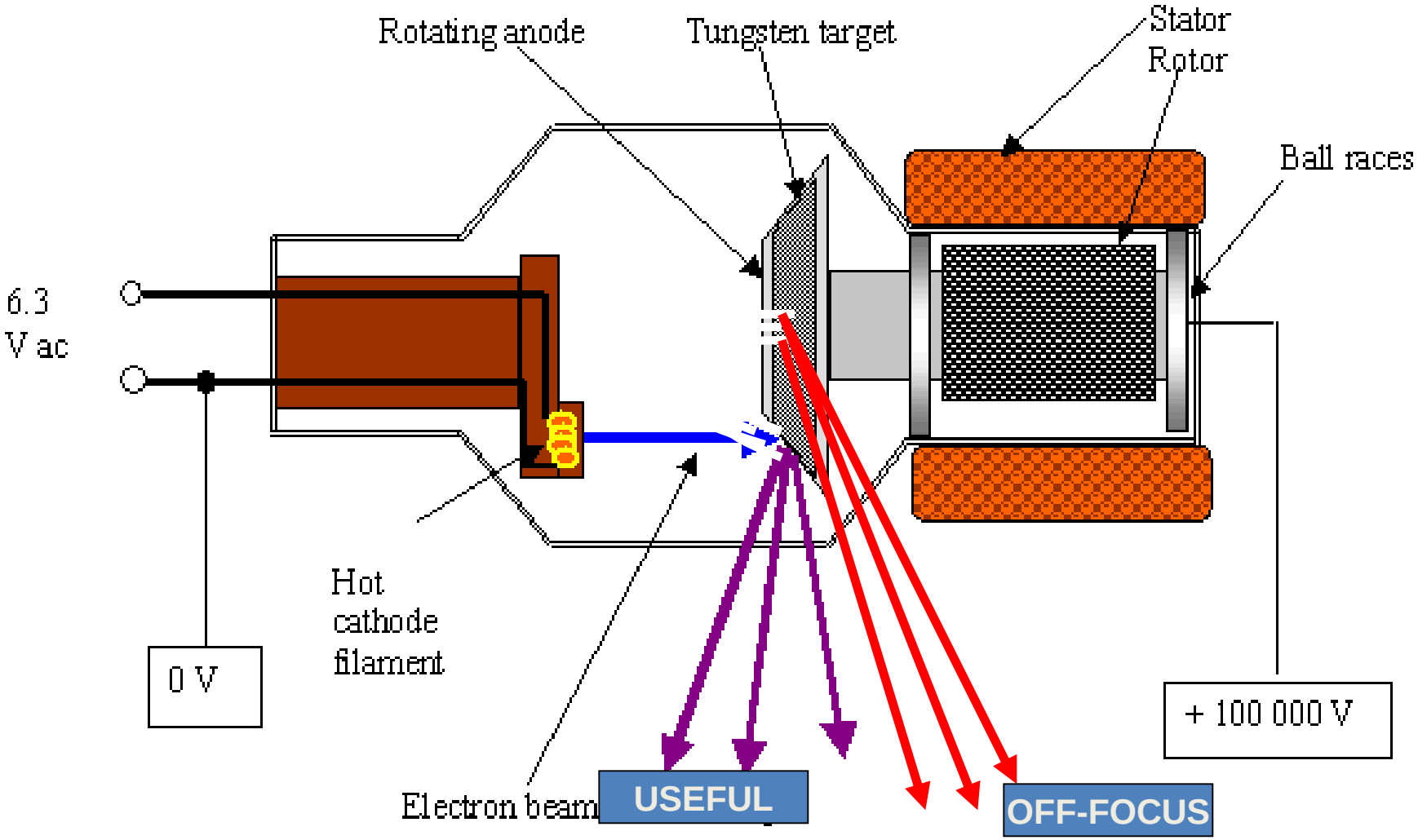


# LEAKAGE RADIATION

HOUSING



# OFF-FOCUS RADIATION



# USE OF RADIOISOTOPES IN MEDICINE

# Use Of Radioisotopes In Medicine

- Reactor Radioisotopes (half-life indicated)
- Molybdenum-99 (66 h): Used as the 'parent' in a generator to produce technetium-99m.
- Technetium-99m (6 h): Used in to image the skeleton and heart muscle in particular, but also for brain, thyroid, lungs (perfusion and ventilation), liver, spleen, kidney (structure and filtration rate), gall bladder, bone marrow, salivary and lacrimal glands, heart blood pool, infection and numerous specialised medical studies.

# Use Of Radioisotopes In Medicine

- Bismuth-213 (46 min): Used for TAT.
- Chromium-51 (28 d): Used to label red blood cells and quantify gastro- intestinal protein loss.
- Cobalt-60 (10.5 mth): Formerly used for external beam radiotherapy.
- Copper-64 (13 h): Used to study genetic diseases affecting copper metabolism, such as Wilson's and Menke's diseases.

# Use Of Radioisotopes In Medicine

- Dysprosium-165 (2 h): Used as an aggregated hydroxide for synovectomy treatment of arthritis.
- Erbium-169 (9.4 d): Use for relieving arthritis pain in synovial joints.
- Holmium-166 (26 h): Being developed for diagnosis and treatment of liver tumours.

# Use Of Radioisotopes In Medicine

- Iodine-125 (60 d): Used in cancer brachytherapy (prostate and brain), also diagnostically to evaluate the filtration rate of kidneys and to diagnose deep vein thrombosis in the leg. It is also widely used in radioimmuno- assays to show the presence of hormones in tiny quantities.
- Iodine-131 (8 d): Widely used in treating thyroid cancer and in imaging the thyroid; also in diagnosis of abnormal liver function, renal (kidney) blood flow and urinary tract obstruction. A strong gamma emitter, but used for beta therapy.

# Use Of Radioisotopes In Medicine

- Iridium-192 (74 d): Supplied in wire form for use as an internal radiotherapy source for cancer treatment (used then removed).
- Iron-59 (46 d): Used in studies of iron metabolism in the spleen.
- Lutetium-177 (6.7 d): Lu-177 is increasingly important as it emits just enough gamma for imaging while the beta radiation does the therapy on small (eg endocrine) tumours. Its half-life is long enough to allow sophisticated preparation for use.

# Use Of Radioisotopes In Medicine

- Palladium-103 (17 d): Used to make brachytherapy permanent implant seeds for early stage prostate cancer.
- Phosphorus-32 (14 d): Used in the treatment of polycythemia vera (excess red blood cells). Beta emitter.
- Potassium-42 (12 h): Used for the determination of exchangeable potassium in coronary blood flow.
- Rhenium-186 (3.8 d): Used for pain relief in bone cancer. Beta emitter with weak gamma for imaging.

# Use Of Radioisotopes In Medicine

- Rhenium-188 (17 h): Used to beta irradiate coronary arteries from an angioplasty balloon.
- Samarium-153 (47 h): Sm-153 is very effective in relieving the pain of secondary cancers lodged in the bone, sold as Quadramet. Also very effective for prostate and breast cancer. Beta emitter.
- Selenium-75 (120 d): Used in the form of seleno-methionine to study the production of digestive enzymes.
- Sodium-24 (15 h): For studies of electrolytes within the body.

# Use Of Radioisotopes In Medicine

- Strontium-89 (50 d): Very effective in reducing the pain of prostate and bone cancer. Beta emitter.
- Xenon-133 (5 d): Used for pulmonary (lung) ventilation studies.
- Ytterbium-169 (32 d): Used for cerebrospinal fluid studies in the brain.
- Yttrium-90 (64 h): Used for cancer brachytherapy and as silicate colloid for the relieving the pain of arthritis in larger synovial joints. Pure beta emitter.
- Radioisotopes of caesium, gold and ruthenium are also used in brachytherapy.

# Use Of Radioisotopes In Medicine

- Cyclotron Radioisotopes
- Carbon-11, Nitrogen-13, Oxygen-15, Fluorine-18: These are positron emitters used in PET for studying brain physiology and pathology, in particular for localising epileptic focus, and in dementia, psychiatry and neuropharmacology studies. They also have a significant role in cardiology. F-18 in FDG has become very important in detection of cancers and the monitoring of progress in their treatment, using PET.
- Cobalt-57 (272 d): Used as a marker to estimate organ size and for in-vitro diagnostic kits.

# Use Of Radioisotopes In Medicine

- Gallium-67 (78 h): Used for tumour imaging and localisation of inflammatory lesions (infections).
- Indium-111 (2.8 d): Used for specialist diagnostic studies, eg brain studies, infection and colon transit studies.
- Iodine-123 (13 h): Increasingly used for diagnosis of thyroid function, it is a gamma emitter without the beta radiation of I-131.

# Use Of Radioisotopes In Medicine

- Krypton-81m (13 sec) from Rubidium-81 (4.6 h): Kr-81m gas can yield functional images of pulmonary ventilation, e.g. in asthmatic patients, and for the early diagnosis of lung diseases and function.
- Rubidium-82 (65 h): Convenient PET agent in myocardial perfusion imaging.
- Strontium-92 (25 d): Used as the 'parent' in a generator to produce Rb-82.
- Thallium-201 (73 h): Used for diagnosis of coronary artery disease other heart conditions such as heart muscle death and for location of low-grade lymphomas.

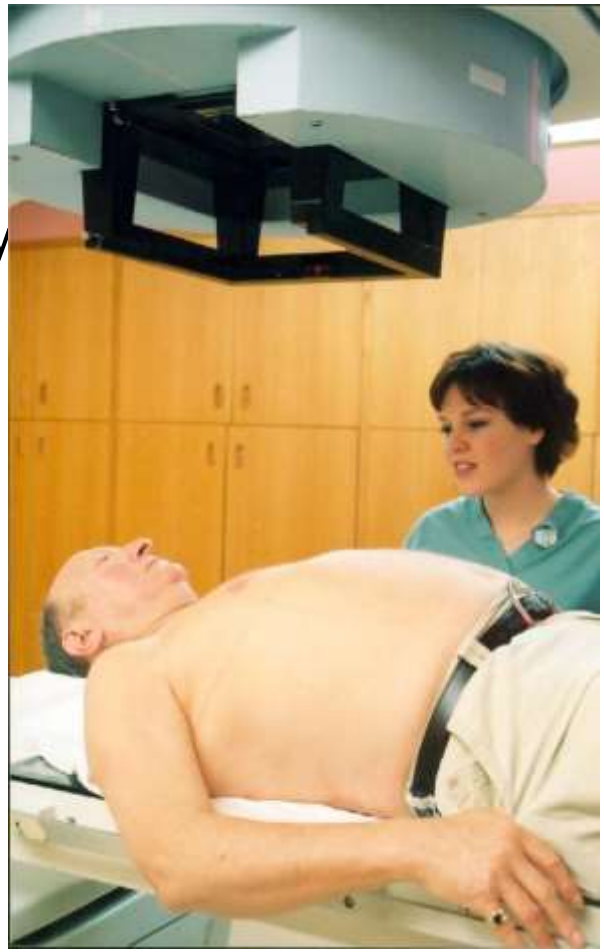
# Understanding Radiation Therapy

# Introduction to Radiation Oncology

- Radiation has been an effective tool for treating cancer for more than 100 years.
- Radiation oncologists are doctors trained to use radiation to eradicate cancer.
- About two-thirds of all cancer patients will receive radiation therapy as part of their treatment.

# What Is Radiation Therapy?

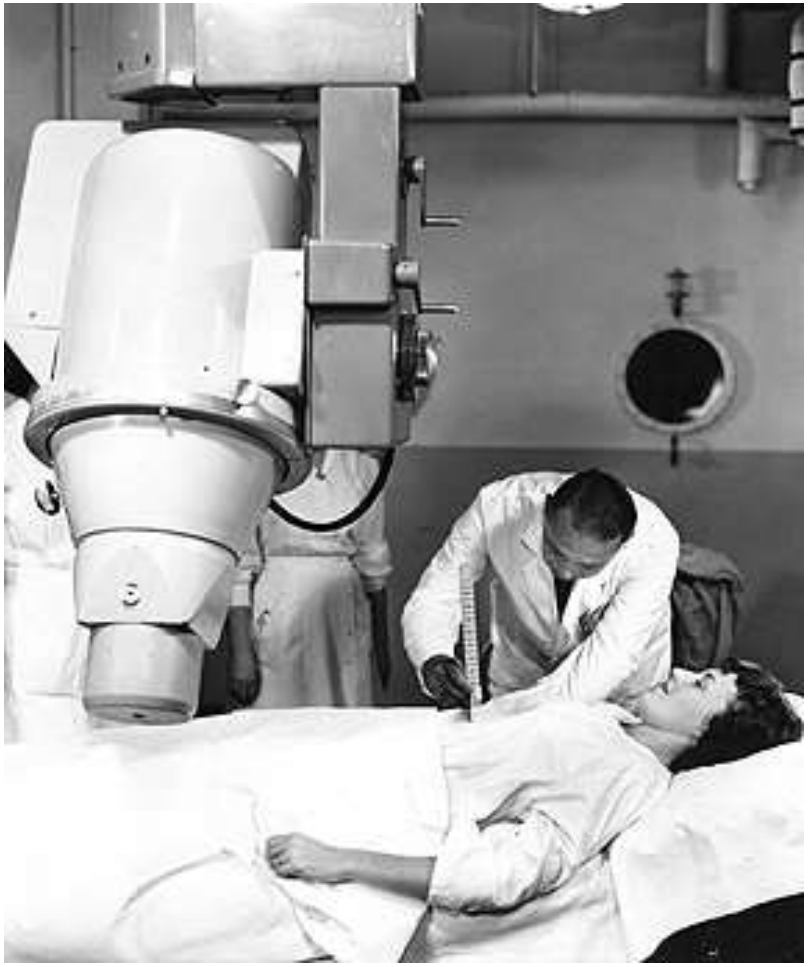
- Radiation therapy works by damaging the DNA within cancer cells and destroying their ability to reproduce.
- When the damaged cancer cells are destroyed by radiation, the body naturally eliminates them.
- Normal cells can be affected by radiation, but they are able to repair themselves.
- Sometimes radiation therapy is the only treatment a patient needs.
- Other times, it is combined with other treatments, like surgery and chemotherapy.



# Brief History of Radiation Therapy

- The first patient was treated with radiation in 1896, two months after the discovery of the X-ray.
- Back then, both doctors and non-physicians treated cancer patients with radiation.
- Rapid technology advances began in the early 1950s with cobalt units followed by linear accelerators a few years later.
- Recent technology advances have made radiation more effective and precise.

# Methods of Delivering Radiation Therapy



Early 1950s

Today

# How Is Radiation Therapy Used?

Radiation therapy is used two different ways.

- To cure cancer:
  - Destroy tumors that have not spread to other body parts.
  - Reduce the risk that cancer will return after surgery or chemotherapy.
- To reduce symptoms:
  - Shrink tumors affecting quality of life, like a lung tumor that is causing shortness of breath.
  - Alleviate pain by reducing the size of a tumor.

