

Diagnostic and Therapeutic Equipments Lab Report

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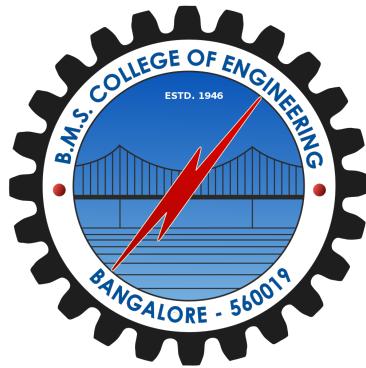
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Certificate



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Lab Report on:

Diagnostic and Therapeutic Equipments

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1 Blood Pressure Measurements

1.1 Aim:

To determine the blood pressure of the subject using mechanical and electronic BP meters.

1.2 Apparatus:

Sphygmomanometer, stethoscope, and a digital BP monitor.

1.3 Theory:

1.3.1 Sphygmomanometer

Sphygmomanometer is a medical device used to measure blood pressure. It typically consists of an inflatable cuff that is wrapped around the upper arm, a measuring unit (mercury) and a mechanism for inflating the cuff, usually a bulb and a valve.



1.3.2 Digital BP Monitor

A digital blood pressure (BP) monitor is an electronic device designed to measure blood pressure and heart rate. It automates the process of inflating the cuff, measuring the blood pressure, and displaying the results, making it easier to use compared to traditional manual sphygmomanometers.



1.4 Procedure

1.4.1 Sphygmomanometer

- Subject is made to sit parallel to the mercury level of the monitor. The mercury knob is made opened.
- Rough side of the cuff is placed on top of the left hand and is tied tightly on the brachial artery (point on left hand, where pulse is felt).
- Stethoscope is placed on brachial artery just below the cuff's sensor to record Korotkoff's sounds (Heard when medical personnel listen for when they are taking blood pressure using a non invasive procedure).
- The pressure is increased till 180mmHg using rubber bulb or inflator.

1.4.1.1 Note

- Onset point of Korotkoff sound is the Systolic pressure
- Dying of the Korotkoff sound is Diastolic pressure
and the readings are taken accordingly.

1.4.2 Digital Blood Pressure Monitor

Digital sphygmomanometers are automated, providing blood pressure reading without needing someone to operate the cuff or listen to the blood flow.

1.5 Observation

Observation table for Mechanical BP meter

Data taken from Mechanical BP meter

Student Name	BP Readings	Mean Arterial Pressure (MAP)	Analysis
Kulkarni sir	120/80	93.33	Normal
Monika	110/70	83.33	Normal
Kushaal	130/90	103.33	Pre-hypertension
Namyatha	120/83	95.33	Normal
Karthik	125/85	98.33	Pre-hypertension
Janane	110/65	80.00	Normal
Omar	110/70	83.33	Normal
Hasan	100/70	80.00	Normal
Saad	120/85	96.66	Normal
Manasa	90/86	87.33	Normal
Mayuri	110/75	86.66	Normal
Nidhi	110/90	96.66	Normal
Lakshita	100/70	80.00	Normal

Source: DTE Lab, 4th floor, Dept of Medical Electronics

Observation table for Digital BP meter

Data taken from Digital BP meter

Student Name	BP Readings	Mean Arterial Pressure (MAP)	Analysis
Kulkarni sir	117/85	95.66	Normal
Monika	99/64	75.66	Hypotension
Kushaal	112/80	90.66	Normal
Namyatha	126/74	91.33	Normal
Karthik	119/80	93.00	Normal
Janane	112/70	84.00	Normal

Omar	117/67	83.66	Normal
Hasan	98/70	79.33	Hypotension
Saad	115/76	89.00	Normal
Manasa	82/69	73.33	Hypotension
Mayuri	115/76	89.00	Normal
Nidhi	100/80	86.66	Normal
Lakshita	85/73	77.00	Hypotension

Source: DTE Lab, 4th floor, Dept of Medical Electronics

1.6 Calculations

$$MAP = \frac{1}{3}(SP - DP) + DP$$

where MAP is Mean Arterial Pressure

Sphygmomanometer

$$\frac{1}{3}(120 - 80) + 80 = 93.33$$

Digital BP meter

$$\frac{1}{3}(117 - 85) + 85 = 95.66$$

1.7 Analysis

- We observe that there is a change in MAP with change in BP levels.
- Generally, if there's a difference between systolic and diastolic pressure is 40 mmHg, the subject is considered to be normal.
- If the difference between systolic and diastolic pressure ranges between 30 – 50 mmHg, the subject is considered to be normal depending on the conditions.
- If systolic and diastolic pressure difference is < 30mmHg, the subject has low BP which leads to hypotension.
- If difference is > 50mmHg, the subject has high BP which leads to hypertension.

1.8 Result

The working and analysis of mechanical and electronic BP meters are analyzed.

