An Introduction to Bio Medical Instrumentation Science

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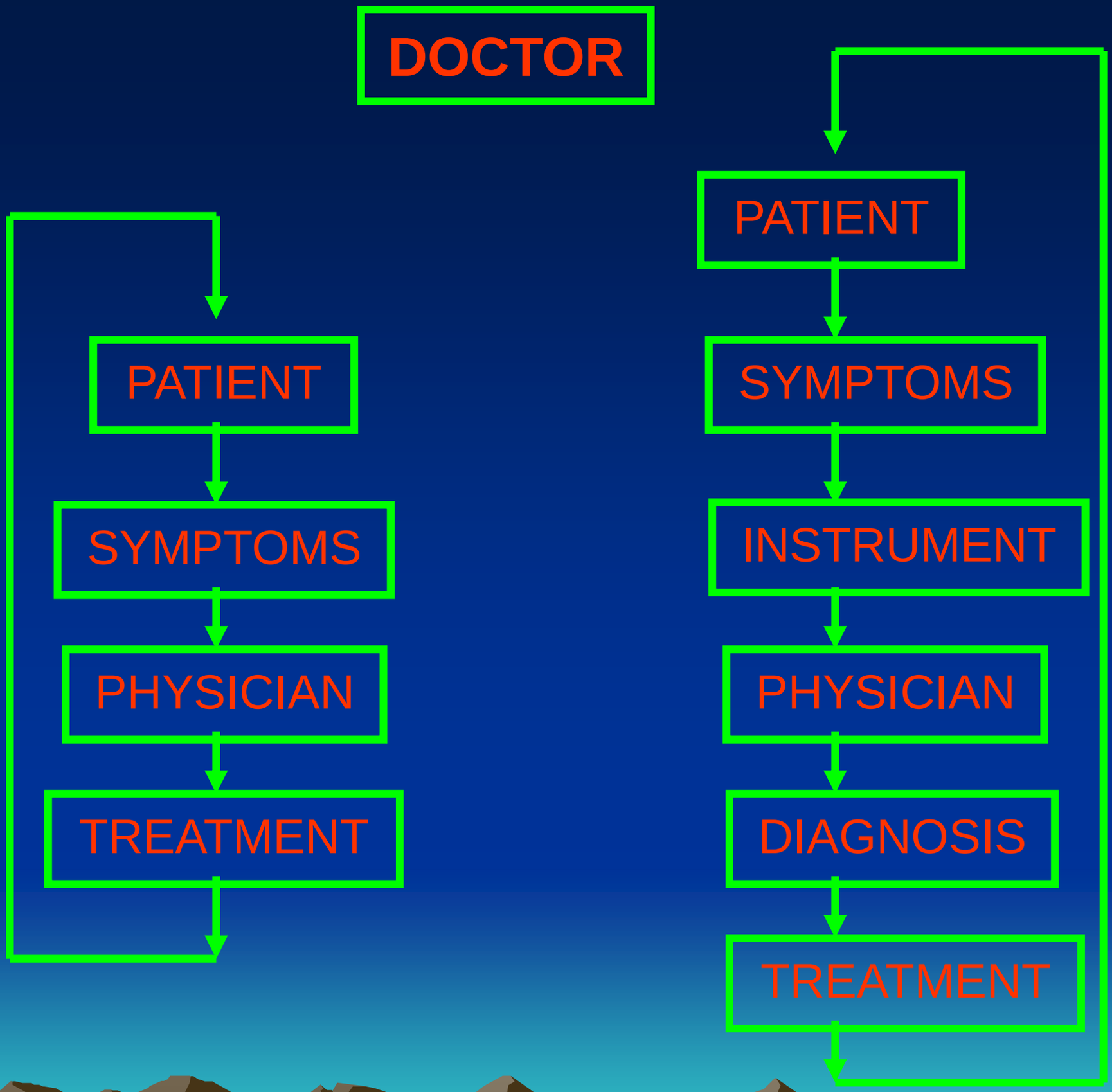
SCOPE

The study of Engineering principles from Biomedical Engineering involves following interests :

To understand mechanisms, efficiencies & physical changes of various subsystems of the body.

To evolve an instrumentation system for diagnosis, therapy and supplementation of body function.

To obtain qualitative & quantitative knowledge through different instruments which can help for analysis of disorders, and further the Biomechanics of the cure process.



A.THE PHYSICIAN **B.**MODERY PHYSICIAN

HISTORY

Stethoscope, the first medical instrument of its own kind was invented in by French Physician Laennec.