# Meet the Radiation Oncology Team

- **Radiation Oncologist**
  - The doctor who oversees the radiation therapy treatments.
- **Medical Radiation Physicist**
  - Ensures that complex treatment plans are properly tailored for each patient.
- **Dosimetrist**
  - Works with the radiation oncologist and medical physicist to calculate the proper dose of radiation given to the tumor.
- **Radiation Therapist**
  - Administers the daily radiation under the doctor's prescription and supervision.
- **Radiation Oncology Nurse**
  - Cares for the patient and family by providing education, emotional support and tips for managing side effects.

# Types of Radiation Therapy

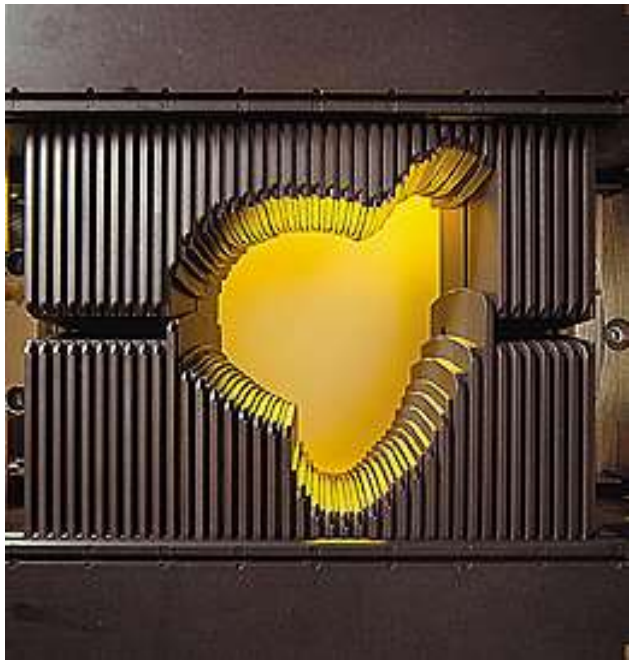
- Radiation therapy can be delivered two ways – externally and internally.
  - External beam radiation therapy delivers radiation using a linear accelerator.
  - Internal radiation therapy, called brachytherapy or seed implants, involves placing radioactive sources inside the patient.
- The type of treatment used will depend on the location, size and type of cancer.

# Planning Radiation Therapy - Simulation

- Each treatment is mapped out in detail using treatment planning software.
- Radiation therapy must be aimed at the same target every time. Doctors use several devices to do this:
  - Skin markings or tattoos.
  - Immobilization devices – casts, molds, headrests.

# External Radiation Therapy

- Specialized types of external beam radiation therapy
  - **Three-dimensional conformal radiation therapy (3D-CRT)**
    - Uses CT or MRI scans to create a 3-D picture of the tumor.
    - Beams are precisely directed to avoid radiating normal tissue.
  - **Intensity modulated radiation therapy (IMRT)**
    - A specialized form of 3D-CRT.
    - Radiation is broken into many “beamlets” and the intensity of each can be adjusted individually.



# External Radiation Therapy

- Proton Beam Therapy
  - Uses protons rather than X-rays to treat certain types of cancer.
  - Allows doctors to better focus the dose on the tumor with the potential to reduce the dose to nearby healthy tissue.
- Neutron Beam Therapy
  - A specialized form of radiation therapy that can be used to treat certain tumors that are very difficult to kill using conventional radiation therapy.
- Stereotactic Radiotherapy
  - Sometimes called stereotactic radiosurgery, this technique allows the radiation oncologist to precisely focus beams of radiation to destroy certain tumors, sometimes in only one treatment.

# Internal Radiation Therapy

- Places radioactive material into tumor or surrounding tissue.
  - Also called brachytherapy – brachy Greek for “short distance.”
  - Radiation sources placed close to the tumor so large doses can hit the cancer cells.
  - Allows minimal radiation exposure to normal tissue.
  - Radioactive sources used are thin wires, ribbons, capsules or seeds.
  - These can be either permanently or temporarily placed in the body.

# Side Effects of Radiation Therapy

- Side effects, like skin tenderness, are generally limited to the area receiving radiation.
- Unlike chemotherapy, radiation usually doesn't cause hair loss or nausea.
- Most side effects begin during the second or third week of treatment.
- Side effects may last for several weeks after the final treatment.

# Is Radiation Therapy Safe?

- Many advances have been made in the field to ensure it remains safe and effective.
- Multiple healthcare professionals develop and review the treatment plan to ensure that the target area is receiving the dose of radiation needed.
- The treatment plan and equipment are constantly checked to ensure proper treatment is being given.

# UNIT 5

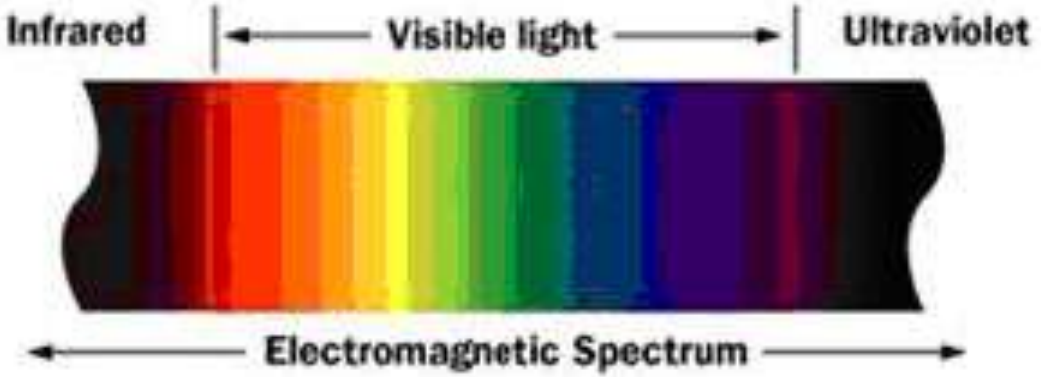
# THERMOGRAPHY

# Infrared Energy & Radiation

- Part of electro magnetic spectrum
- It travels through space at the speed of light.
- The thermal energy emitted from the surface of a material is called IR radiation.
- Temperature of an object=IR radiation emitted from it.
- Eg: x-ray, ultra violet, radio waves.

# Electromagnetic Spectrum

- Infrared radiation, visible light & ultra violet light form energy in spectrum.
- Categorized by wave length & frequency.
- Human eye can see narrow range of wavelength.(0.4-0.75 micron)



# Thermography

- It’s a - infrared imaging science.
  - cost effective method.
  - non invasive method.
  - non contact method.
- Applications include building diagnostics, plant maintenance, research, etc.

# Definition

- IRT is the technique that used for producing a visible image of invisible IR energy emitted by objects.
- Since wavelength is too long for the sensors in our eyes, IR cameras are used.

- It can be applied in any situation where a problem or condition can display itself by means of a “thermal difference”.
- For example, firefighters use it to see through smoke, find persons, and localize hotspots of fires. Cooled IR cameras can also be found at most major astronomy research telescopes.

- Its non contact.

  -uses remote sensing, keeps the user out of danger.

- It is two dimensional.

  -thermal patterns can be analyzed, comparison between areas of target is possible.

- It is real time.

  -fast scanning of stationary targets, capture of fast moving targets & fast changing thermal patterns.

# Principle

- Black body radiation-Black body is that which absorbs completely all the radiations falling on it.

- The law is associated with “Thermodynamics”.

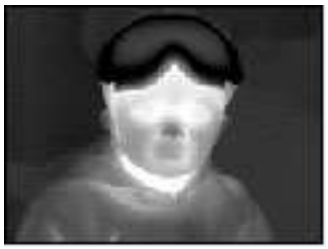
- Every object whose surface temperature is above absolute zero (-273 °C) radiates energy at a wavelength corresponding to its surface temperature.

# Thermographic Camera

- Produces a live TV image of heat radiation.
- It converts invisible IR energy into a 2d visual image & displays on std. TV monitor.
- Thermal image produced is called thermogram.
- It allows us to see what our eyes can't.
- It resembles a std. camcorder.

# How camera see heat?

- It can image temperatures from -20 to 500 degree Celsius & can be extended down to -40 & up to 2000 degree Celsius.
- It converts invisible IR energy to 2d visual image.
- Then displays on a TV monitor.



# Types of Thermographic Cameras

2 types:

- Cooled cameras-They are contained in a vacuum sealed case & cryogenically cooled. Drawbacks- expensive to produce & run, several minutes to cool down before it begin working.
- Uncooled cameras-Use sensors that work by change of resistance, volume & current when heated. It is smaller & less costly.
- Cooled cameras provide superior image quality than uncooled.

# Process

- IR camera creates an image.

  -convert radiant heat energy into a signal.

- Colorizing IR images.

  -camera assigns black to coolest area & white to hottest area.

- Adjusting images for clarity.

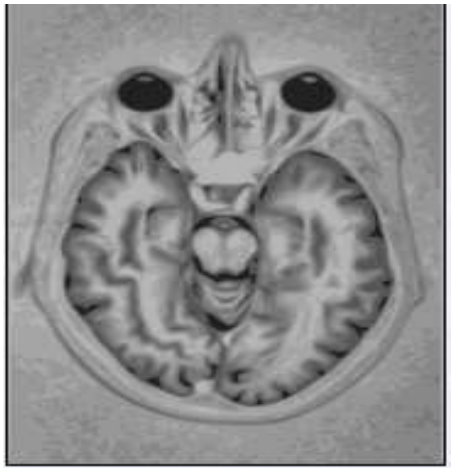
  -upper & lower temperature limits are adjusted to get the clearest picture.

# Applications

- Medical imaging
- Night vision
- Non destructive testing
- Medical field
- Condition monitoring

# Medical Imaging

- The technique used to create images of human body for clinical purposes or medical science.
- Imaging technology:
  - Electron microscope.
  - Fluoroscopy.
  - Magnetic Resonance Imaging (MRI).
  - Positron Emission Tomography (PET).



# Night Vision

- Ability to see in a dark enviornment.
- Possible by 2 approaches: spectral range, intensity range.
- NVD used in military forces.
- Absence of Tapetum lucidum is the reason for poor night vision in humans.
- Thermal imaging cameras helps in seei rain and smoke.

# Non-Destructive Testing (NDT)

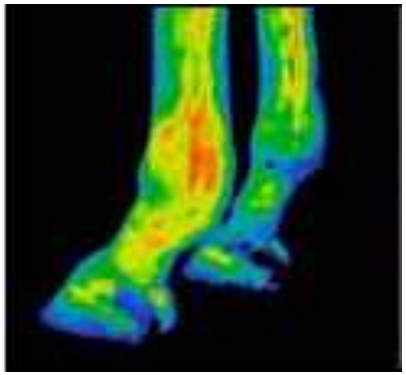
- It is the testing that does not destroy the test object.
- Aimed mainly at industrial NDT.
- Destructive testing is not possible for forensic investigation.
- Eg:-Aircraft skins need regular checking to detect cracks.

  Underground pipelines are subject to corrosion & stress corrosion cracking.

# Medical Thermography

It can be done in 2 fields

-Vetinary Minor injuries to muscle tissue may go unnoticed until the problem is more severe.IR imaging aids expert trainer in caring for the horse.



# Medical Thermography

-Human beings

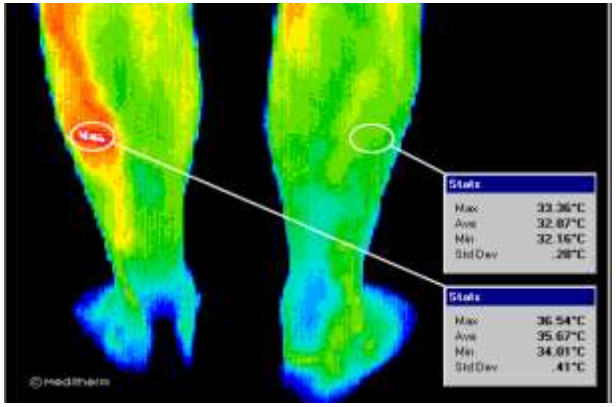
- Respiratory dysfunctions-asthma,bronchitis
- Digestive disorders-hyper &hypo gastric secretions.
- Urinary diseases-urinary tract inspections.
- Cardiovascular & circulatory

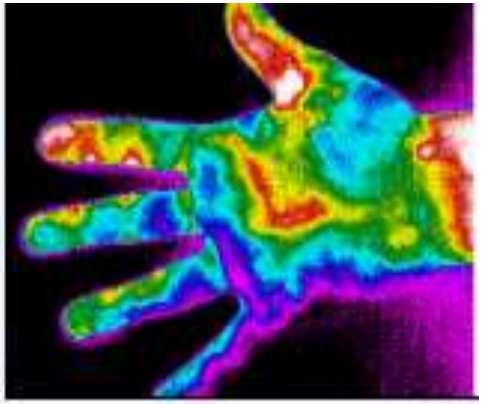
  disorders-heart disease, varicose vein.
- Nervous dysfunctions-brain, spinal cord, nerves.

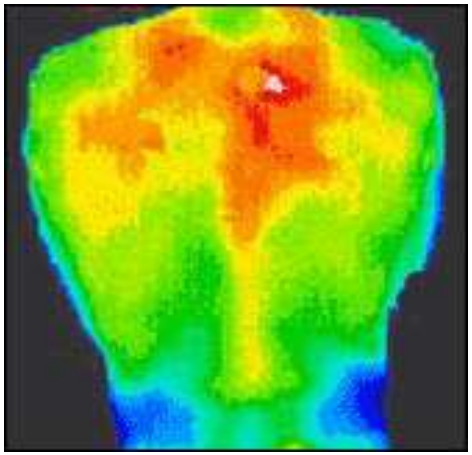
# Medical Thermography

- Locomotors disorders-arthritis, disk injury.
- Surgical assistance-tumours size, surgical area.
- Skin problems-skin cancer & tumours.
- Dentistry-inflammation in oral cavity.
- Endocrine disorders-hypo & hyperthyroidism.
- Ear, Nose & Throat dysfunctions-tonsillitis, sinusitis.

# Some Examples





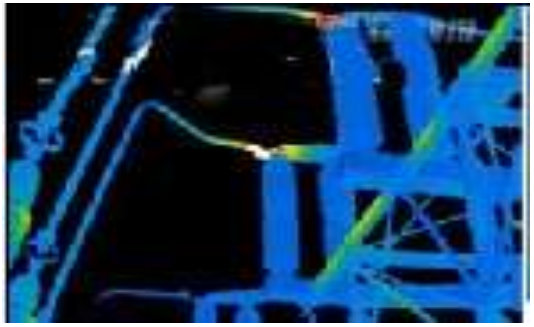
# Condition Monitoring

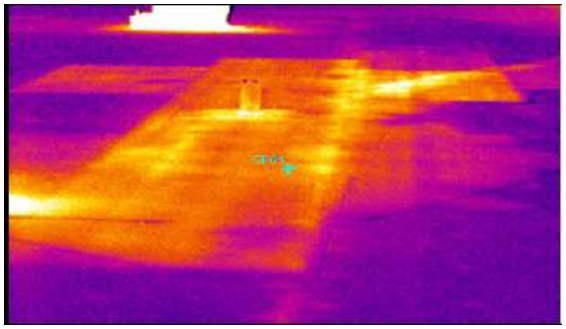
- Monitoring a parameter of condition in machinery, such that a significant change is indicative of a developing faliure.
- Major component of predictive maintenance.
- Cost effective than allowing the machinery to fail.
- Serviceable machinery-rotating machines & stationary plant like boilers, heat exchangers.