2 Electrocardiogram (ECG) Measurement

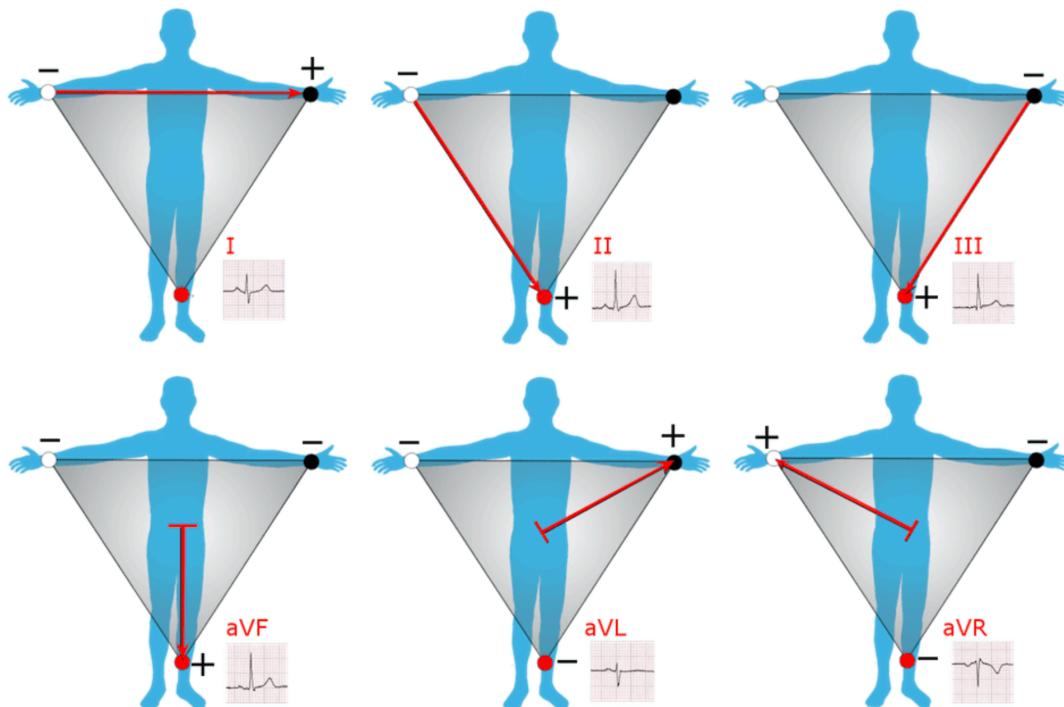
2.1 Aim

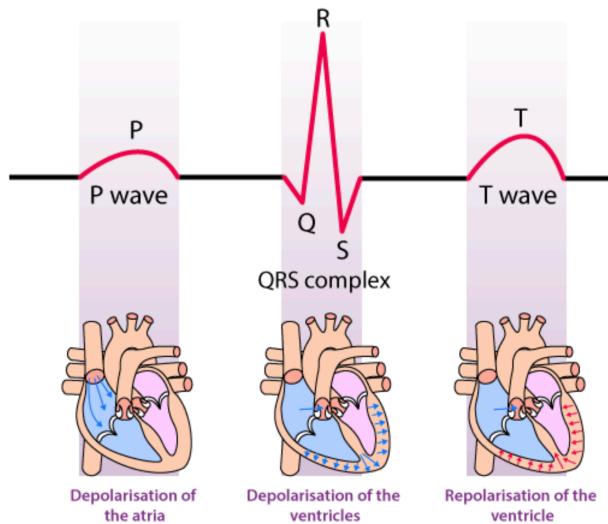
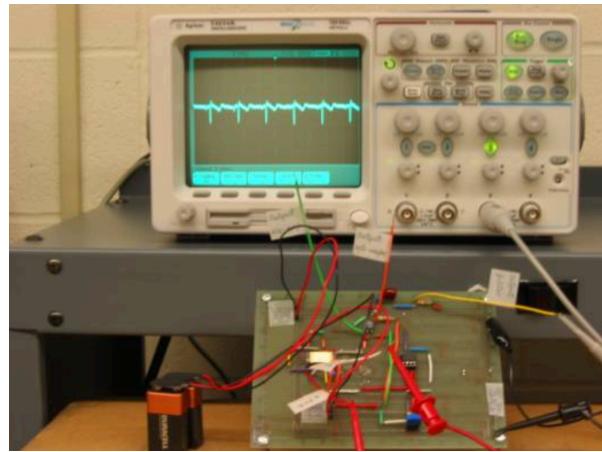
Aquisition of ECG signal with the help of Power lab and Bio-pac systems.

2.2 Theory

Electrocardiogram records from the body surface and registers the differences in electrical potential generated by the heart. Signal recorded is determined by action potentials generated by millions of individual cells and their sequence of activation. A multitude of factors (both cardiac and extracardiac) alter the final electrical signal. For instance, the electrical forces generated by heart are subsequently altered by the position of the heart within the body, the nature of intervening tissue and the distance to the recording electrode.

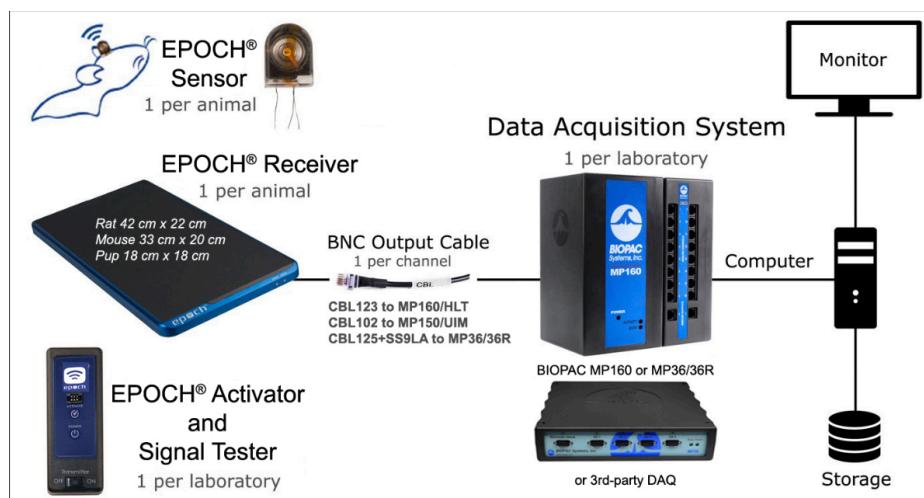
- Lead 1 = RA, LA, RL
- Lead 2 = RA, LL, RL
- Lead 3 = LA, LL, RL





2.2.1 Bio-pac system

We acquire ECG signal using the Bio-pac system



2.3 Procedure

1. BIOPAC lessons are opened on the PC
2. Select ECG1 and click OK.
3. Electrodes are placed on respective channel (CH:2) according to lead configurations. Transducer used is SS2L and subject should be at rest.
4. System is first calibrated and checked for proper contact of electrodes.
5. ECG setup is thus simulated, and the readings are recorded for each lead configuration
6. After recording the signals, BIOPAC lessons is clicked to save readings, which display the peak to peak voltage.
7. $L_1 + L_3 = L_2$ is thus verified.

2.4 Observation

ECG Lead analysis

Peak-to-Peak Values, Frequencies, Time Intervals, and Beats per Minute (BPM) for ECG Leads

Lead Number	Peak to Peak	Frequency f (in Hz)	Time (in sec) = 1/f	Beats per Min = 60/T
Lead 1	0.47	1.27	0.78	76.92
Lead 2	0.55	1.25	0.80	75.00
Lead 3	0.08	1.26	0.79	75.94

2.5 Analysis

The Biopac software shows consistent heart rate readings across all leads (75-77 bpm) indicating accurate and stable heart rate rhythm detection.

ECG analysis if the subject is acquired and $Lead1 + lead3 = Lead2$ was verified. Using frequency of the signal acquired, the bpm was also found.

$$Lead 1 = 0.47$$

$$Lead 3 = 0.08$$

$$Lead 2 = 0.47 + 0.08 = 0.55$$

$$\frac{1}{f} = T = 0.78 \text{ and } \frac{60}{0.78} = 76.92$$

2.6 Result

The ECG signal was aquired and $L_1 + L_3 = L_2$ is verified.

3 Electromyogram (EMG) Measurement

3.1 Aim

Acquisition of EMG Signal with the help of nerve stimulation and Bio-pack Systems.