Today in 1997 even at a district place in India computer aided tomography equipment is easily available.

For many years, the doctors depended upon pulse rate, thermometer and stethoscope , however today hundreds of sophisticated biomedical instruments are available.

BREAK THROUGH

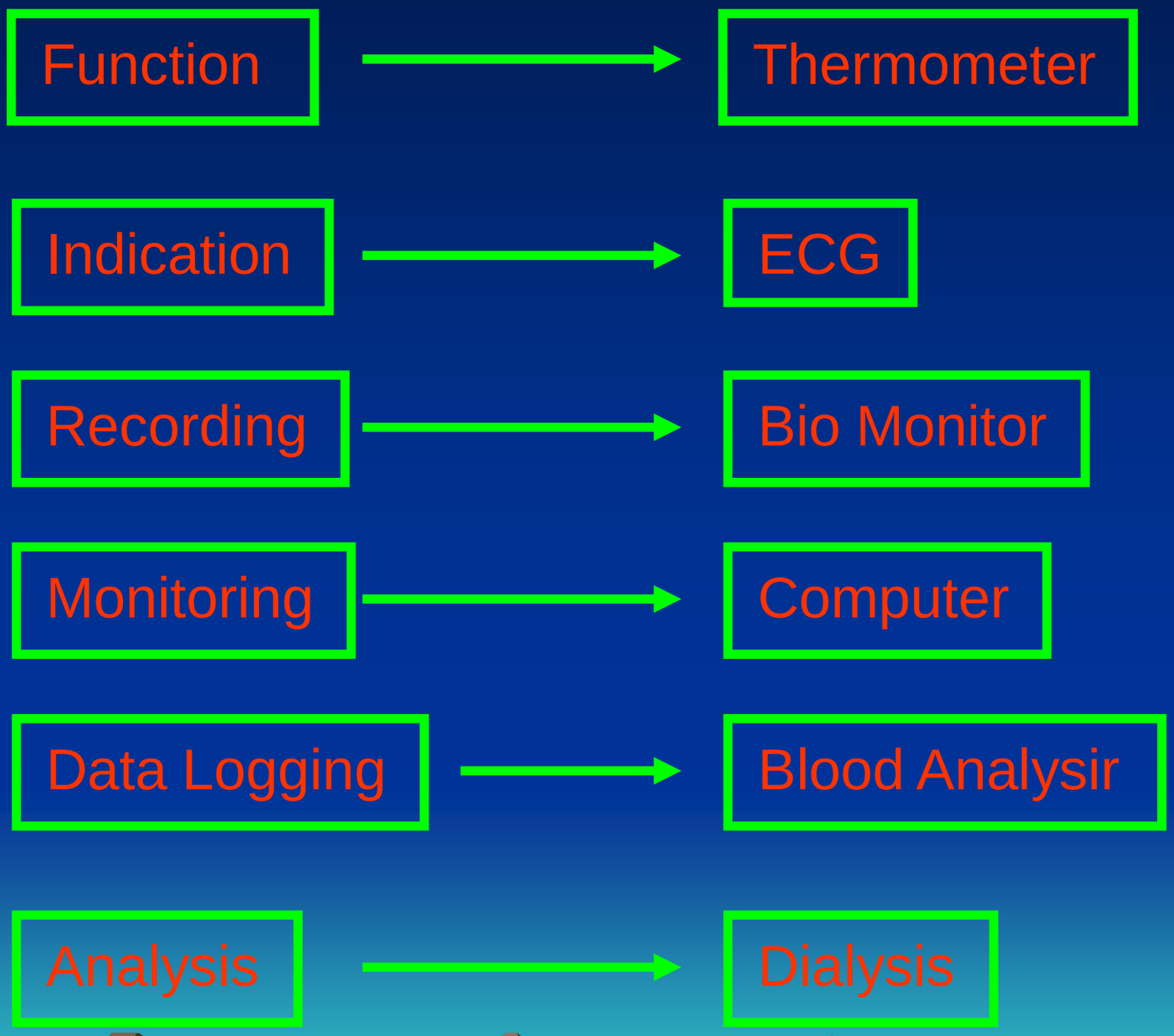
A major break through in the form of ECG was invented by Dutch scientist in 1930.

It was the first step forward towards modernization of Biomedical Instrumentation.