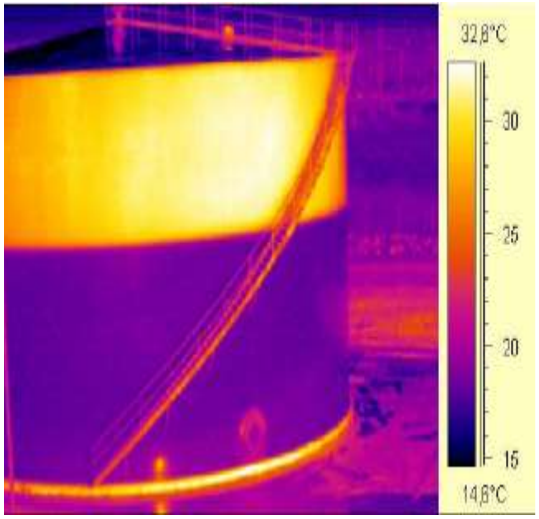
# Condition Monitoring

- Electrical maintenance-camera can see the difference in the heat of defected & normal components.
- Buildings-monitors the heat loss & air leakage.
- Furnace & boilers-finds incipient defects in power plant equipments.
- Tanks & vessels-inspects for tank leaks & to verify tank level.

# Cond…..







# Active & Passive Thermography

- In passive thermography, inspected parts are naturally at a higher or lower temperature than the background.
- In active thermography, an energy source is required to produce a thermal contrast.
- The defects can be either detected as hot (active) or cold spots (passive) on the surface.

# Advantages

- Non-destructive test method.
- Capable of catching moving targets in real time.
- Find defects in shafts and other metal parts.
- Measurement in areas inaccessible or hazardous for other methods.
- Condition monitoring.
- Help to compare temperatures over a large area .

# Limitations

- Training and staying proficient in IR scanning is time consuming.
- Images is hard to interpret accurately even with experience.
- Quality cameras have a high price range.
- Cameras have worse accuracy.

# Conclusion

- Thermography enables us to see and measure heat.
- It is a method that utilizes a thermal image to detect, display and record thermal patterns and temperatures across the surface of an object.
- It is the future in water damage and mold claims adjudication for the insurance industry.

# ENDOSCOPY

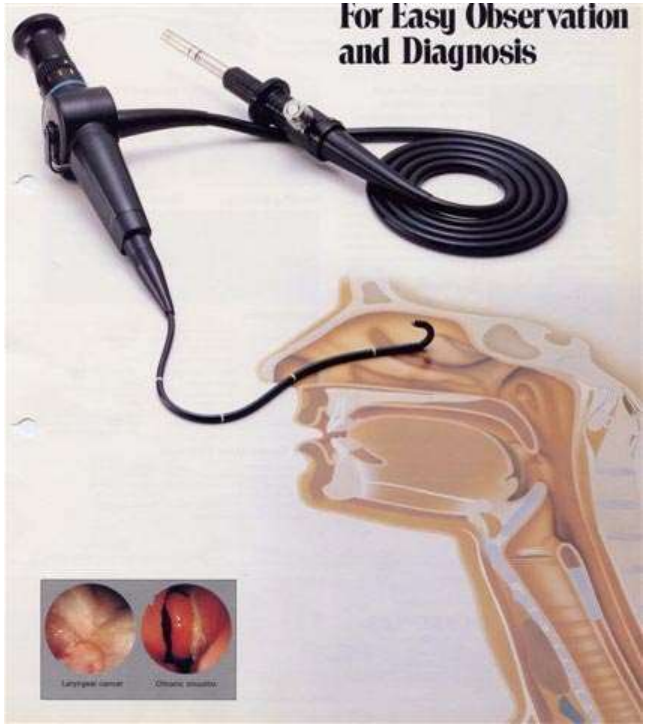
# ENDOSCOPY

Endoscopy, is the examination of internal body cavities using a specialized medical instrument called an endoscope.

Physicians use endoscopy to diagnose, monitor, and surgically treat various medical problems.

# ENDOSC

- An endoscope is a slender, flexible tube equipped with lenses and a light source. Illumination is done by the help of a number of optical fibres.
- Reflected light rays are collected by CCD( Charge coupled device) and electrical signals are produced, which are fed to the video monitor to get image.
- Thorough one channel of endoscope water and air is conducted to wash and dry the surgical site.



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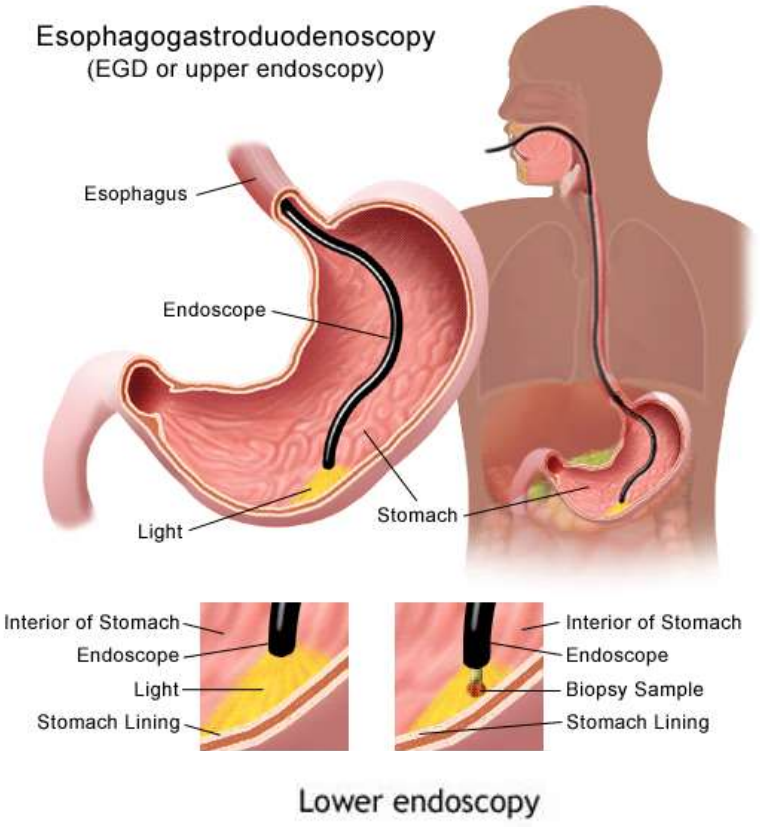
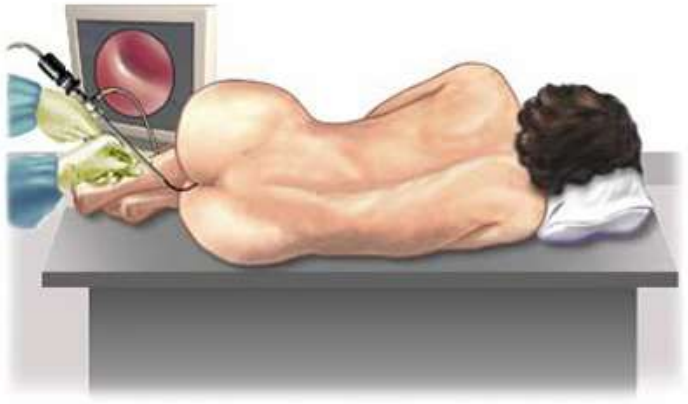
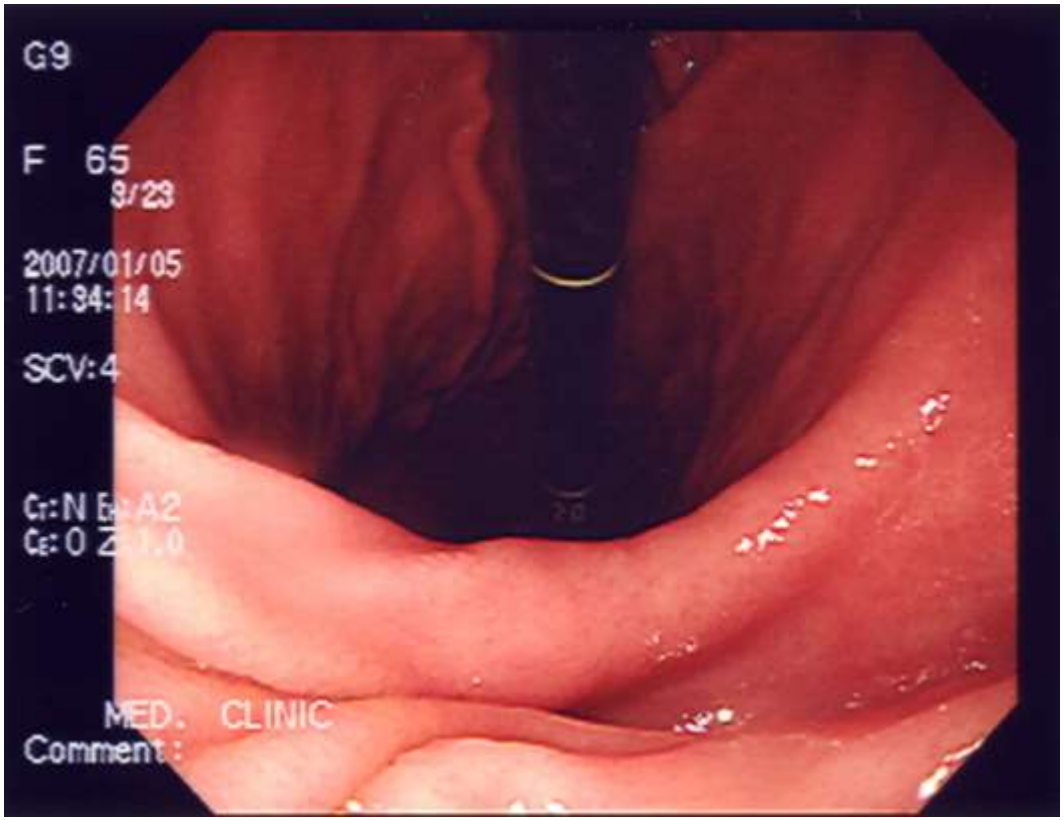



- The endoscope also has a channel through which surgeons can manipulate tiny instruments, such as forceps, surgical scissors, and suction devices.
- A variety of instruments can be fitted to the endoscope for different purposes.

- A surgeon introduces the endoscope into the body either through a body opening, such as the mouth or the anus, or through a small incision in the skin.



# ENDOSCOPY




- The endoscope gives visual evidence of the problem, such as ulceration or inflammation
- It can be used to collect a sample of tissue; remove problematic tissue, such as polyps
- It is used to take photograph of the hollow internal organs

# ENDOSCOPY

- Depending on the body part, each type of endoscopy has its own special term, such as

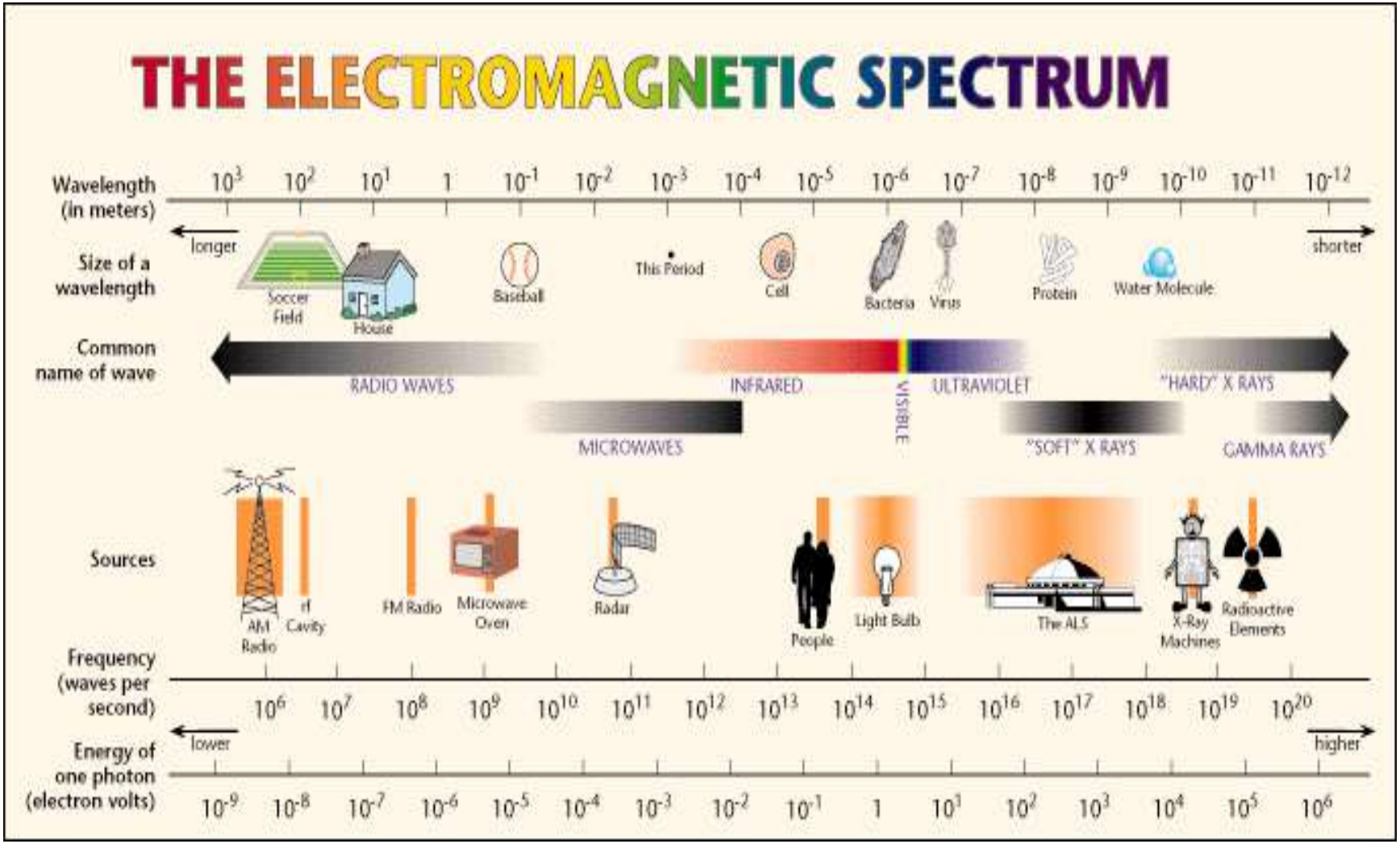
  laparoscopy (abdomen, uterus, fallopian tube),
  laryngoscopy (vocal cords),
  bronchoscopy (lungs),
  colonoscopy (colon),
  arthroscopy (joint) and
  Gastroscopy (Stomach).