3.2 Apparatus

- EMG Stimulator
- Ring electrodes and other hardware components
- Biopac software

3.3 Theory

Electromyography records electrical activity produced by skeletal muscles. The signal is determined by action potentials generated by muscle fibers during contraction and relaxation. EMG signals provide valuable information to diagnose neuromuscular disorders and study motor control. EMG results can reveal nerve dysfunction, muscle dysfunction or problems with nerve-to-muscle signal transmission. Motor neurons transmit electrical signals that cause muscles to contract. An EMG uses tiny devices called electrodes to translate these signals into graphs, sounds or numerical values that are then interpreted by a specialist.

3.4 Nerve stimulator

- The selector has two options, the EMG, and the stimulator. The EMG is used to record the EMG signal and the stimulator is used to generate stimulus in the body to obtain a signal.
- To produce a stimulus, the stimulator is set to 100ms and the intensity is varied accordingly.
- After selecting EMG in the selector region, the gain is set to 1 and is set on the EMG mode to enable the acquisition of the signal.
- Two wires from this system are connected as input to the Ag/AgCl electrodes placed on the fingers.
- Two wires are connected as output to the storage oscilloscope to record the EMG signal.



3.4.1 Procedure

1. The Ag/AgCl electrodes are placed on the index finger (+ve), ring finger (-ve) of the right hand and the reference electrode is placed on any finger on the left hand.
2. The subject should not be wearing any metallic accessories on the hand since it creates noise while acquiring the signal.
3. The fingers of both the hands are then contracted and relaxed until a spike is observed on the oscilloscope.
4. The amplitude of the signal is calculated and then multiplied with 100 mV and the amplitude of the EMG signal is thus obtained.

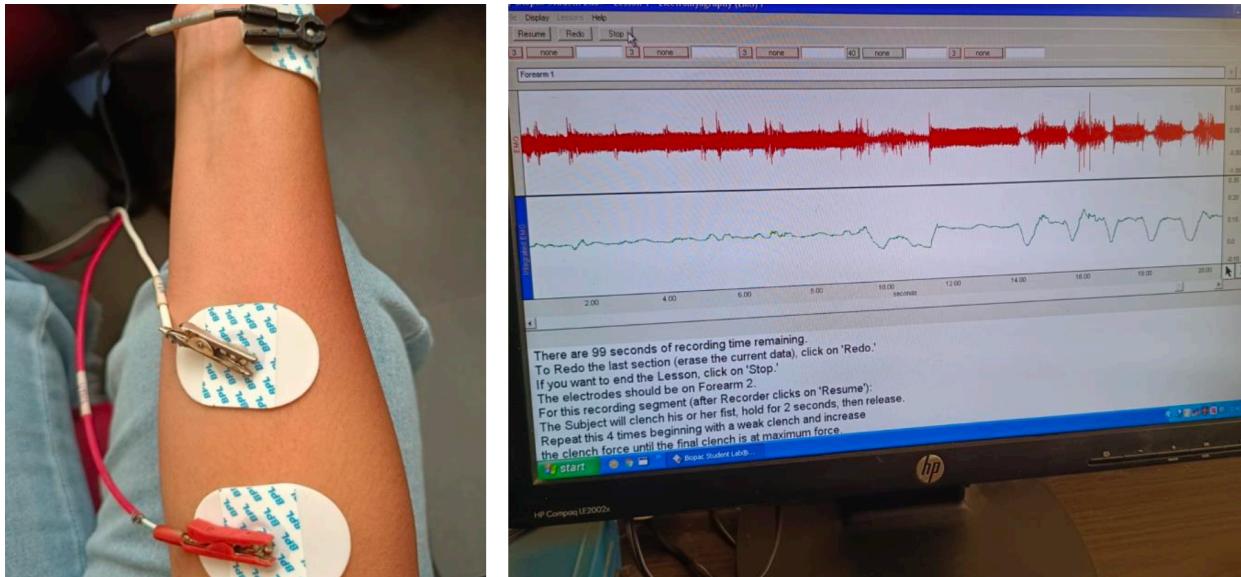


3.5 Bio-PAC system

Using the Bio-pack system, we acquire the EMG signal.

3.5.1 Procedure

1. Select icon BSL Lessons.
2. Select EMG 1. Click Ok.
3. Colour code is mentioned to connect the electrodes.
4. Click Calibrate. The subject is asked to clench fist as hard as possible and then release.
5. The subject also uses headphones to listen to the noise.
6. Statistical parameters are measured and recorded.
7. Minimum, maximum, peak-to-peak, mean, standard deviation is found and are plotted and recorded.



3.6 Observation

3.6.1 Nerve stimulator

EMG
Muscle contraction voltages for each subject

Subject	Muscle contraction voltage (in Volts)
Kulkarni sir	10.0
Mayuri	6.0
Namyatha	7.0
Kushaal	7.1

3.6.2 Bio-PAC system

EMG Biopac analysis
Peak-to-Peak Values, Frequencies, Mean and Std Deviations

Hands of subjects	Peak to Peak voltage (in mV)	Vmax (in mV)	Vfreq (in Hz)	Mean (mV-s)	Std. Dev (in mV)
Left Hand_1	1.7120	0.893	0.383	0.113	0.150
Left Hand_2	1.5890	0.672	1.586	0.105	0.147
Right Hand_1	1.5011	0.229	0.304	0.129	0.116
Right Hand_2	1.9590	0.860	0.060	0.114	0.150

3.7 Analysis

The EMG signals are acquired from the above-mentioned approaches (Ring electrodes and Surface electrodes) The amplitude of signals for peak voltage and mean voltages are analyzed to identify various muscle conditions like Muscle weakness and neuro muscular abnormalities. This also helps us find out the subjects dominant and non-dominant hand by assessing the mean voltage of a particular interval.

% Difference in mean of weakest and strongest clench can be found to find the dominant hand.

$$\text{Left hand: } \frac{0.129 - 0.114}{0.129} * 100 = 11.62\%$$

$$\text{Right hand: } \frac{0.113 - 0.105}{0.113} * 100 = 7.079\%$$

Thus, the subject's **Right hand** is the dominant hand from the above analysis.

3.8 Result

The EMG signal is thus acquired and recorded.