CLASSIFICATION OF INSTRUMENTS

- Engineering
  - Indicating
  - Recording
  - Monitoring
  - Data Logging
  - Analysis
  - Control
- Medical
  - Diagnostic
  - Therapeutic
  - Supplementary

FUNCTION OF INSTRUMENTS



Engineering Classification of Biomedical Instrumentation

1. Measuring Instruments.
2. Audiometer
3. Blood cell counter
4. Blood Pressure meter
5. Blood PH meter
6. Blood flow meter
7. Digital BP meter
8. GSR meter
9. Stethoscope

Recording Instruments

1. Electrocardiograph (ECG)
2. Electromyograph (EMG)
3. Electro encephalograph (EEG)
4. Expirograph
5. Phonocardiograph
6. Plethysmograph
7. Thermograph
8. Tomograph
9. Ultra sonograph
10. Radio graph (x-ray)

Monitoring Instruments

1. Bed – side monitor
2. Bio – monitor
3. Foetal monitor

Analyzing Instruments

1. Colorimeter
2. Spectrometer
3. Flame photo meter

Monitoring Instruments

1. Bed – side monitor
2. Bio – monitor
3. Foetal monitor

Data Logging Instruments

1. Computer

Controlling Instruments

1. Defibrillator
2. Dialysis instrument
3. Heart lung machine

A] Medical Classification of BMI

1. Diagnotic Instruments
2. Endoscope
3. Stethoscope
4. Microscope

B] THERAPEUTIC INSTRUMENTS

1. Shortwave diathermy
2. Ultrasound therapy
3. Electro surgery
4. Nuclear Medicine

C] SUPPLEMENTARY

1. Aid for blind
2. Hearing aid
3. Pace maker

FUNCTIONAL CLASSIFICATION OF INSTRUMENTS

A] BLOOD INSTRUMENTS

1. Blood Pressure meter
2. Blood PH meter
3. Blood flow meter
4. Blood cell counter
5. Calorimeter
6. Spectra – Photometer
7. Flame photometer
8. Digital BP meter

B] HEART INSTRUMENT

1. ECG
2. Pace Maker
3. Defibrillator
4. Heart Lung Machine
5. Bed side monitor
6. Electronic stethoscope
7. Phonocardiograph
8. Plethysmograph

C] BRAIN INSTRUMENTS

1. EEG
2. Tomograph

D] MUSCLE INSTRUMENTS

1. EMG

2. Muscle Stimulater

E] KIDNEY INSTRUMENTS

1. Dialysis Instrument

2. Lithotripsy

F] EAR INSTRUMENTS

1. Audiometer

2. Hearing aid

G] EYE INSTRUMENTS

1. Occulometer

2. Aid for blind

H] LUNG INSTRUMENTS

1. Spirometer

I] BODY INSTRUMENTS

1. Ultra Sonography
2. Thermograph
3. Radiograph
4. EPF
5. Endoscope

J] PHYSIOTHERAPHY INSTRUMENTS

1. Diathermy, Short wave
2. Electrosleeper
3. Vibrator (Massage type)
4. U.V. Lamph
5. Microwave diathermy

1.BIO METRICS

It is the branch of science that includes measurements of physiological variables and parameters.

BMI provides the tools by which these measurements can be achieved.

1.1 - RANGE

The range of an instrument is generally considered to include all the levels of input amplitude & frequency over which the device is expected to operate.

The objective is to provide an instrument that will give a usable reading from the smallest expected value of the variable or parameter being measured to the largest.

1.2 – SENSITIVITY

The sensitivity of an instrument determines how small a variation of a variable or parameter can be really reliably measured.

1.3 – LINEARITY

The degree to which variations in the output of an instrument follow input variations is referred to as the linearity of the device.

1.4 – HYSTERESIS

It is a characteristic of some instruments where by a given value of the measured variable results in a different reading when reached in an ascending direction from that obtained when it is reached in a descending direction .

1.5 - FREQUENCY RESPONSE

The frequency response of an instrument in its variation in sensitivity over the frequency range of the measurement. It is important to display a wave shape that is a faithful reproduction of the original physiological signal.

1.6 – ACCURACY

It is a measure of systemic error. Errors can occur in a multitude of ways. Although not always present simultaneously, the following errors should be considered.

1. Errors due to tolerances of electronic components.
2. Mechanical errors in meter movements.
3. Component errors due to drift or temperature variations.
4. Errors due to poor frequency response.
5. Errors due to change in atmospheric pressure or temperature.