# Laser Therapy

# Laser Therapy

- Light Amplification by the Stimulated Emission of Radiation

- Compressed light of a wavelength from the cold, red part of the spectrum of electromagnetic radiation
  - Monochromatic - single wavelength, single color
  - Coherent - travels in straight line
  - Polarized - concentrates its beam in a defined location/spot


THE ELECTROMAGNETIC SPECTRUM
Wavelength (in meters)
$10^{3}$ $10^{2}$ $10^{1}$ 1 $10^{-1}$ $10^{-2}$ $10^{-3}$ $10^{-4}$ $10^{-5}$ $10^{-6}$ $10^{-7}$ $10^{-8}$ $10^{-9}$ $10^{-10}$ $10^{-11}$ $10^{-12}$
longer
shorter
Size of a wavelength
Soccer Field
House
Baseball
This Period
Cell
Bacteria
Virus
Protein
Water Molecule
Common name of wave
RADIO WAVES
INFRARED
VISIBLE
ULTRAVIOLET
"HARD" X RAYS
MICROWAVES
"SOFT" X RAYS
GAMMA RAYS
Sources
AM Radio
rf Cavity
FM Radio
Microwave Oven
Radar
People
Light Bulb
The ALS
X-Ray Machines
Radioactive Elements
Frequency (waves per second)
$10^{6}$ $10^{7}$ $10^{8}$ $10^{9}$ $10^{10}$ $10^{11}$ $10^{12}$ $10^{13}$ $10^{14}$ $10^{15}$ $10^{16}$ $10^{17}$ $10^{18}$ $10^{19}$ $10^{20}$
Energy of one photon (electron volts)
lower
higher
$10^{-9}$ $10^{-8}$ $10^{-7}$ $10^{-6}$ $10^{-5}$ $10^{-4}$ $10^{-3}$ $10^{-2}$ $10^{-1}$ 1 $10^{1}$ $10^{2}$ $10^{3}$ $10^{4}$ $10^{5}$ $10^{6}$

- Albert Einstein – 1st described this theory that was transformed in to laser therapy
- By the end of the 60's, Endre Mester (Hungary) -
  - was reporting on wound healing through laser therapy
- In early 1960's, the 1st low level laser was developed.
- In Feb. 2002, the MicroLight 830 (ML830) received FDA approval for Carpal Tunnel Syndrome Treatment (research treatment)
- Laser therapy – has been studied in Europe for past 25-30 years; US 15-20 years

# Types of LASER

- Therapeutic Laser
- Low Level Laser Therapy
- Low Power Laser Therapy
- Low Level Laser
- Low Power Laser
- Low-energy Laser
- Soft Laser
- Low-reactive-level Laser

# Types of LASER

- Low-intensity-level Laser
- Photobiostimulation Laser
- Photobiomodulation Laser
- Mid-Laser
- Medical Laser
- Biostimulating Laser
- Bioregulating Laser

# Working of LASER

- Laser light waves penetrate the skin with no heating effect, no damage to skin & no side effects.

- **Laser light directs biostimulative light energy to the body's cells which convert into chemical energy to promote natural healing & pain relief.

- Optimizes the immune responses of blood & has anti-inflammatory & immunosuppressive effects.

# Physiological Effects

- Biostimulation – improved metabolism, increase of cell metabolism
  - Increases speed, quality & tensile strength of tissue repair
- Improved blood circulation & vasodilation
  - Increases blood supply
- Increases ATP production
- Analgesic effect
  - Relieves acute/chronic pain
- Anti-inflammatory & anti-edematous effects
  - Reduces inflammation

# Physiological Effects

- Stimulation of wound healing
  - Promotes faster wound healing/clot formation
  - Helps generate new & healthy cells & tissue
- Increase collagen production
  - Develops collagen & muscle tissue
- Increase macrophage activity
  - Stimulates immune system
- Alter nerve conduction velocity
  - Stimulates nerve function

# Tissue & Cellular Response

- Red light affects all cell types
  - Absorbed by the mitochondrial present in all cells
  - Cytochromes (respiratory chain enzymes) within the mitochondria have been identified as the primary biostimulation chromophores (*primary light-absorbing molecules*).
  - Since enzymes are catalysts with the capability of processing thousands of substrate molecules, they provide amplification of initiation of a biological response with light.

- Infrared light is more selective absorbed by specific proteins in the cell membrane & affects permeability directly

# Laser Generators

- Components of a generator:
  - Power supply – electrical power supply that can deliver up to 10,000 volts & 100's amps
  - Lasing medium – gas, solid, liquid
  - Pumping device –
    - high voltage, photoflash lamps, radio-frequency oscillators or other lasers (pumping is used to describe the process of elevating an orbiting electron to a higher, excited energy level)
  - Optical resonant cavity – contains lasing medium

# Types of Lasers

- **4 categories of lasers**
  - Crystal & Glass (*solid* - rod)
    - Synthetic ruby & others (synthetic ensures purity)
  - Gas (*chamber*) – 1961
    - HeNe, argon, $CO_2$, & others (HeNe under investigation)
  - Semiconductor (*diode* - channel) - 1962
    - Gallium Arsenide (GaAs under investigation)
  - Liquid (Dye) - Organic dyes as lasing medium
  - Chemical – extremely high powered, frequently used for military purposes

# High vs. Low Level Lasers

- High
  - Surgical Lasers
  - Hard Lasers
  - Thermal
  - Energy – 3000-10000 mW
- Low
  - Medical Lasers
  - Soft Lasers
  - Subthermal
  - Energy – 1-500 mW
  - Therapeutic (Cold) lasers produce maximum output of 90 mW or less
  - 600-1000 nm light

# Laser Light Properties

- Monochromaticity
  - 1 color – 1 wavelength
  - <400 nm
  - Ultraviolet spectrum
- Coherence
  - Waves same length & traveling in same phase relationship
  - 400-700 nm
  - Visible
- Collimation
  - Degree to which beam remains parallel with distance
  - 700-10,000 nm
  - Infrared

# Parameters

- Patient
  - Need medical history & proper diagnosis
    - Diabetes – may alter clinical efficacy
  - Medications
    - Photosensitivity (antibiotics)
  - Pigmentation
    - Dark skin absorbs light energy better
- Laser
  - Wavelength
  - Output power
  - Average power
  - Intensity
  - Dosage

# Parameters - Wavelength

- Nanometers (nm)
- Longer wavelength (lower frequency) = greater penetration
- Not fully determined
- Wavelength is affected by power

# Parameters – Power

- Output Power
  - Watts or milliwatts (W or mW)
  - Important in categorizing laser for safety
  - Not adjustable
- Power Density (intensity)
  - W or $mW/cm_2$
  - Takes into consideration – actual beam diameter If light spread over lager area – lower power density
  - Beam diameter determines power density
- Average Power
  - Continuous or pulse-train (burst) frequency mode
  - Knowing average power is important in determining dosage with pulsed laser
  - If laser is continuous – avg. power = peak output power
  - If laser is pulsed (burst) then avg. power is = to peak output power X duty cycle

# Parameters – Energy Density

- Dosage (D)
- Amount of energy applied per unit area
- Measured in Joules/square cm ($J/cm^2$)
  - Joule – unit of energy
  - 1 Joule = 1 W/sec
- Dosage is dependent on:
  - Output of laser in mW
  - Time of exposure in seconds
  - Beam surface area of laser in $cm^2$
- Various dosage ranges per site (1-9 $J/cm^2$)

# Parameters – Energy Density

- Recommended Dosage Range
  - Therapeutic response = 0.001-10 J/$cm_2$
  - Minimal window threshold to elicit response
  - Too much – suppressive effect
  - Open wounds – 0.5-1.0 J/$cm_2$
  - Intact skin – 2.0-4.0 J/$cm_2$
  - Average treatment – 6 /$cm_2$

# Helium Neon Lasers

- Uses a gas mixture in a pressurized tube
  - Now available in semiconductor laser
- Emits red light
- Wavelength:  632.8 nm
- Power output: 1.0-25.0 mW
- Energy depth: 6-10 mm

- The higher the output lasers (even though they are still low power) allow reduced delivery time

# Indium-Gallium-Aluminum-Phosphide

- InGaAip
- Replacing HeNe lasers
- Semiconductor
- Wavelength:  630-700 nm
- Power output:  same as HeNe
- Energy depth: superficial wound care

# Gallium Arsenide

- Semiconductor - produces an infrared (invisible) laser
- Wavelength:  904–910 nm
- Power output: may produce up to 100 mW
- Energy depth: 30-50 mm
- Short pulse-train (burst) duration (100-200 ns)

# Gallium Aluminum Arsenide

- GaAlAs
- Semiconductor
- Wavelength: 780-890 nm
- Power Output: 30-100 mW (up to 1000 mW)

# Indications

- ***Indications***
  - Soft tissue injuries
  - Fractures
  - Osteoarthritis, Rheumatoid Arthritis
  - Pain
  - Wounds & Ulcers
  - Acupuncture

# Contraindications

- ***Contraindications***
  - Application over eyes
  - Possibly can damage cellular structure or DNA
  - Cancerous growths
  - Pregnancy – over & around uterus
  - Over cardiac region & Vagus nerve
  - Growth plates in children
  - Over & around thyroid gland & endocrine glands
  - Patients who have been pre-treated with one or more photosensitizers

# Treatment Precautions

- Better to underexpose than to overexpose
- Avoid direct exposure into eyes (If lasing for extended periods of time, safety glasses are recommended)
- May experience a syncope episode during treatment during chronic pain, but very rare
- If icing – use BEFORE phototherapy
  - Enhances light penetration
- If using heat therapy – use AFTER phototherapy
  - Decreases light penetration

# Treatment Techniques

- Gridding Technique
  - Divide treatment areas into grids of square centimeters
- Scanning Technique
  - No contact between laser tip in skin; tip is held 5-10 mm from wound
- Wanding Technique
  - A grid area is bathed with the laser in an oscillating fashion; distance should be no farther than 1 cm from skin
- Point Application (Acupuncture point)

# Treatment Techniques

- Simple
- For general application, only treatment time & pulse rate vary
- Dosage
    - Most important variable in laser therapy & may be difficult to determine because of the above conditions
- Handheld applicator
- Tip should be in light contact with skin while laser is engaged for calculated time
- Maintain laser perpendicular to treatment surface
- Firm contact unless open wound
- Clean area prior to treatment
- Begin with minimal treatment and gradually increase
- Check for pre/post-treatment changes
- Ask the patient how they are doing prior to next treatment
    - May have to adjust dosage

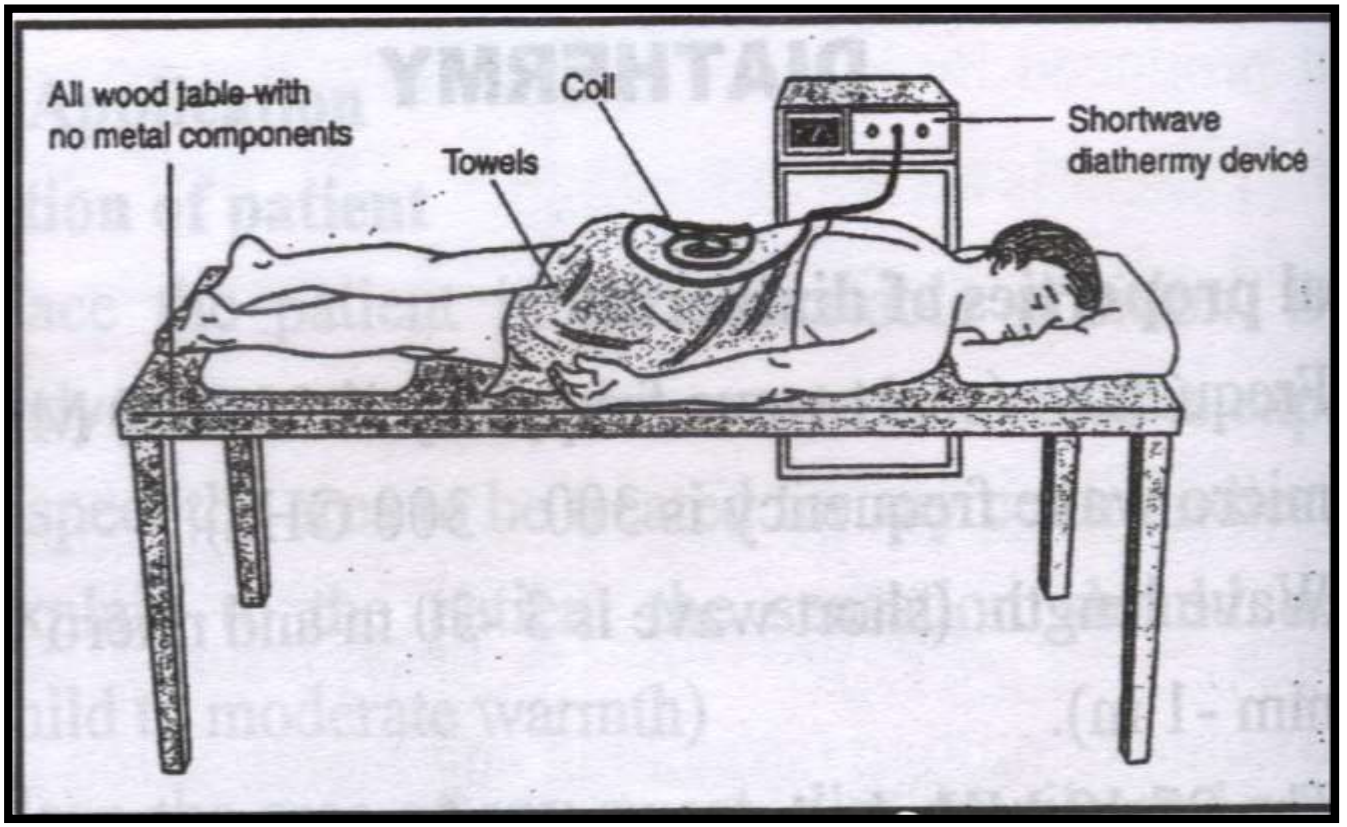
- Dynatron's Solaris D880 Infrared Therapy
  - 880 nm wavelength – SLD (32 ) (deep)
  - 660 nm – LED (4)  (superficial)
  - 10 minute max. treatment or 60 Joules
  - Place probe on treatment area.  Maintain constant contact with the skin.
    - Do not bathe the area with the probe.
  - FDA cleared to "provide topical heating for temporary increase in blood circulation, temporary relief of minor muscle & joint aches, pain & stiffness & relaxation of muscles; for muscle spasms & minor pain & stiffness associated with arthritis."
    - Dynatron Solaris 709