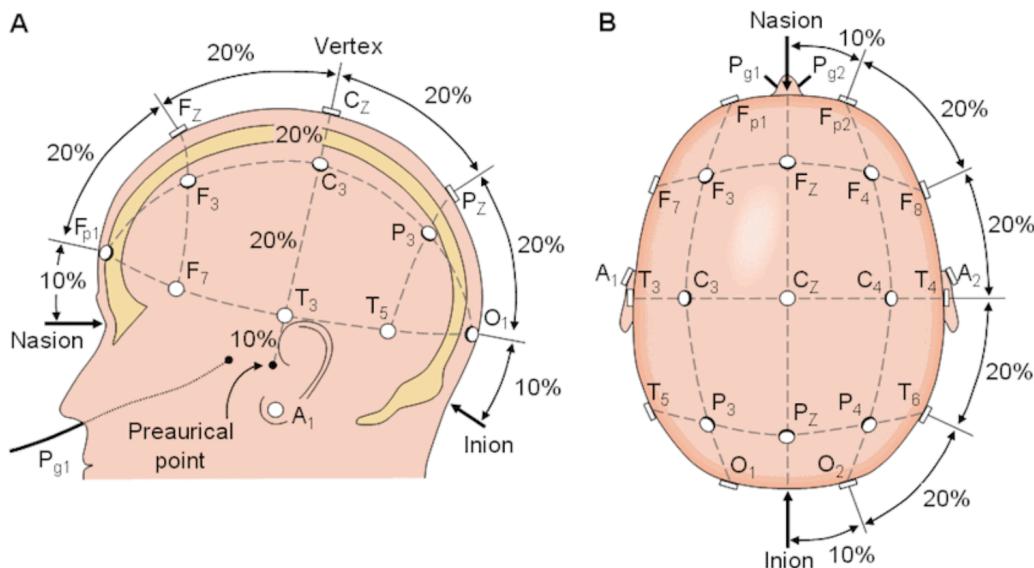
4 EEG Signal Acquisition with Bio-PAC and ENOBIO

4.1 Aim

Acquisition of EEG Signal using Bio-PAC using Bio-PAC system.

4.2 Theory

4.2.1 EEG Electrode Placement



- Electrodes are typically placed on the scalp according to the International 10-20 system, which standardizes positions based on the relative distances between key points on the head.
- Each electrode location is labeled with a combination of a letter and a number (e.g., F3, P4), where the letter indicates the brain region (e.g., F for frontal, P for parietal) and the number indicates the hemisphere and position.

4.2.2 Frequency bands of EEG

- Delta - δ (0.5-4 Hz): Associated with deep sleep.
- Theta - θ (4-8 Hz): Related to light sleep, relaxation, and drowsiness.
- Alpha - α (8-13 Hz): Linked to relaxed wakefulness, often seen when eyes are closed.
- Beta - β (13-30 Hz): Associated with active thinking, focus, and problem-solving.
- Gamma - γ (30-100 Hz): Related to high-level information processing and cognitive functioning.

4.3 Using Bio-PAC

4.3.1 Procedure for Bio-PAC

1.

- Active Electrode (A1) [Red wire]: Place this electrode on the Forehead Right.
 - Reference Electrode (R) [Black wire]: Place this electrode on the mastoid bone behind the ear or on an earlobe.
 - Ground Electrode (G) [White wire]: Place this electrode on the Forehead Left.
2. To ensure calibration of electrodes, go to Bio-PAC > Lesson3 > channel 1 and select EEG1. Specify the channels associated with electrodes then click on calibrate.
3. Now position the subject away from computer, ask to close their eyes and relax. Then carry out recording and saving for each subject acquisition data then copy and paste in excel.

4.3.2 Observation

EEG analysis
Statistical analysis of EEG Data from different subjects

Subject ID	Peak to Peak (in micro volts)	Delta	Delta T	Frequency f (in Hz)	Mean	Std. Dev	Samples
Subject 1	19.30228	1.0947	28.505	0.037729	NA	NA	8975
Subject 2	25.17906	-47.7230	24.745	0.040400	10.11118	5.62537	8761

4.4 Using ENOBIO

4.4.1 Procedure for ENOBIO

1. Open the NIC 2 application
2. Select appropriate protocol or create one. Drag and drop the channel names into the right side bar.
3. Ensure all the electrodes are properly touching the skull
4. Calibrate and start recording. Use .easy file for analysis in Python.

4.4.2 Observation

```
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns

# Read and preprocess the .easy file
file_path = '/Users/karthik/Desktop/Raw EEG Analysis/20240702153206_JEEVAN 1_Protocol 1.easy'
column_names = [f'Channel_{i+1}' for i in range(8)] + ['Unused_1',
'Unused_2', 'Unused_3', 'Unused_4', 'Timestamp']

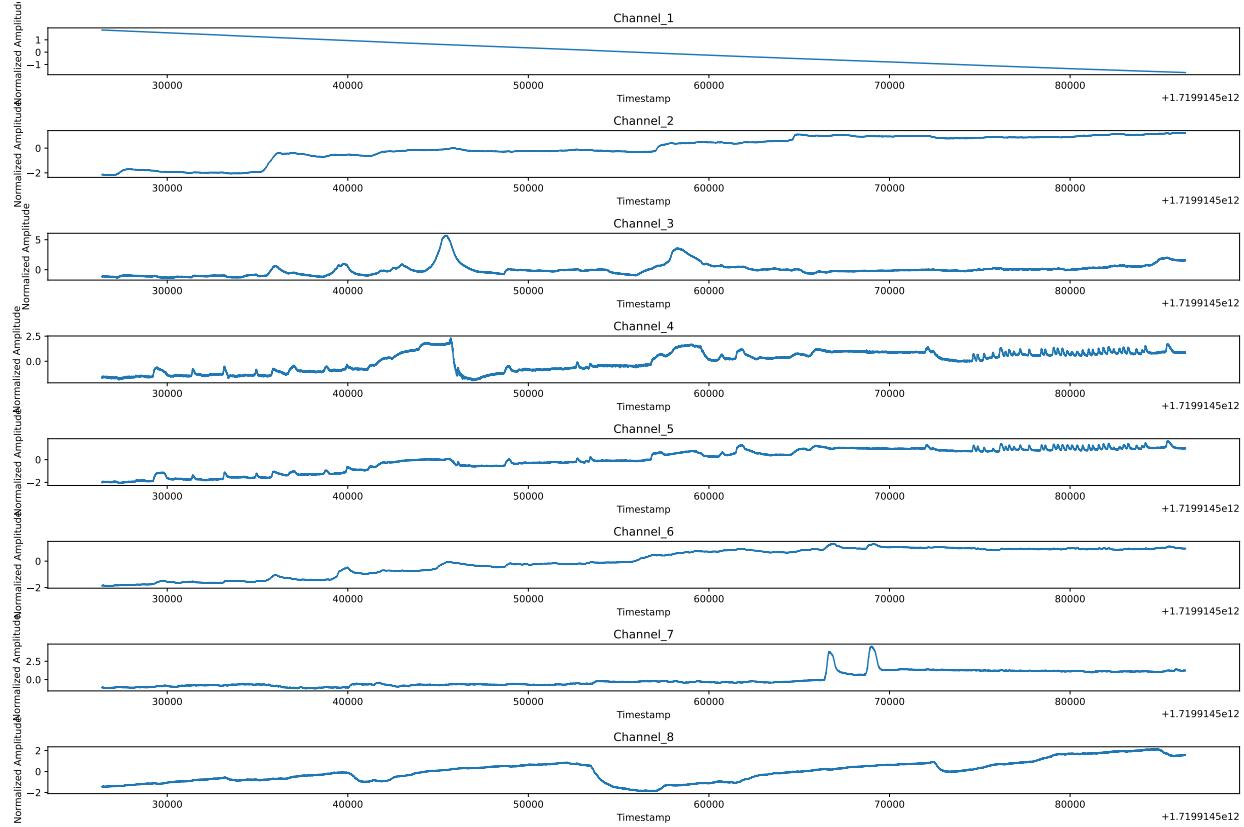
eeg_data = pd.read_csv(file_path, delim_whitespace=True, header=None,
names=column_names)

# Extract only the EEG channels and the timestamp
eeg_channels = eeg_data[column_names[:8]]
timestamps = eeg_data['Timestamp']

# Normalize the data
eeg_channels_normalized = (eeg_channels - eeg_channels.mean()) / eeg_channels.std()

plt.figure(figsize=(18, 12))
for i, channel in enumerate(eeg_channels_normalized.columns):
    plt.subplot(8, 1, i + 1)
    sns.lineplot(x=timestamps, y=eeg_channels_normalized[channel])
    plt.title(channel)
    plt.xlabel('Timestamp')
    plt.ylabel('Normalized Amplitude')

plt.tight_layout()
plt.show()
```