6. Reading errors due to parallel inadequate illuminations or excessively wide ink traces on a pen recording.

- Two additional sources of Errors are correct instrument zeroing or making correct baseline.
- The effect of the instrument on the parameter to be measured & vice versa. (Specially in measurements in living organism)

1.7 - SIGNAL TO NOICE RATIO

- It is important that the signal to noise ratio be high as possible.

1.8 – STABILITY

- In control engineering, Stability is the ability of a system to resume a steady state conditions following a disturbance at the input rather than be driven into uncontrollable oscillation.

1.9 - ISOLATION

- Electrical isolation is to be made for avoiding interference between different instruments used simultaneously. It can be achieved by using magnetic or optional coupling technique or using radio tetermetry.

- Telemetry is also used where movement of the person or animal to be measured.

1.10 – SIMPLICITY

- All systems & instruments should be as simple as possible to eliminate the chance of component or human error.

INSTRODUCTION TO THE MAN MACHINE SYSTEM

A classical exercise in Biomedical engineering analysis involves the measurement of OUTPUTS from an unknown system as they are affected by various combinations of INPUTS.

The object is to learn the nature & characteristics of the system. This unknown system, often reffered to as a BLACK BOX, may have a variety of configuration for a given combination of INPUTS and OUTPUTS. The end product of such an exercise is usually a set of Input – output equations intended to define the internal functions of the Box. These functions may be relatively simple or extremely complex.

BLACK BOX

One of the most complex black box is living organism.

HUMAN BODY AS BLACK BOX

Human body is Bio – chemico – physico – electro – thermo – hydraulico – pneumatico – magnatico mechanically engineered machine, which runs automatically through the vital force, now a days called Bio energy.

BIO POTENTIAL SIGNALS

It is a well known fact that human body is a source of various bio- potential signals, which are most useful during physiological ,clinical & therapeutic biological activities of living body.

These signals can be picked up from the surface of the body or from within the body.

These signals are used as parameters in various Bio- medical studies. This black box (Human body) consists biological , chemicals , physical , electrical , thermal , haudralic, pneumatic, magnetically & mechanical systems, all interacting with each other.

- It also contains a powerful computer, several types of communicating systems, and a great variety of control systems. To further complicate the situation.

1. Upon attempting to measure the INPUTS & OUTPUTS, It would be soon learnt that none of the INPUT & OUTPUTS relationship is deterministic i.e. repeated applications of a given set of INPUT values will not always produce the same OUTPUT values.

   In fact , many of the outputs seems to show a wide range of responses to a given set of INPUTS, depending on some seemingly relevant conditions, where as others appear to be completely random & totally unrelated to any of the inputs.

2. Many of the important variables to be measured are not readily accessible to measuring devices. The result is that some key relationships can not be determined or that less accurate substitute measures must be used.

3. Due to high degree of interaction among the variables, it is often impossible to hold one variable constant while measuring the relationship between two others.

4. It is difficult sometime to determine which are the inputs & which are the outputs, for they are never labeled & almost inevitably include one or more feedback paths.

5. The application of measuring device. Which often affects the measurements to the extent that they many not represent normal conditions reliably.

6. The process of measuring must not in any way endanger the life of the person on whom the measurements are being made, & he should not get any pains, discomfort or any other undesirable conditions. Additional factors that add to the difficulty of obtaining valid measurements are

A. Safety considerations

B. The environment of the hospital where these measurements are performed,

C. The medical person usually involved in measurements.

D. Ethical & Legal considerations.

Because the large amount of interaction between the instrumentation system & the subject being measured. It is essential that the person on whom measurements are made be considered an integral part of the Instrumentation system.

In other words – In order to make sense out of the data to be obtained from the black box the internal characteristics of the black box must be considered in the design & application of any measuring instruments, consequently the overall system, which includes both the human organism & Instrumentation required for the measurement of the human is called the MAN – MACHINE SYSTEM.

INSTRUMENTATION SYSTEM

It is defined a set of instruments & equipments utilized in the measurement of one or more characteristic or phenomena + the presentation of information obtained from those measurements in a form that can be read , interpreted recorded and preserved by man.

BASIC OBJECTIVES OF THE INSTRUMENTATION

1. Information Gathering
2. Diagnosis
3. Evaluation
4. Monitoring
5. Control

1. INFORMATION GATHERING

In this system, machine is used to measure natural phenomena & other variables to aid man in his search for the knowledge about himself and the universe in which he lives.

In this setting, the characteristic of the measurements may not be known in advance.

2. **DIAGNOSIS**

Measurements are made to help in the detection & the correction of some malfunction of the system being measured.