# DIATHERMY

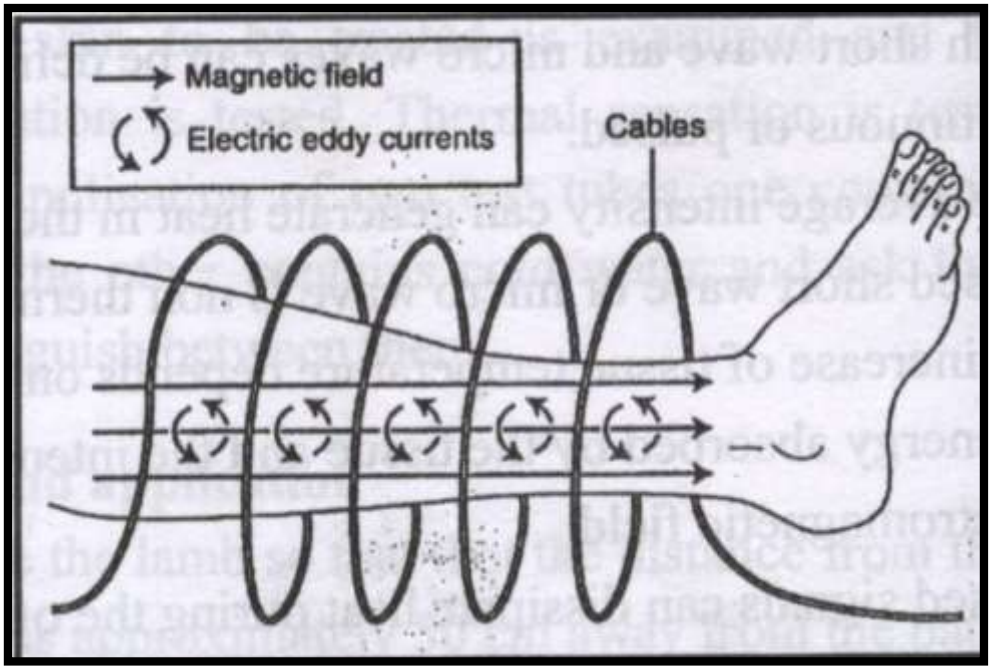
# DIATHERMY

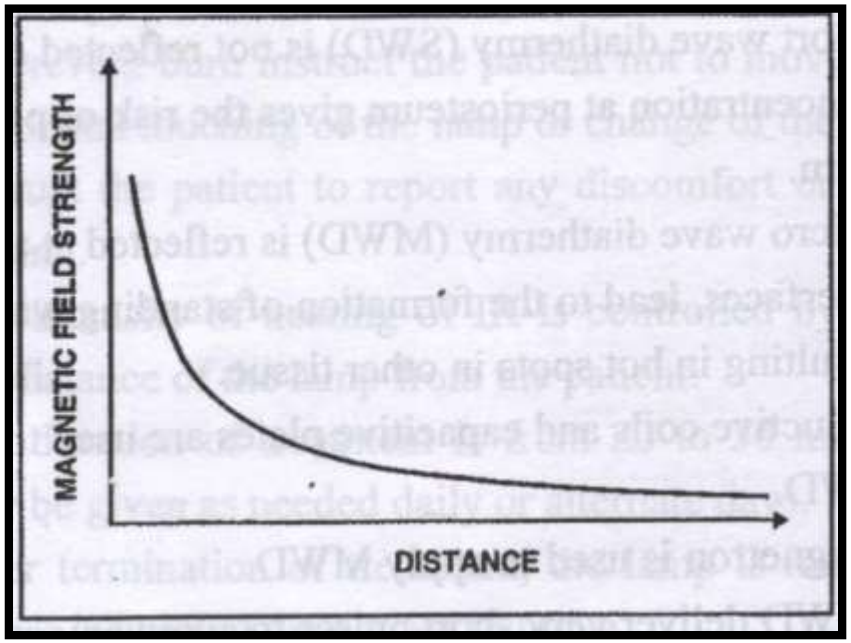
## Physical properties of diathermy

**Inductive coil**



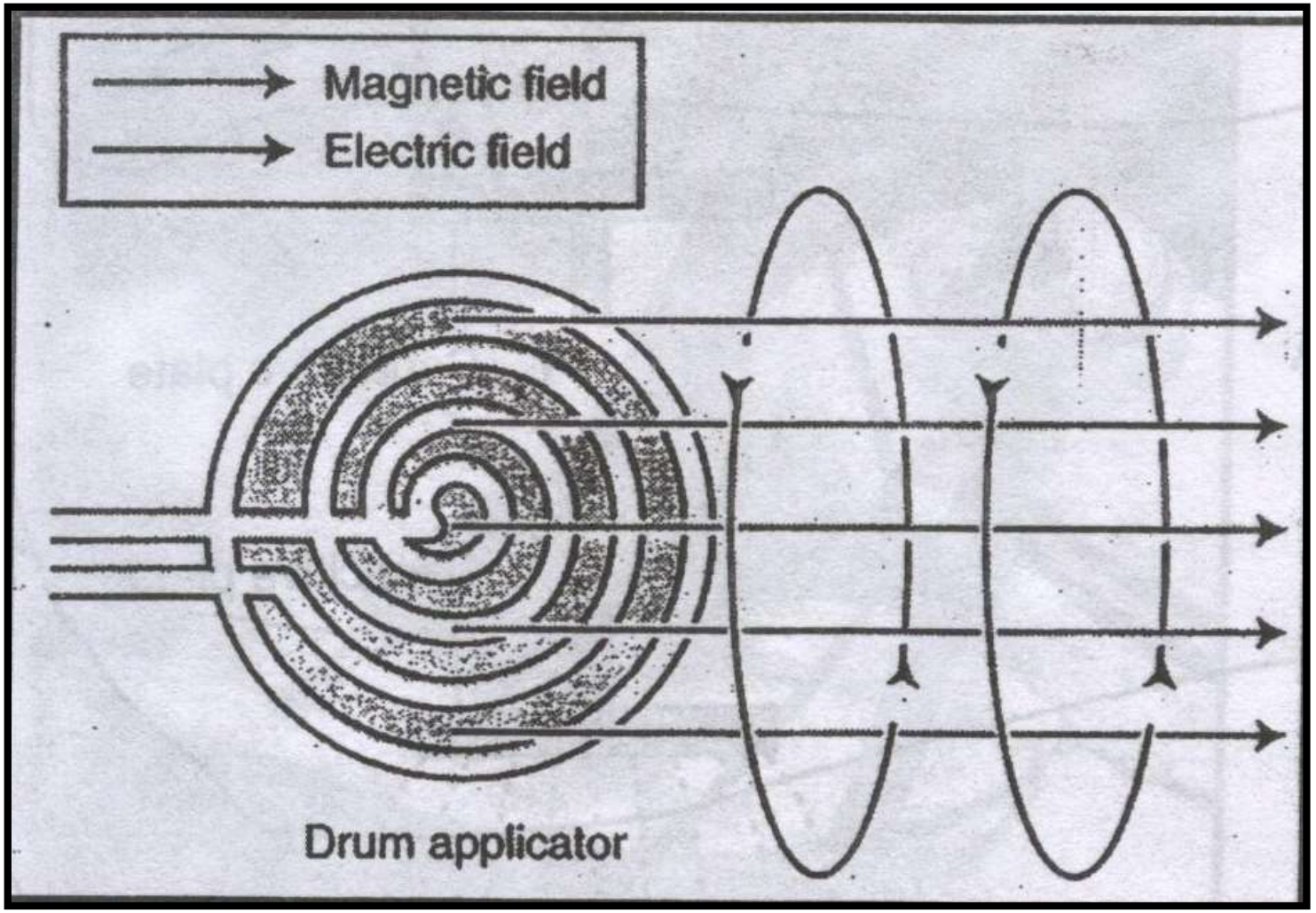
# Generation of magnetic field




# Behavior of magnetic field

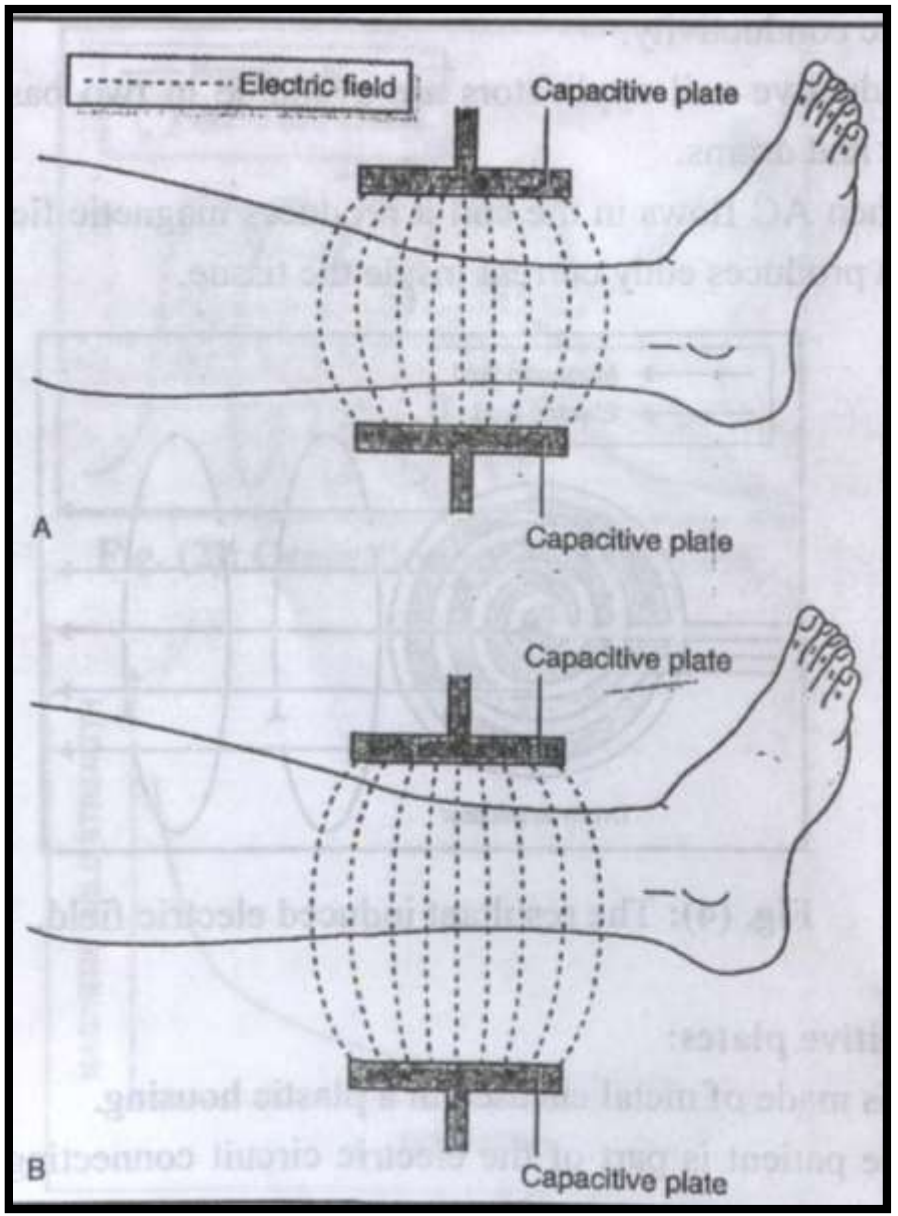
# Inductive coil



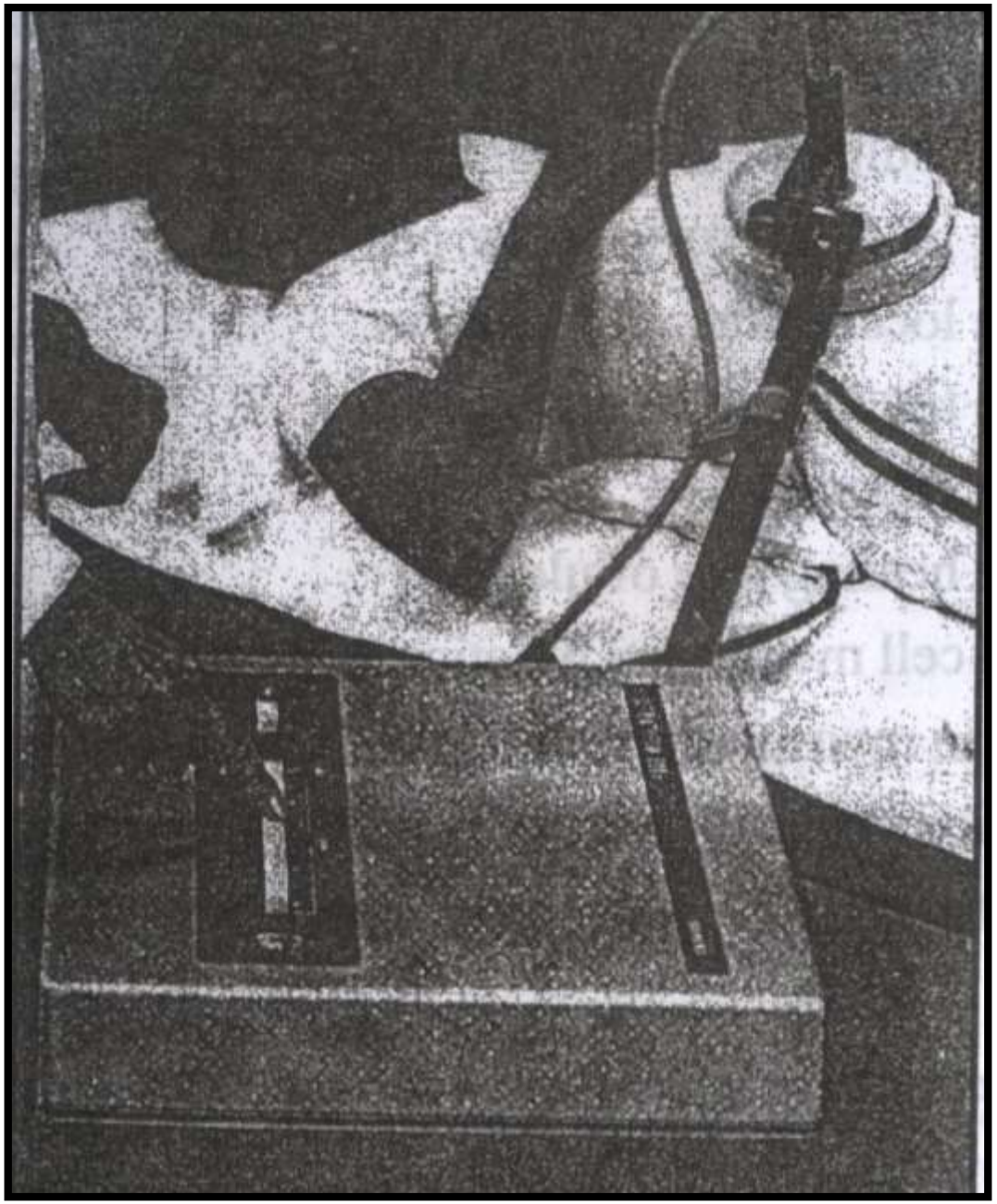

**The resultant induced electric field**

# Capacitive plates

**Electric field distribution**



# Magnetron



**Capacitive plates of diathermy applicator**

# *Effect of Diathermy:*

## Thermal effects

1. **Increase tissue temperature.**
2. **Vasodilatation.**
3. **Increased rate of nerve conduction.**
4. **Decrease pain.**
5. **Acceleration of enzymatic activity.**
6. **Increased soft tissue extensibility.**
7. **Increase cutaneous circulation.**
8. **Increase muscular circulation.**

# Non thermal effects

1. Any transient heat of tissue is dissipated by the blood per fusing the area during off time of the pulse.
2. Physiological effects are due to modification of ion binding and cellular functions by the incident electro magnetic field and the resulting electric current.
3. Increase local micro-vascular per fusion.
4. Increase local tissue oxygenation.
5. Increase tissue nutrients availability.
6. Increase phagocytosis.
7. Increase healing rate of ulcers.
8. Altered cell membrane function and cellular activity.
9. Change in myosin phosporylation.
10. Regulation of the cell cycle by altering calcium ion binding
11. Stimulation of ATP and protein synthesis.