Plot for Waveforms of channel_1 to channel_8

```
import numpy as np
from scipy.signal import welch

statistics = eeg_channels.describe()

print("Basic Statistics for each channel:")
```

Basic Statistics for each channel:

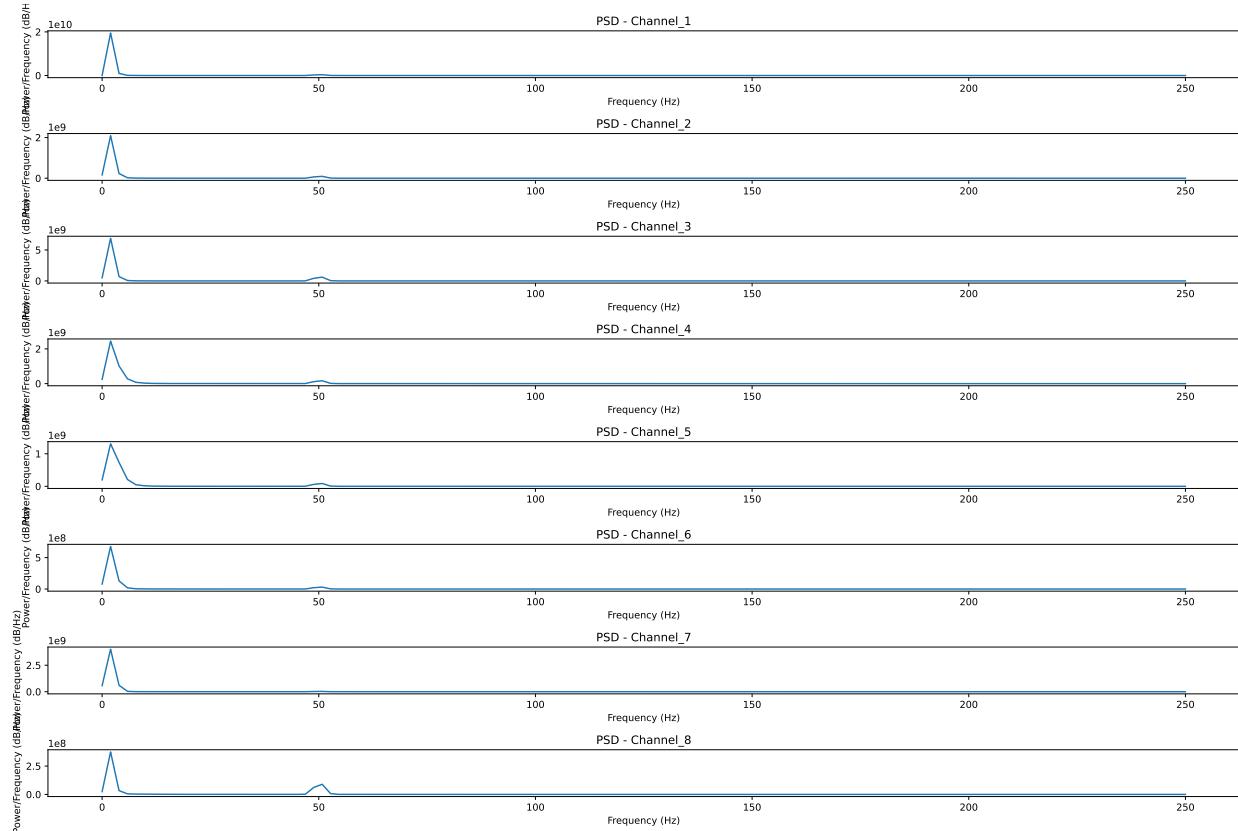
```
print(statistics)
```

	Channel_1	Channel_2	...	Channel_7	Channel_8
count	3.000000e+04	3.000000e+04	...	3.000000e+04	3.000000e+04
mean	-2.090649e+08	-3.681771e+07	...	-3.710497e+07	-2.014704e+07
std	4.776417e+07	2.883546e+06	...	7.582251e+05	8.920607e+05
min	-2.881841e+08	-4.315196e+07	...	-3.806277e+07	-2.184501e+07
25%	-2.505293e+08	-3.800060e+07	...	-3.766180e+07	-2.088949e+07
50%	-2.106696e+08	-3.701573e+07	...	-3.738470e+07	-2.013874e+07
75%	-1.682614e+08	-3.422193e+07	...	-3.626013e+07	-1.955419e+07
max	-1.233849e+08	-3.321896e+07	...	-3.364406e+07	-1.822300e+07

[8 rows x 8 columns]

```
# Plot the power spectral density (PSD) for each channel
plt.figure(figsize=(18, 12))
for i, channel in enumerate(eeg_channels.columns):
    plt.subplot(8, 1, i + 1)
    freqs, psd = welch(eeg_channels[channel], fs=500)
    sns.lineplot(x=freqs, y=psd)
    plt.title(f'PSD - {channel}')
    plt.xlabel('Frequency (Hz)')
    plt.ylabel('Power/Frequency (dB/Hz)')

plt.tight_layout()
plt.show()
```



Power Spectral Density graph for each of the channels.

4.5 Analysis

The EEG Signals are acquired from the above mentioned readings. We recorded the raw EEG while the subject was relaxed with eyes closed. For EEG recording with MP35 system, it was important to position the subject away from the computer and to place MP35 away from the computer (set aside or clip to subject).

In the ENOBIO recording, the subject's Power spectrum showed most of the frequencies were around 10-15 Hz in majority of the channels. For channel_8 some frequencies were found to be $\sim 50\text{Hz}$.

4.6 Result

The EEG Signal is acquired, recorded and analysed for statistical parameters.