In some applications, this type of instrumentation may be classed as – “ Trouble shooting equipments.”

3. EVALUATION

Measurements are used to determine the ability of a system to meet its functional requirements.

These could be classified as “ Proof – of – performance” or “ Quality control” tests.

4. MONITORING

Instrumentation is used to monitor some process or operation in order to obtain continuous or periodic information about the state of the system being measured.

5. CONTROL

Instrumentation is sometimes used to automatically control the operation of a system based on changes in one or more of the internal parameters or in the output of the system.

Bio – Medical instrumentation can generally be classified into two major types :

Clinical Instrumentation

Research Instrumentation

Clinical Instrumentation

Basically devoted to the area of

- Diagnosis
- Patient care
- Treatment of Patients (Therapeutic use)

Research Instrumentation

It is used primarily in the search for new knowledge related to various systems that compose the human organism.

Some instruments can be used in both areas.

MEASUREMENTS

Biomedical instrumental measurements are divided in to two categories.

In Vivo
In Vitro

1. In vivo measurements are made on or within the living organism itself.

e.g. A device inserted into the blood stream to measure the PH of the blood directly.

2. In vitro measurements are made outside the body , even though it relates to the functions of the body.

e.g. Measurements of PH of sample of blood, that has been drawn from patients body.

MAN MACHINE SYSTEM

Components of Man Machine system.

1. The subject

The subject is the human being on whom the measurements are made.

2. STIMULUS

In many measurements the response to some form of external stimulus is required.

The instrumentation used to generate & present this stimulus to the subject is a vital part of the Man – Machine system whenever responses are measured.

The stimulus may be visual (e.g. a flash of light) , auditory (e.g. a tone), tactile (e.g. a blow to the Achilles tendon), or direct electrical stimulation of some part of the nervous system.

3. THE TRANSDUCER

A transducer is a device, capable of converting one form of energy or signal to another.

In Man – Machine system each transducer is used to produce an electrical signal that is an analog of the phenomenon being measured. The transducer may measure temperature, Pressure , flow, or any of the other variables that can be found in the body, but its output is always an electric signal.

Two or more transducers may be used simultaneously to obtain relative variations between phenomena.

4. SIGNAL PROCESSIN UNIT.

It is the part of the instrumentations system that amplifies , modifies or in any other way changes the electric output of the transducer.

It is also used to combine or relate the outputs of two or more transducers.

The purpose of SPU is to process the signals from the transducers in order to satisfy the functions of the system & to prepare signals suitable for operating the display or recording equipment that follows.

5. DISPLAY MACHINE

The electrical output of the signal – processing unit (SPU) must be converted into a form that can be perceived by one of the human beings senses and that can convey the information obtained by the measurement in a meaningful way.

The input to the display machine is the modified electric signal from the SPU. Its output is some form of visual, audible, or sometime tactile information.

In Man – Machine system the display machine may include a graphic pen recorder which produces & permanent record of data.

6. RECORDING

Data – processing and transmission equipment

It is often necessary, or at least desirable to record measured information for possible later use or to transmit it from one location to another.

(Local to Local or local to global).

Where automatic storage or processing of data is required or where computer control is employed on online analog or digital computer may be part of instrumentation system.

Recorders are of two types

Graphic pen recorder is a device used to produce a paper record of analog waveforms.

Magnetic tape recorder is a device used for data recording for future playback.

7. CONTROL DEVICES

Where ever it is desirable to have automatic control of the stimulus, transducers or any other part of Man – Machine system, a control system is incorporated.

It usually consists of a feedback loop in which part of the output from the signal processing unit (SPU) or display machine is used to control the operation of the system in some way.

PHYSIOLOGICAL SYSTEMS OF THE BODY

- It is well known fact that human body is Bio – chemico – electro – thermo – hydraulico – pneumatieo – physico – magnato – mechano – dynamically engineered machine.
- To obtain valid measurements from a living human being. It is necessary to have deep understanding of the subject on which the measurements are being made.
- Within the human body can be found Biological, chemical, electrical, thermal , hydrolical pneumatical, physical, magnetic mechanical & dynamical & many other types of the systems each of them communicates with an external environment & internally with the other systems of the body.
- By the help of a multilevel control system and communication network, these individual systems are organized to perform many complex functions of the body.
- Through the integrated operations of all these systems, & their various subsystems, man is able to sustain life, learn to perform usual tasks, acquire personality and behavioral traits , and even reproduce himself.