## *Clinical Indication of Diathermy:*

### Thermal level diathermy:

1. **Decrease pain.**
2. **Accelerate healing.**
3. **Rheumatic pain.**
4. **Chronic sprains and strains.**
5. **Improve joint function, if applied in conjunction with stretching.**

# Non-thermal level:

- **Decrease pain.**
- **Decrease edema.**
- **Increase wound healing rate.**
- **Increase nerve healing rate.**
- **Increase bone healing rate.**
- **Management of neuropathy.**
- **Management of ischemic skin flaps.**

## *Contra Indications:*

### Thermal diathermy:

- Metal implants
- Malignancy
- Eyes
- Growing epiphysis
- Pacemaker
- Pregnancy
- Testes

### Non-thermal diathermy:

- Peace makers.
- Metal implants at the treatment site.
- Substitutes for conventional therapy for edema and pain.
- As a treatment of internal organs.

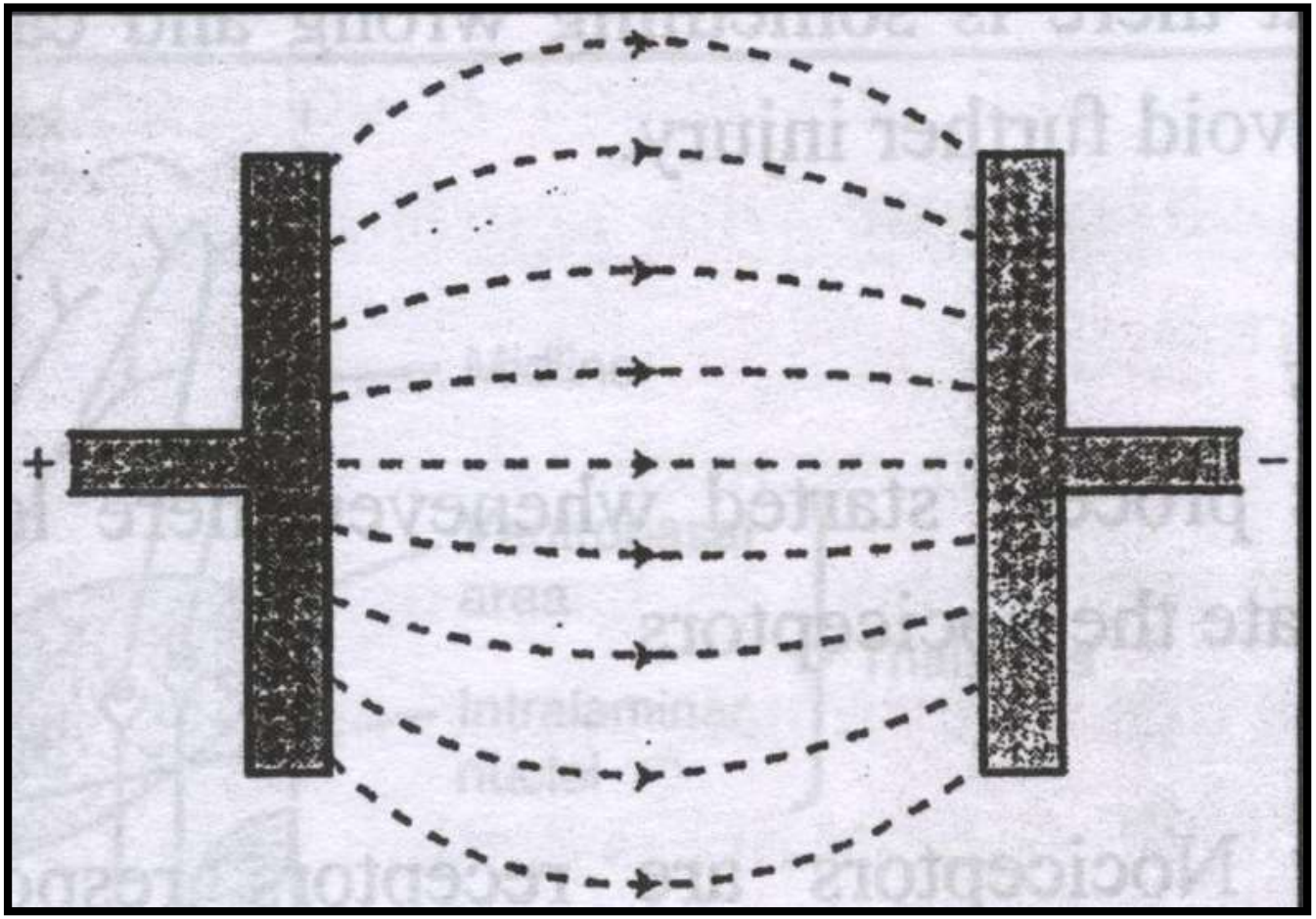
## *precautions:*

### Thermal diathermy:

- **Electronic or magnetic equipment in the field.**
- **Obesity.**
- **Copper bearing intra uterine contraceptive devices.**

### Non-thermal diathermy:

- **Pregnancy.**
- **Skeletal immature patients.**




# Electric field distribution in tissue

# ELECTROSURGICAL DIATHERMY

# ❑ PURPOSE

- ESU are used for surgical cutting and for controlling bleeding by causing coagulation “hemostasis” at the surgical site.

- It is “high frequency diathermy” involves the transference of electrical energy into heat which ,when impact to the bodily tissues, will heat the normal cell fluid, eventually through it is boiling point.

- What dose “DIATHERMY” mean?

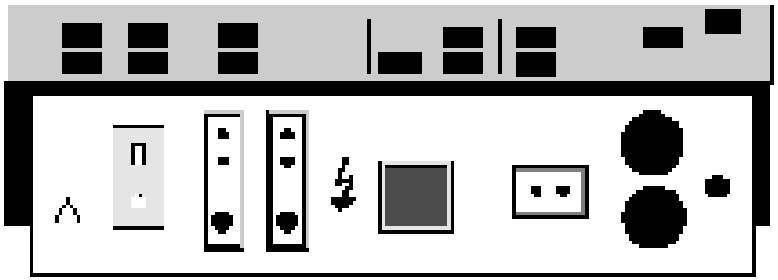
DIA = through

THERMO = temperature heat

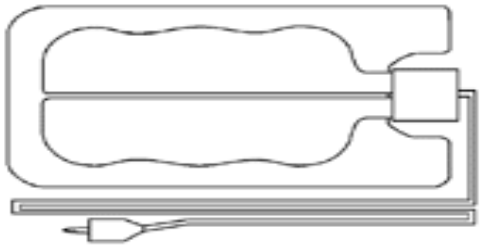
# ❑ Principle

- ESU machine is an alternating current source that operates at radio frequency “RF”.
- A high frequency current flowing through active electrode “high current concentration”.
- Cell ruptured-fumes or evaporates.
- Return path through dispersive electrode “low current and heat dissipates”.
- Patient is included in circuit.
- Current concentration or density depends on the size of the area through which the current flows.
- HF generation can be activated by a foot switch or finger switch on the surgical handle.

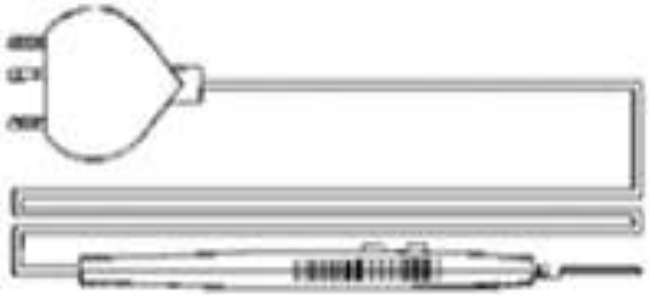
# System Components



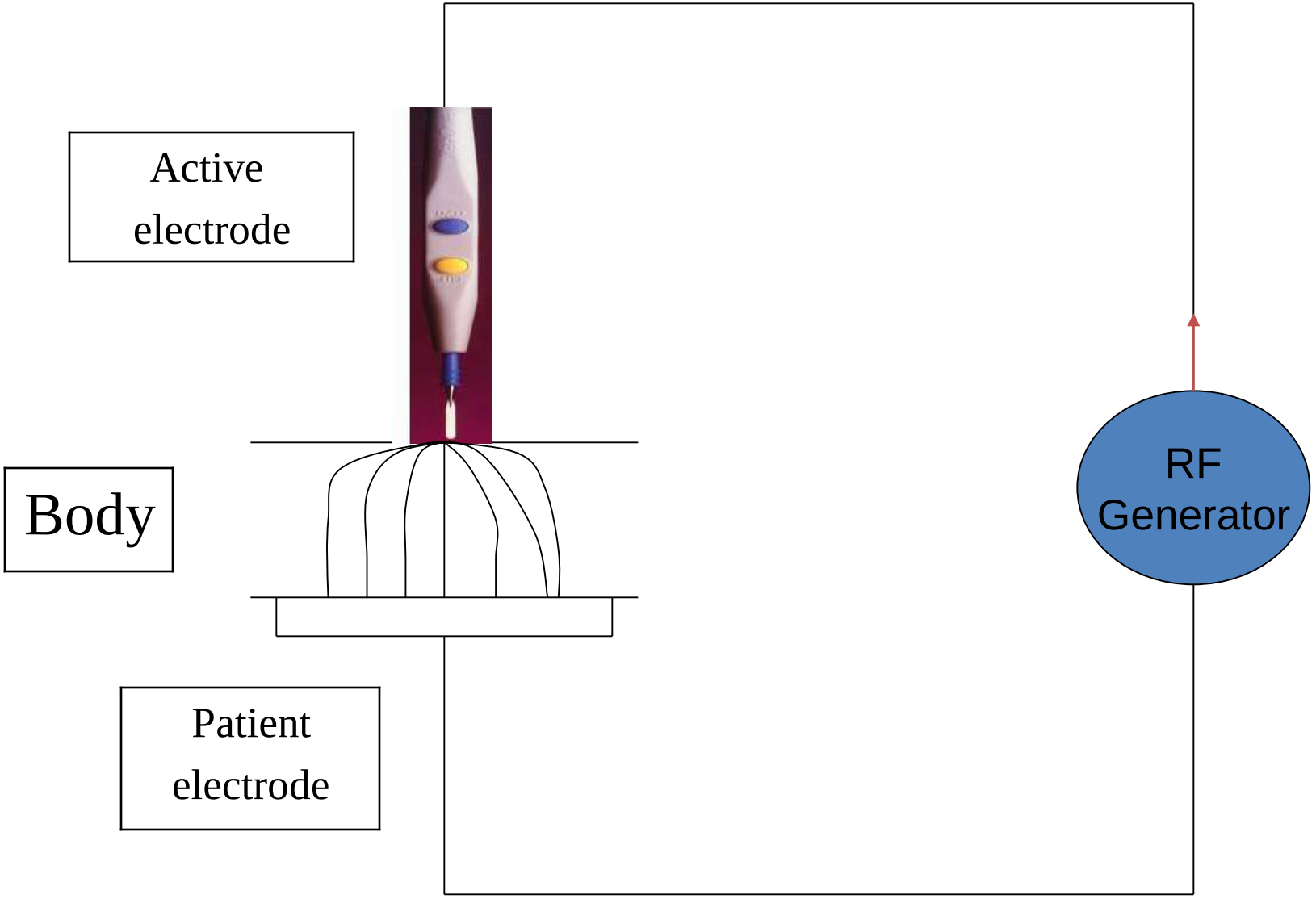
Electrosurgery Unit

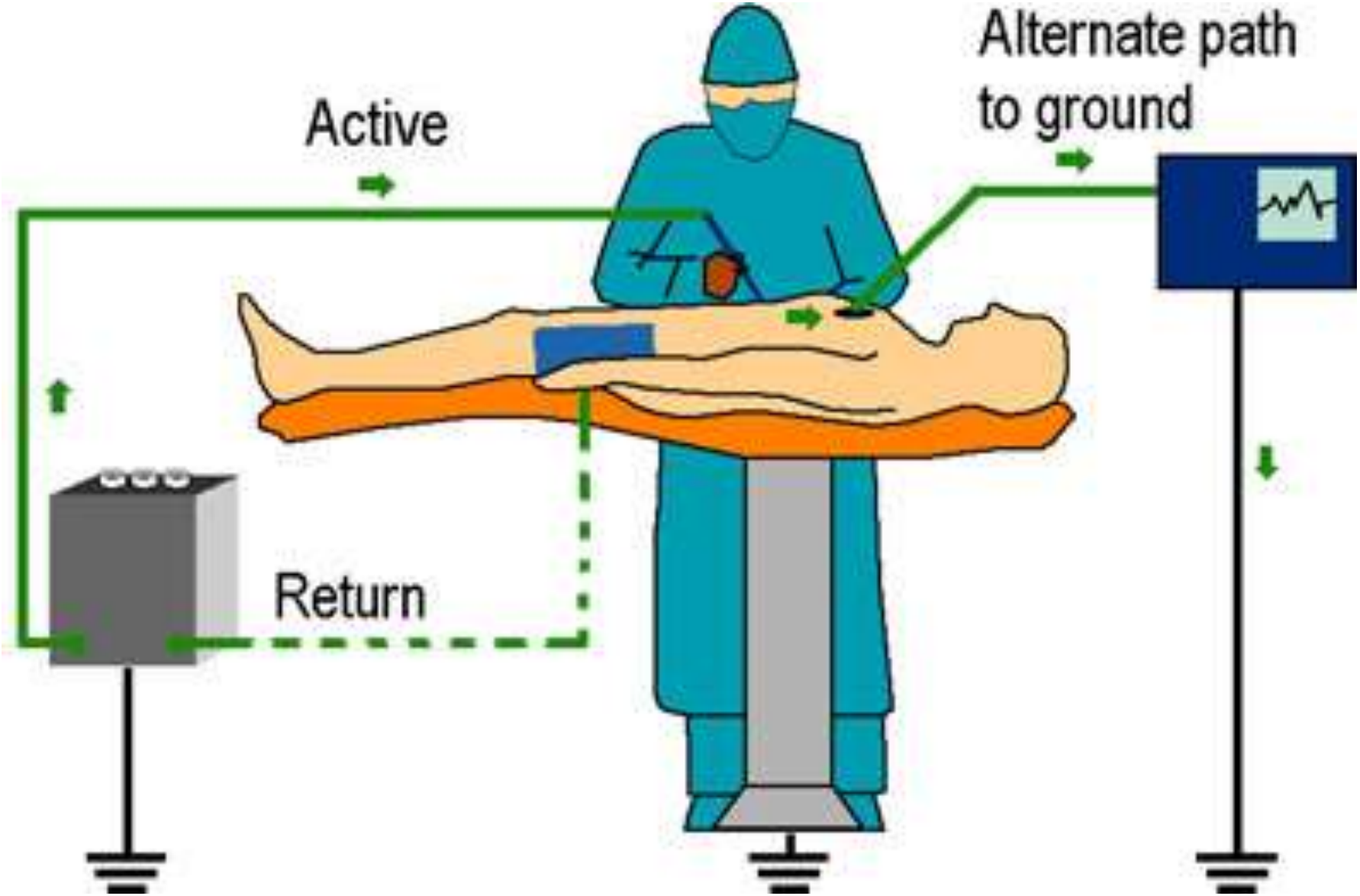


Dispersive Electrode



Active Electrode


Active electrode
Body
Patient electrode
RF Generator


Alternate path
to ground
Active
Return

# ❑ Effect of RF on cell

- When a high frequency current applied to the tissues the tissues gets turn apart and get the following effect:

1. Thermal effect.
2. Electrolytic effect.
3. Faradic effect.

# ❑ Operating frequency and typical value

- Operating frequency of solid state surgical diathermy machine is 300 KHz –to-3MHz
- Monopolar :CUT “0-to-350”watts for load 5
  COAG”0-to-100” watts
- Bipolar : CUT “0-to-50” watts
  COAG “0-to-10” watts

# ❑ Types of ESU

- ➢ Spark gap generator – 1924
- Still in use today “urology , open- heart surgery”.