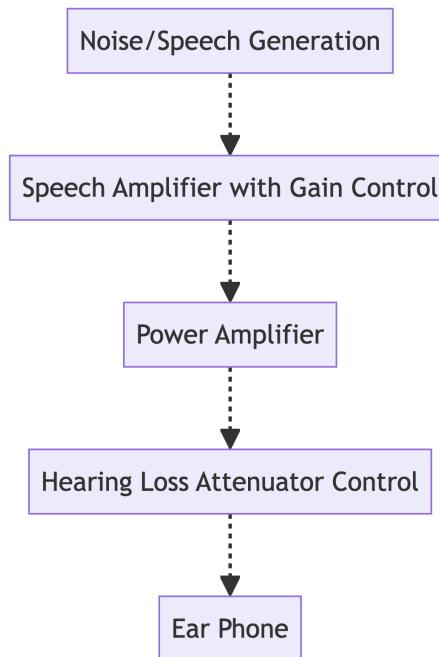
5 Audiometry

5.1 Aim

To measure the hearing loss of a person and conduct the air conduction and bone conduction tests.

5.2 Theory

Audiometry is a branch of audiology and the science of measuring hearing acuity for variations in sound intensity and pitch and for tonal purity, involving thresholds and differing frequencies. Typically, audiometric tests determine a subject's hearing levels with the help of an audiometer, but may also measure ability to discriminate between different sound intensities, recognize pitch, or distinguish speech from background noise.



Pure tone audiometry and audiograms - is a standardized hearing test in which air conduction hearing thresholds in decibels (db) for a set of fixed frequencies between 250 Hz and 8,000 Hz are plotted on an audiogram for each ear independently. A separate set of measurements is made for bone conduction. There is also high frequency Pure Tone Audiometry covering the frequency range above 8000 Hz to 16,000 Hz.

Air and Bone conduction testing are methods of evaluating hearing loss by comparing the perception of sounds transmitted by air or by bone:

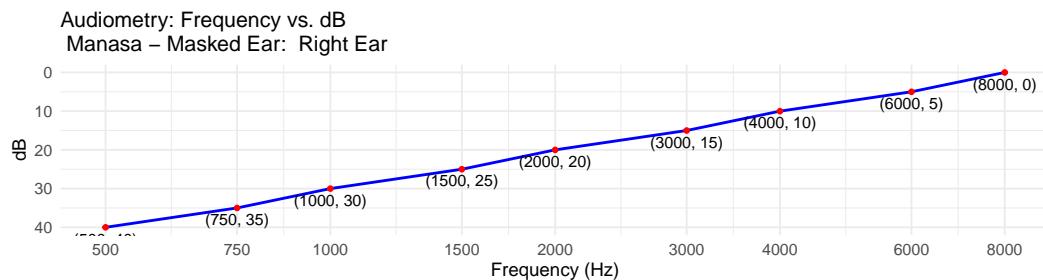
- In air-conduction testing, a pure tone is presented via an earphone or a loudspeaker, and the signal travels through the outer, middle, and inner ear.
- In bone-conduction testing, an electromechanical earphone is placed on the skull, and the signal bypasses the outer and middle ear. The Rinne test is a common example of air and bone conduction testing.

5.3 Procedure

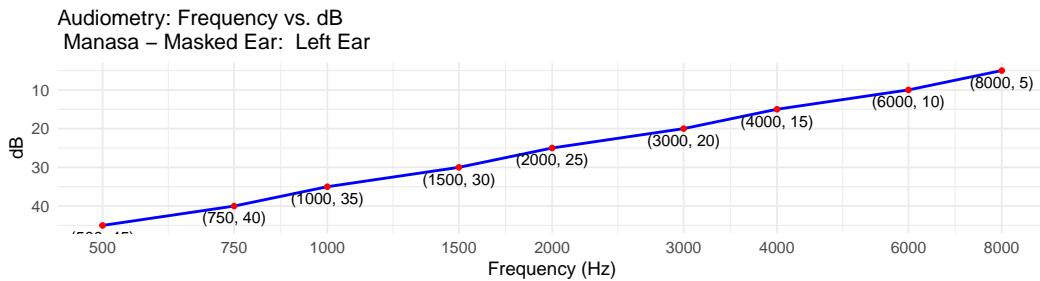
1. Switch the computer ON.
2. Connect the USB (of Air conduction & Bone conduction systems) to the Arphi Audiometry system.
3. Open Arphi 2001 Audiometry system on the Computer.
4. For Air Conduction click on ACR/ACL and for Bone Conduction click on BCR/BCL.
5. Ask the person to put on the respective instruments (headphones).
6. Select a Masking frequency.
7. Alter the frequency levels and dB levels & allow the person to click every time they hear a sound → click on PLOT.
8. Analyze the graph for both right and left ear.
9. Click on save test → type the name & save the data.
10. The same procedure can be repeated for both Air & Bone Conduction Tests.

5.4 Observation: Air Conduction test

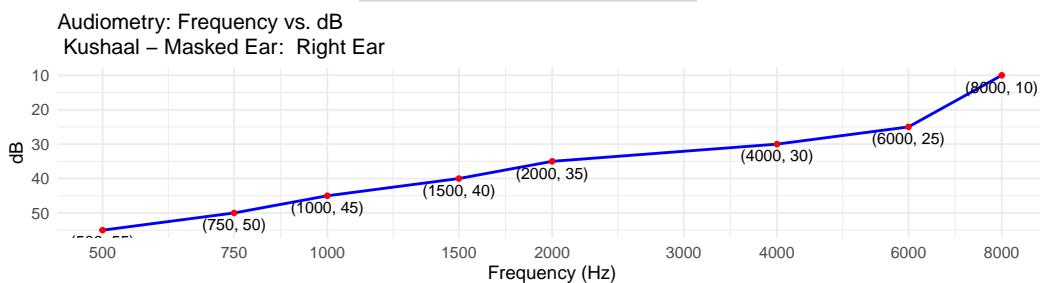
Audiometry Data			
Manasa - Masked Ear: Right Ear			
Frequency (Hz)	dB	Label	Coordinates
500	40	Hearing	(500, 40)
750	35	Hearing	(750, 35)
1,000	30	Hearing	(1000, 30)
1,500	25	Hearing	(1500, 25)
2,000	20	Hearing	(2000, 20)
3,000	15	Hearing	(3000, 15)
4,000	10	Hearing	(4000, 10)
6,000	5	Hearing	(6000, 5)
8,000	0	No hearing	(8000, 0)



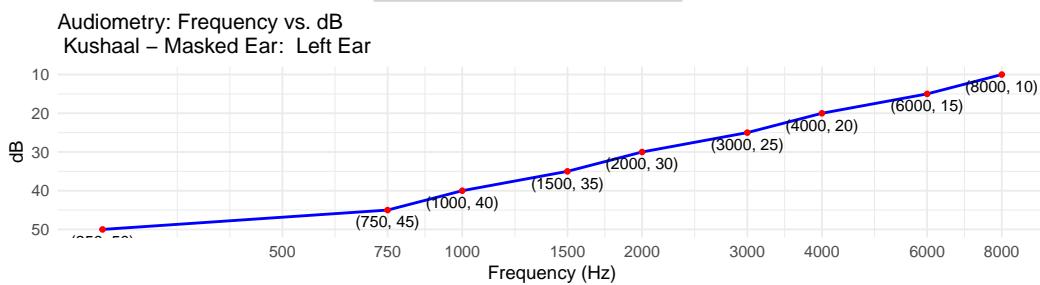
Audiometry Data			
Manasa - Masked Ear: Left Ear			
Frequency (Hz)	dB	Label	Coordinates
500	45	Hearing	(500, 45)
750	40	Hearing	(750, 40)
1,000	35	Hearing	(1000, 35)
1,500	30	Hearing	(1500, 30)
2,000	25	Hearing	(2000, 25)
3,000	20	Hearing	(3000, 20)
4,000	15	Hearing	(4000, 15)
6,000	10	Hearing	(6000, 10)
8,000	5	Hearing	(8000, 5)



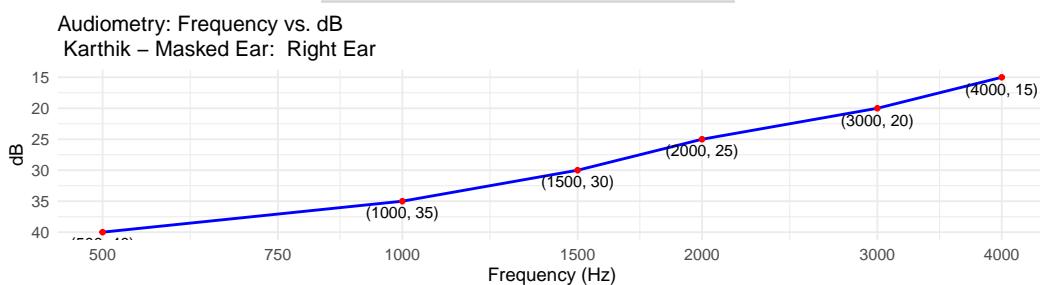
Audiometry Data			
Kushaal - Masked Ear: Right Ear			
Frequency (Hz)	dB	Label	Coordinates
500	55	Hearing	(500, 55)
750	50	Hearing	(750, 50)
1,000	45	Hearing	(1000, 45)
1,500	40	Hearing	(1500, 40)
2,000	35	Hearing	(2000, 35)
4,000	30	Hearing	(4000, 30)
6,000	25	Hearing	(6000, 25)
8,000	10	No hearing	(8000, 10)



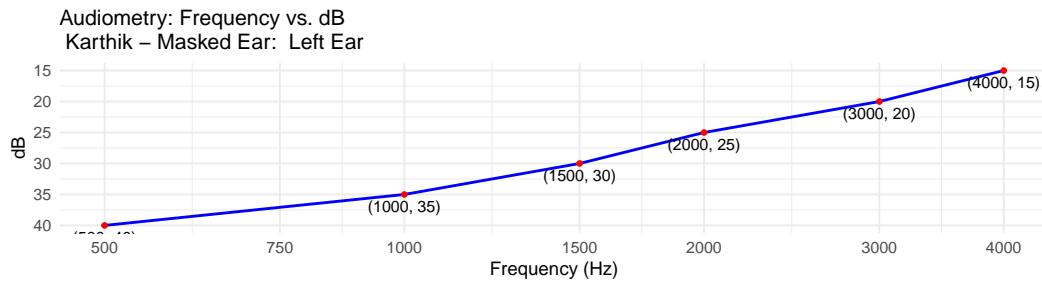
Audiometry Data			
Kushaal - Masked Ear: Left Ear			
Frequency (Hz)	dB	Label	Coordinates
250	50	Hearing	(250, 50)
750	45	Hearing	(750, 45)
1,000	40	Hearing	(1000, 40)
1,500	35	Hearing	(1500, 35)
2,000	30	Hearing	(2000, 30)
3,000	25	Hearing	(3000, 25)
4,000	20	Hearing	(4000, 20)
6,000	15	Hearing	(6000, 15)
8,000	10	No hearing	(8000, 10)



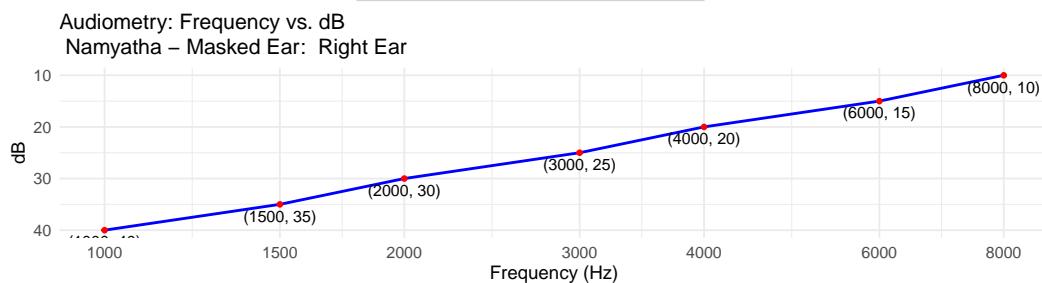
Audiometry Data			
Karthik - Masked Ear: Right Ear			
Frequency (Hz)	dB	Label	Coordinates
500	40	Hearing	(500, 40)
1,000	35	Hearing	(1000, 35)
1,500	30	Hearing	(1500, 30)
2,000	25	Hearing	(2000, 25)
3,000	20	Hearing	(3000, 20)
4,000	15	No hearing	(4000, 15)



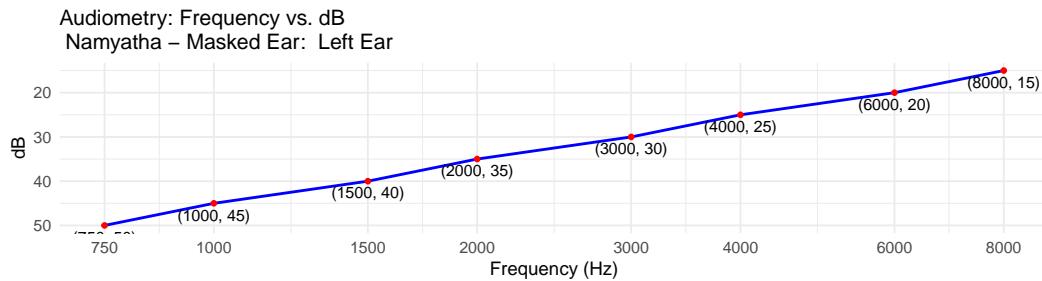
Audiometry Data			
Karthik - Masked Ear: Left Ear			
Frequency (Hz)	dB	Label	Coordinates
500	40	Hearing	(500, 40)
1,000	35	Hearing	(1000, 35)
1,500	30	Hearing	(1500, 30)
2,000	25	Hearing	(2000, 25)
3,000	20	Hearing	(3000, 20)
4,000	15	No hearing	(4000, 15)