- Spark gap / vacuum-tube device use spark –gap circuits to generate high frequency waveforms.

- It is not offer the same safety feature as solid state unites.

# ➢ Recent technology

- Argon/argon enhanced technology.
- It uses a computer-controlled tissue feedback system that senses tissue impedance and automatically adjusts the current and output voltage to maintain a constant surgical effect .
- It is reduces the need to adjust power setting for different types of tissue.
- It is also gives improved performance at low power setting to reduce the risk of patient injury.

# ➢ Solid state device - 1968

- It is more recent and more prevalently used technology.
- Contain  oscillator circuits and transistor-based amplifier that vary the frequency and modify the shape of the line signal to create an array of different waveforms for pure CUT,COAG, BLEEND .
- Highly safety.

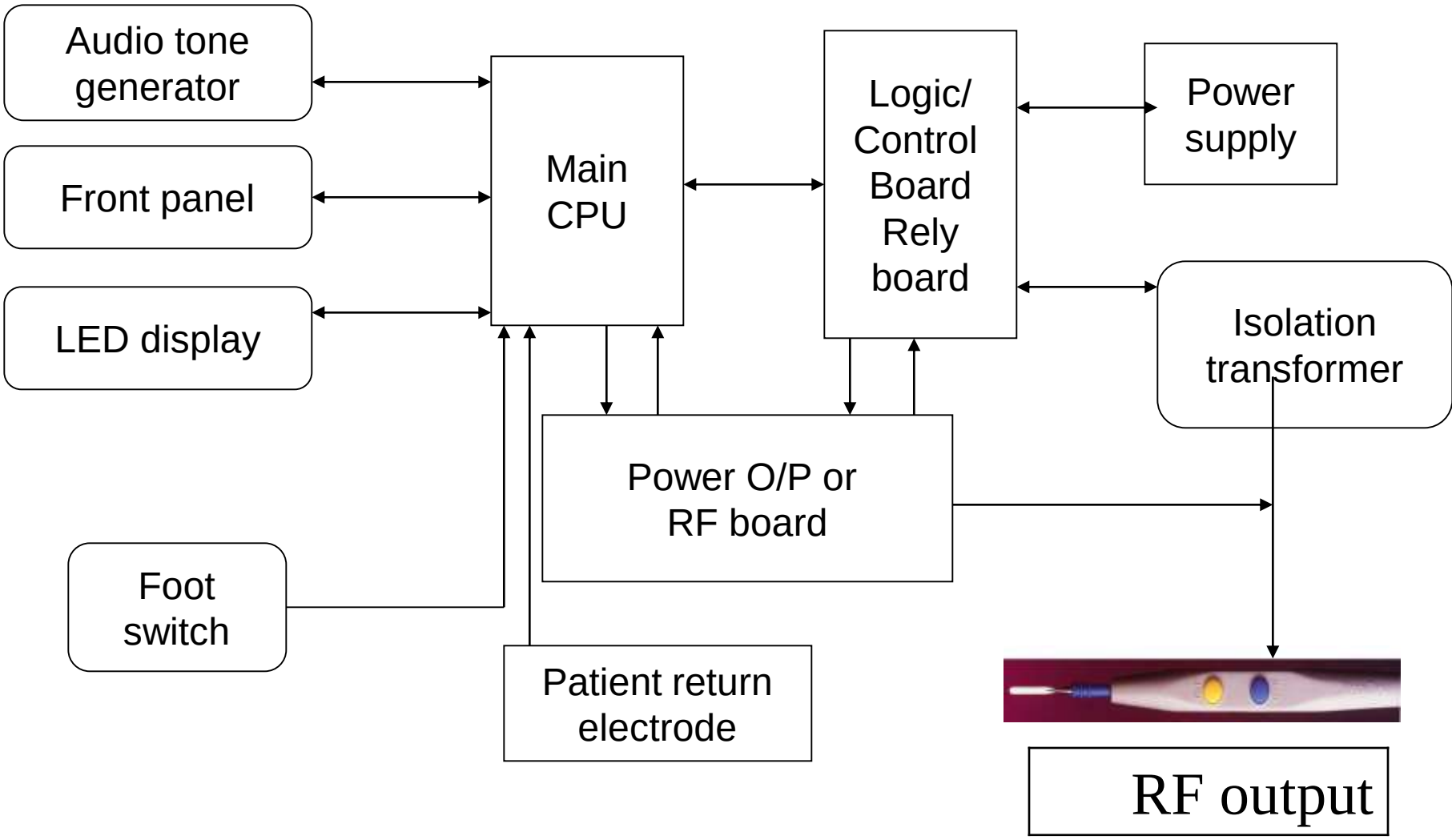
# ❑ Modes of Electro surgery

- Monopolar surgery
- Bipolar surgery

# ❑ Modes of electrosurgery

- Electrotomy/cutting
- desiccation / coagulation
- Blend
- fulgurations

# General Block Diagram



# ULTRASOUND DIATHEMRY

# Ultrasound

- Ultrasound is the most commonly used deep heating modality in use today.  Penetration is between 3-5 cm.
- Acoustical energy, not electromagnetic as most other units
- frequency is between .8 and 3 MHz (audible f= 15-20,000 Hz)

# Purpose and Use of Ultrasound

- Thermal
  - ↑ Blood Flow
  - ↓ Spasms
  - ↓ Pain
  - ↓ Collagen Extensibility
- Non-thermal
  - ↓ Subacute and chronic inflammation
  - Tissue changes resulting from mechanial effect
    - increase in cell permeability
    - collagen synthesis and realignement

# Equipment

- Electrical generator with step up or down transformer to overcome impedance of the crystal
- Oscillating circuits: optimizing frequency and allows us to impose a duty cycle
- coaxial cable carries current and minimizes any distortion
- transducer converts electrical energy into crystal into mechanical vibration (sound waves)

# The Crystal

- piezoelectric effect: *electricity* across the crystal causes deformation and vibration
- The quartz crystal requires high amount of voltage to cause piezoelectric effect and must therefore have well insulated coaxial cables to deliver electricity to the transducer.
- Capable of delivering mechanical and thermal effects to the tissue

# Terminology for Effects:

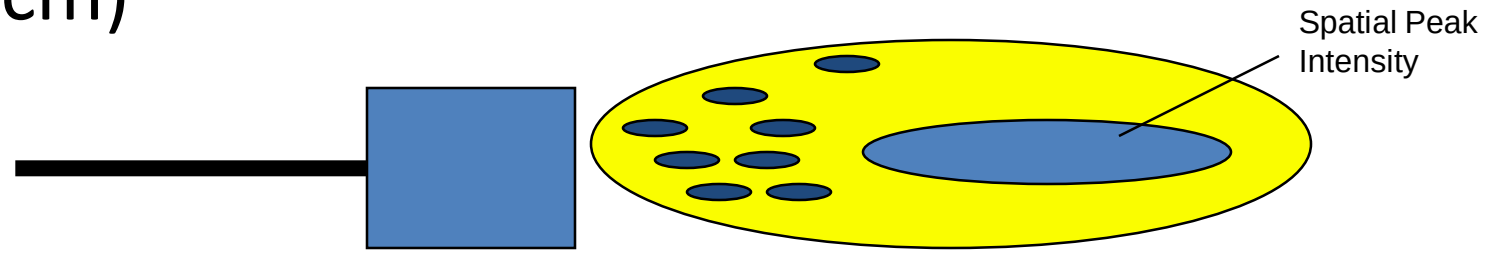
- Continuous or pulsed: this determines the production of heat. If the US is pulsed the % means the percent of time the sound will be delivered in a unit of time (i.e. 20% duty cycle will give 2 msec of sound every sec.)
- Condensation: areas of high energy collection
- Rarefraction areas of lower energy, gaps between waves of molecules

# Propagation:

- Sound waves are most effectively transmitted through dense materials.
  - Soft tissue is analogous to liquid when US travels in longitudinal manner
  - Bone may be longitudinal or transverse. Bone can cause a shear force near tissue interfaces
  - US travels best in homogeneous material, interfaces cause more scattering of waves.
    - since fat is homogeneous it will transmit the waves and allow deeper penetration

# Special considerations for Equipment

- Spatial peak intensity: because the US beam is not uniform, some regions will be more intense.  The spatial peak intensity is the greatest intensity anywhere within the beam
- Spatial average: a measurement of the average intensity It is a measurement of the total power output (Watts) divided by the area (cm)



# Effect Radiating Area (ERA)

- Area of the sound head that produces US waves. Measured in square centimeters
- ERA is always smaller than the transducer surface area. Manufacturers will typically list the ERA and not the surface area when referring to the size of the transducer head.
- The closer the ERA and transducer surface area the better. This will allow a more consistent contact and therapeutic dose.

# Beam Non-uniformity Ratio (BNR)

- Describes the consistency (uniformity of the US output ratio.
  - This factor is the determining factor in purchasing a unit.
  - It tells the quality of the crystal.
- Lower the BNR more uniform the beam.
- The BNR is expressed in ratio from 10:1 down to 2:1.
  - A 6:1 BNR is acceptable but a 3:1 or 2:1 is best.8:1 is considered unsafe

# US effects in tissues

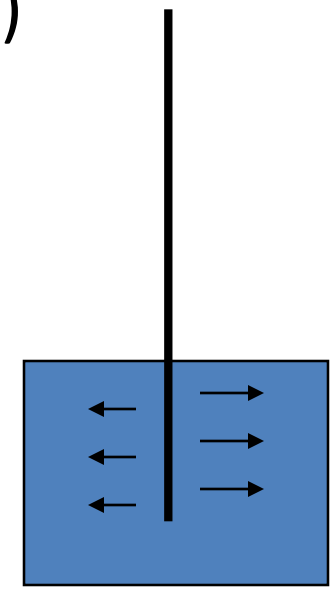
- Depth of penetration depends on the absorption and scattering of the US beam as it travels through the tissue. The frequency of oscillation determines the depth of penetration (the lower the frequency, the deeper the penetration)
- Absorption: the uptake of heat converted from acoustic energy by propagation of US through the tissues.

# Absorption

- Directly proportional to the protein content of the tissues sonated.
  - bone, cartilage, tendon and skin are 20-25% protein content
  - blood vessels are 15-20%
  - muscle, fat and blood are 10-15%
- Tissues which are selectively heated by US are the "target tissues" for US use.
  - Superficial bone, joint capsules, tendon, scar tissue, peripheral nerves, myofascial interface and cell membranes

# Absorption Cont.

- The more homogeneous the tissue, the less US energy is absorbed
  - example: fat, metallic and synthetic implants are very homogeneous and US produces very little temperature increase.
- High frequency sound (3 MHz) is absorbed more readily than lower frequencies (1 MHz)

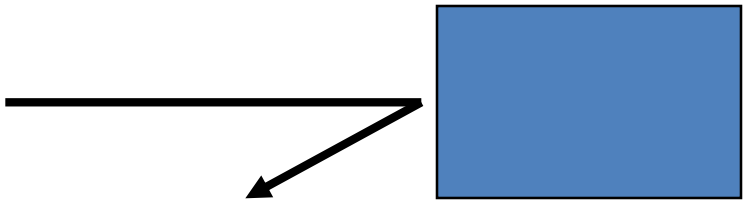


# Scattering

- The diffuse reflection or refraction of US from irregular surfaces or in homogeneities within the tissues
  - Reflection: the reversal of the direction of propagation of the ultrasound wave
  - Refraction: the reflection of energy from a straight path when passing obliquely from one medium to another

# Reflection:

- Reflection occurs when there is a mismatch of acoustic impedance between two tissue levels. The greater the acoustical impedance difference, the great the heat generated.
  - Acoustic impedance of muscle, fat and water is low with about 1% of the energy reflected

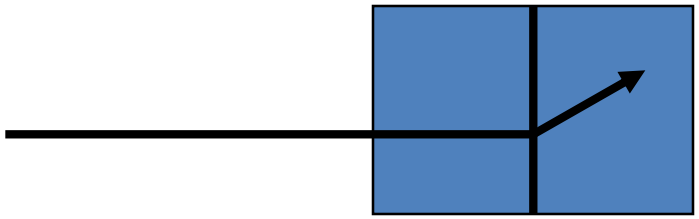


# Reflection Cont.

- Impedance of bone is high with about 25% of the energy reflected from the bone into the adjacent tissues
  - Results are significantly higher intensity in tissues close to the bone: periosteum, tendons, and aponeurotic attachment of muscle, cartilaginous coverings of joint surfaces, and peripheral nerves lying close to bones.
  - Poor blood supply in these tissues offers little heat dissipation by circulation which can lead to pain

# Refraction:

- The bending of energy can lead to concentrations of US at the point of refraction
  - Example: where tendon joins bone



# US Output Parameters

- Frequency (MHz)
  - The effective depth of penetration (1 or 3 MHz)
- Intensity
  - The amount of power generated by unit

# Treatment Parameters

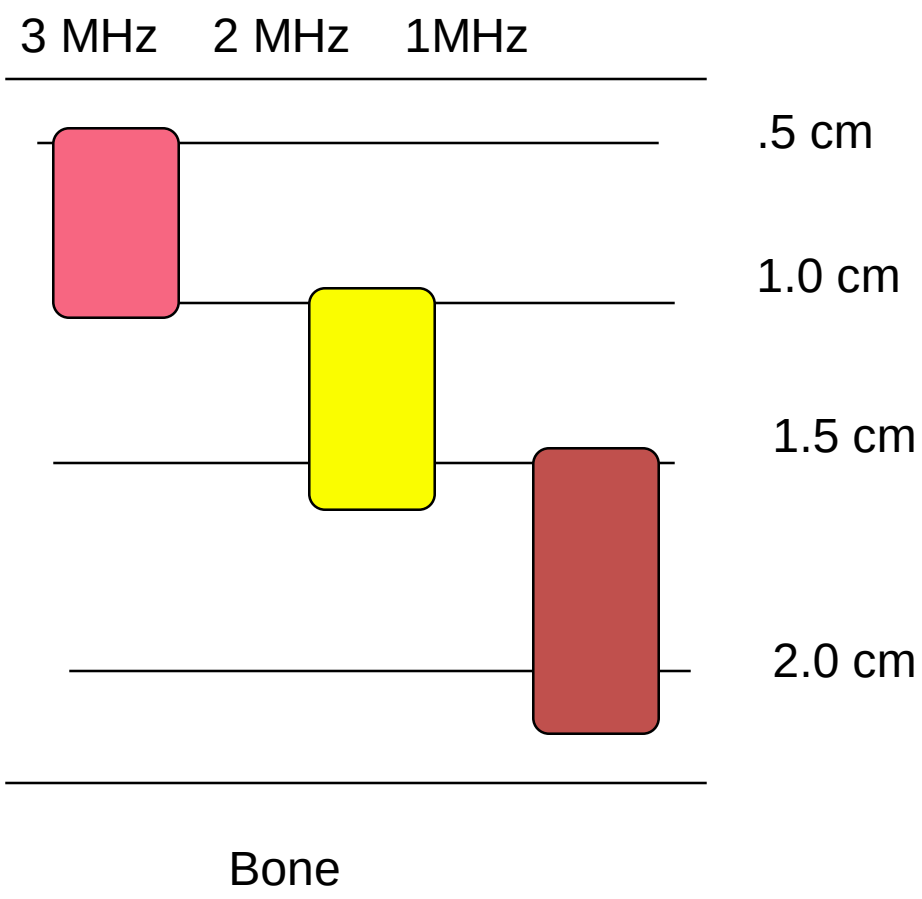
- Intensity: the rate at which energy is delivered per unit area and is expressed in $W/cm^2$
- Power: the total output of the transducer and is expressed in watts.  it is measured on an US power meter
- Frequency: the number of sound oscillations in one second and is expressed in MHz.
- Transducer Size: the smaller the transducer surface area the greater the be a divergence. Always select the largest size transducer with the best ERA and lowest BNR that will offer the most consistent contact with surface.

# Intensity:

- Everyone's tolerance is different
- The feeling of warmth is desired (if using for thermal properties)
- Begin at 1.0 $W/cm^2$ and increase intensity until the patient feels heat (not pain) and reduce until a gentle heating if felt
- Some researchers site: 1.0 $W/cm^2$ for "thin" tissues and 1.0-2.0 $W/cm^2$ for "thick" tissues

# Frequency

- 3MHz 0-1cm
- 2 MHz 1-2 cm
- 1 MHz 2-3 cm



# Transducer:

- Choose an area that is an appropriate size
  - no greater than 1.5 to 2 times the ERA
- Speed of rotation will vary the heat

# Therapeutic Applications

| Effect | Temp. Increase | Application |
|---|---|---|
| Non Thermal | None | Acute, Injury, Edema, Healing |
| Mild Thermal | 1° C | Sub Acute Injury Hematoma |
| Moderate Thermal | 2° C | Trigger points |
| Vigorous | 3° C | Stretch Collagen |

# US Application Time

- Continuous: A duty factor of 100% is needed to elevate tissue temperature to physiologically significant temperature (104-112 degrees F)
  - This results in a reduction of pain and muscle spasm as well as an increase in tissue extensibility and increase blood flow.
- Pulsing: the sound wave will decrease the depth of US delivery
  - Current machines have % pulsed, thus you can modify depth of delivery

# Application Techniques

- Coupling Medium: US energy will not pass through the air or skin without the presence of a coupling medium. The ideal coupling medium should have the following qualities:
  - High transmission and low absorption of US energy
  - Exclude air, minimal air entrapment
  - good impedance
  - low drag coefficient
  - good viscosity
  - low salt content
  - economical cost
  - easy to use

# Coupling Agents

- Gel
- Water Immersion
- Bladder Method (water filled balloon)
- Phonophoresis

# Application Techniques

- Researchers note best medium is aqueous gel (different from electrical stim. gel)
- Water meets all of the criteria, good for irregular or small body parts (aqueous gels are mainly water)
- Biofreeze or Flex-all does not allow as great a healing effect
- Phonophoresis “jury still out”

# Water Immersion Bath

- Use room temperature degassed water in a plastic treatment tub
  - Do not use in a metal tank!
- The transducer should be applied in a moving technique as close as possible, but still remaining perpendicular to the treatment area.
- Precaution is advised when immersing the clinician’s hand into the water bath during treatment or when removing bubbles from the transducer's face since the dangers of long term exposure to US are not known at this time.

# Stretching

- Stretching window is 3 minutes
  - After 3 minutes the tissues temperature drops past tissue extensibility

# PreHeating

- Preheating should be a decision based on patient comfort
- Research indicates that pre heating (HP, emersion) increased superficial heat temperatures significantly
  - Deep tissues are unaffected

# PreCooling

- Research has indicated that precooling retard increase of heat in the tissue
- Cooling may also anesthetize the area limiting sensation

# Ultrasound and Electrical Stimulation

- Theoretically to create effects of both US and electrical stim
- Research is lacking but claims for use include:
  - trigger points
  - superficial pain areas
  - decrease adhesions

# Diathermy

# Diathermy

- Uses energy similar to broadcast radio waves with shorter wavelength.
- Energy is alternating current lacking properties to depolarize motor sensory nerves
- Fiction caused by the movement6 of ions from the High Frequency electromagnetic energy causes heating

# Diathermy

- Tissues with high water content (Fat, blood and muscle) are selectively heated at depth of 2-5cm.
- Local tissue temp. may reach 107ºF, but fat layer dissipated heat secondarily heating muscles
- Deep heating effects last longer than US due to large area heated

# Delivery of Diathermy

- Pulsed
  - Acute and subacute conditions
  - heating related to rations of time “on” and “off”
  - Heating occurs when total amount of energy delivered is greater than 38 watts, below this receive non-thermal effects
- Continuous
  - Mainly used
  - For chronic injuries

# Effect on Injury Response

- Response similar to effects of heat
  - Skin temp raises 4.3ºF
  - Intra-articular temp raises 2.5 ºF
  - Blood flow increases
  - fibroblastic activity, collage deposition and new capillary growth stimulated
  - muscle spasm is resuced by sedation of sensory and motor nerves
  - local increase in cellular metabolic rate

# Set-up and Application of Diathermy

- Condenser and Induction Method will be demonstrated in lab
- General Prep.
  - No metal (including removal of all rings, watches, hairpins etc.)
  - Cover area with terrycloth towel to eliminate sweat
  - Explain to patient warmth should be felt, but no unusual sensations

# Diathermy Set-up

- Duration of Tx
  - 20-30 minutes
  - 2 weeks
  - when using higher tx temp, decrease the duration of tx and apply on alternate days
- Indications
  - Joint Inflammation
  - Larger areas than US
  - Fibrosis
  - Myositis
  - Subactue and Chronic Inflam.
  - Oasteoarthritis

# Diathermy Precautions

- Physician's Prescription (some states)
- Never allow cables to touch (short circuit)
- Do not allow for perspiration
- Never allow direct contact with skin
- Excessive fat in area may overheat area
- Difficult to tx localized areas
- Overheating tissues may cause damage
  - deep acing
  - fat neurosis
  - burning

# Diathermy Contraindications

- Ischemic Areas
- Peripheral vascular disease
- Metal Implants
- Perspiration
- Tendency to hemorrage including menstration
- Cancer
- Fever
- Sensory loss
- Pregnancy
- Cardiac pacemakers
- Areas of particular sensitivity
  - epiphyseal plates
  - genitals
  - infection
  - abdomen
  - eyes and face

# Dosage Parameters

| Dose | Temp. Sensation | Indications | Pulse Width | Pulse Rate |
|---|---|---|---|---|
| NT | NO detectable warmth | Acute trauma, inflam, edema reduction | 65μsec | 100-200 pps |
| 1 | Mild Warmth | Subacute inflamation | 100μsec | 800pps |
| 2 | Moderate warmth | Pain, muscle spasm, Chronic inflam, inc. blood flow | 200μsec | 800pps |
| 3 | Vigorous heating | Stretching collagen tissues | 400μsec | 800pps |

# Electrical Safety in Biomedical Equipment

# Objectives

- **Discuss the role and responsibilities of a biomedical equipment technician (BMET).**
- **Identify two safety responsibilities of a BMET.**
- **Compare the roles and responsibilities of the biomedical engineer and the industrial hygienist.**

# Objectives (cont.)

- **Identify safe electric current leakage limits for biomedical equipment.**
- **Identify the two classes of medical equipment that are safety-tested.**

# Objectives (cont.)

- **Identify wire color codes used in hospitals.**
- **Define preventive maintenance.**
- **Define macroshock and microshock.**
- **Successfully complete 1 procedure in biomedical technology.**

# Biomedical Equipment Technician

- **The need for biomedical equipment technicians (BMETs) arose with the introduction of complex equipment to diagnose, prevent, and cure disease and illness.**

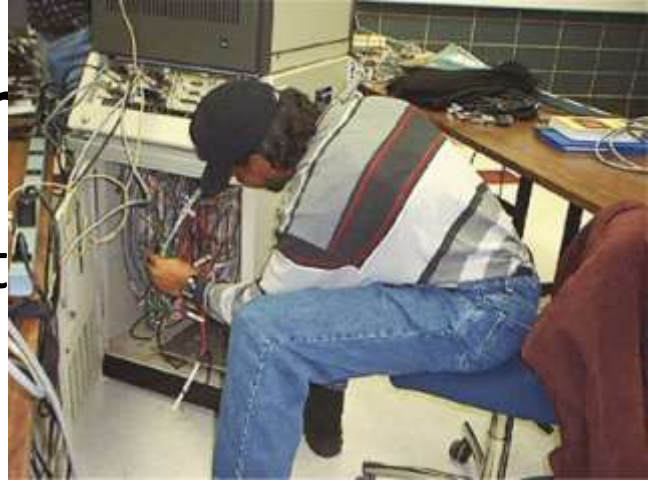
# Biomedical Equipment Technician (cont.)

- **A BMET is knowledgeable about:**
  - **The theory of operation.**
  - **The underlying physiologic principles.**
  - **The practical, safe clinical application of biomedical equipment.**

# Biomedical Equipment Technician (cont.)

- **The Job of the Biomedical Equipment Technician**
  - **BMETs work for:**
    - **Large hospitals.**
    - **Medical equipment manufacturers and distributors.**
    - **Medical supply firms.**
    - **Medical research organizations.**
    - **Teaching establishments.**

# Biomedical Equipr Technician (cont



- **The Job of the Biomedical Equipment Technician (cont.)**
  - **BMETs should have:**
    - **Better than average manual dexterity.**
    - **Mechanical and electrical inclination.**
    - **Numerical ability.**
    - **Color vision.**
    - **An above-average work ethic.**

# Biomedical Equipment Technician (cont.)

- **The Job of the Biomedical Equipment Technician (cont.)**
  - **Install, calibrate, and service equipment.**
  - **Train new users.**
  - **Apply basic troubleshooting to unfamiliar layout and operations.**

# Biomedical Equipment Technician (cont.)

- **The Job of the Biomedical Equipment Technician (cont.)**
  - **Evaluate equipment for servicing.**
  - **Repair equipment.**
  - **Maintain parts inventory.**
  - **Test for electrical safety.**

# Biomedical Equipment Technician (cont.)

- **Education and Internship**
  - **College programs include the study of:**
    - **Details of electronic components and circuits.**
    - **Design and construction of biomedical equipment.**
    - **Physiologic and electronic principles.**
    - **Physics.**
    - **Medical terminology.**
    - **Anatomy and physiology.**

# Biomedical Equi
# Technician (c

- **Job Responsibilities**
  - **Carry out preventive maintenance.**
  - **Train personnel on the use and care of equipment.**
  - **Track maintenance and service.**
  - **Make recommendations on replacements.**

# Biomedical Engineer

- **Uses skills to analyze and solve problems in biology and medicine.**
- **Designs and develops biomedical equipment.**
- **Sometimes called a clinical engineer.**
- **Education ranges from associate degree to Ph.D. degree.**

# Biomedical Engineer (cont.)

- **The Job of the Biomedical Engineer**
  - **Works in specialty areas including biomaterials, biomechanics, medical imaging, rehabilitation, and orthopedic engineering.**
  - **Works with other health care professionals including physicians, nurses, therapists, and technicians.**

# Biomedical Engineer (cont.)

- **Job Responsibilities**
  - **Develop devices such as hearing aids; cardiac pacemakers; artificial kidneys and hearts; synthetic blood vessels; and prosthetic joints, arms, and legs.**
  - **Oversee automated client monitoring during surgery or in intensive care.**
  - **Monitor healthy people in unusual environments such as space.**

# Biomedical Engineer (cont.)

- **Job Responsibilities (cont.)**
  - **Develop therapeutic and surgical devices such as laser systems for eye surgery and automated delivery of insulin.**
  - **Advise on sports medicine, rehabilitation, and support devices.**
  - **Design computerized blood sample analyzers, cardiac catheters, and other equipment for use in clinical laboratories.**

# Biomedical Technology Procedures 30-2

- **Safety**

# Biomedical Technology Procedures (cont.)

- **The Association for the Advancement of Medical Instrumentation (AAMI) developed the first standards for the manufacture and safety of medical equipment.**
- **Biomedical technology departments are expanding into the areas of telemedicine and teleradiology.**

# Safety

- **A current of more than 10 milliamperes can cause paralysis in the human body.**
- **Electrical inspection has become a very complete preventive maintenance (PM) inspection, due to the requirements of the Joint Commission on Accreditation of Healthcare Organizations (JCAHO).**

# Safety (cont.)

- **Electrical Safety Testing**
  - **Keep electricity in its place.**
  - **Medical treatment facilities (MTF) use color-coded wires, plugs, and outlets marked “hospital-grade.”**
  - **Electric currents that continue for more than one heart cycle may cause fibrillation.**

# Safety (cont.)

- **Equipment Classes**
  - **The two classes of medical equipment are class A and class B.**

# Safety (cont.)

- **Class A Equipment**
  - **Used in critical client care areas.**
  - **Usually, with class A equipment, the client has a direct line of electrical conduction to the heart.**
  - **Operating rooms, emergency rooms, and recovery rooms are examples of class A areas.**

# Safety (cont.)

- **Class B Equipment**
  - **Used in general client care and examination rooms.**
  - **Examples of class B equipment are examination tables, electric hospital beds, and laboratory equipment.**

# Safety (cont.)

- **Leakage Current**
  - **Naturally occurring current that results from distributed capacitance within equipment or power cords and that leaks from electronics to the metal chassis of the equipment to ground.**
  - **The acceptable leakage current in class A areas is 10 microamps.**
  - **The acceptable leakage current in class B areas is 500 microamps.**

# Safety (cont.)

- **Leakage Current (cont.)**
  - **The 6 main categories of leakage current are:**
    - **Loss of instrument ground.**
    - **Voltage variations caused by inadequate grounding or improper ground wiring.**
    - **Current originating from an instrument during use on a client.**

# Safety (cont.)

- **Leakage Current (cont.)**
  - **The 6 main categories of leakage current are (cont.):**
    - **Inducted current from other high-energy sources.**
    - **Self-generating currents or voltage differentials.**
    - **Other modes of leakage or means of generating current.**

# Safety (cont.)

- **Macroshock and Microshock**
  - **Macroshock is a large value of electric current that passes from one arm to the other, usually externally on the skin.**
  - **Microshock is a small value of electric current that passes directly through the heart.**