Audiometry Data			
Namyatha - Masked Ear: Right Ear			
Frequency (Hz)	dB	Label	Coordinates
1,000	40	Hearing	(1000, 40)
1,500	35	Hearing	(1500, 35)
2,000	30	Hearing	(2000, 30)
3,000	25	Hearing	(3000, 25)
4,000	20	Hearing	(4000, 20)
6,000	15	Hearing	(6000, 15)
8,000	10	Hearing	(8000, 10)

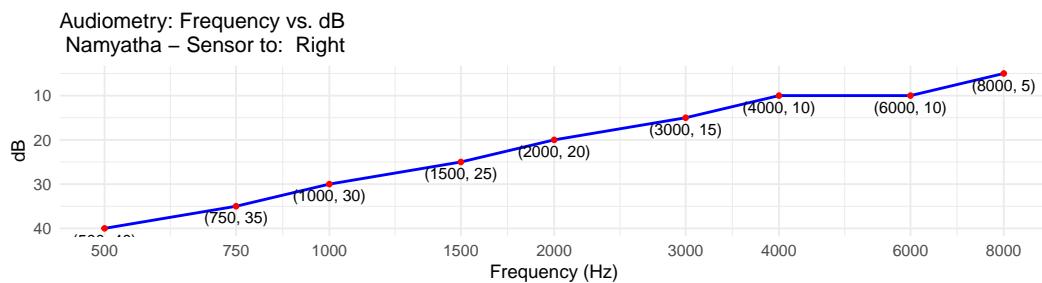


Audiometry Data			
Namyatha - Masked Ear: Left Ear			
Frequency (Hz)	dB	Label	Coordinates
750	50	Hearing	(750, 50)
1,000	45	Hearing	(1000, 45)
1,500	40	Hearing	(1500, 40)
2,000	35	Hearing	(2000, 35)
3,000	30	Hearing	(3000, 30)
4,000	25	Hearing	(4000, 25)
6,000	20	Hearing	(6000, 20)
8,000	15	Hearing	(8000, 15)

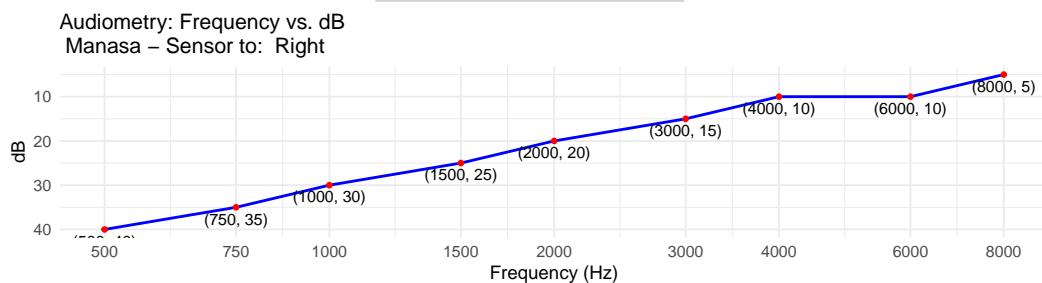


5.5 Observation: Bone Conduction test

Bone Conduction Left (BCL)			
Namyatha - Sensor to: Right			
Frequency (Hz)	dB	Label	Coordinates
500	40	Hearing	(500, 40)
750	35	Hearing	(750, 35)
1,000	30	Hearing	(1000, 30)
1,500	25	Hearing	(1500, 25)
2,000	20	Hearing	(2000, 20)
3,000	15	Hearing	(3000, 15)
4,000	10	Hearing	(4000, 10)
6,000	10	Hearing	(6000, 10)
8,000	5	No hearing	(8000, 5)



Bone Conduction Left (BCL)			
Manasa - Sensor to: Right			
Frequency (Hz)	dB	Label	Coordinates
500	40	Hearing	(500, 40)
750	35	Hearing	(750, 35)
1,000	30	Hearing	(1000, 30)
1,500	25	Hearing	(1500, 25)
2,000	20	Hearing	(2000, 20)
3,000	15	Hearing	(3000, 15)
4,000	10	No hearing	(4000, 10)
6,000	10	No hearing	(6000, 10)
8,000	5	No hearing	(8000, 5)



5.6 Analysis

Calculation of the hearing threshold of a person.

Hearing threshold : It is the lowest threshold of acoustic pressure sensation, possible to perceive by an organism. It is the sound level below which a person's ear is unable to detect any sound. For adults, 0 dB is the reference level. A threshold shift is an increase in the hearing threshold for a particular sound frequency.

Female subjects in the study have hearing threshold of 0dB, while the Male participants in the study have 10 and 15dB.

5.7 Results

The Air Conduction method is analysed.

6 ECG Waveform Simulation

6.1 Aim

1. To understand normal ECG waveform.
2. To understand noise associated with ECG measurement i.e. line Frequency and baseline wandering
3. To understand various abnormalities associated with ECG pattern.

6.2 Pre Requisites

- Knowledge of various physiological system.
- Tools like NI LabVIEW and MATLAB.

6.3 Theory

Human heart is a muscle that works continuously, much like a pump. Each beat of human heart is set in motion by an electrical signal from within heart muscle. The electrical activity of heart is recorded by an electrocardiogram, known as an EKG or ECG.

Human heart's electrical system controls all the events that occur when heart pumps blood. The electrical system also is called the cardiac conduction system.

6.3.1 P Wave

The P wave represents the wave of depolarization that spreads from the SA node throughout the atria, and is usually 0.08 to 0.1 seconds (80-100 ms) in duration. The brief isoelectric (zero voltage) period after the P wave represents the time in which the impulse is traveling within the AV node (where the conduction velocity is greatly retarded) and the bundle of His. Atrial rate can be calculated by determining the time interval between P waves.

6.3.2 QRS Complex

The QRS complex represents ventricular depolarization. Ventricular rate can be calculated by determining the time interval between QRS complexes. The duration of the QRS complex is normally 0.06 to 0.1 seconds. This relatively short duration indicates that ventricular depolarization normally occurs very rapidly. If the QRS complex is prolonged (> 0.1 sec), conduction is impaired within the ventricles. This can occur with bundle branch blocks or whenever a ventricular foci(abnormal pacemaker site) becomes the pacemaker driving

the ventricle. Such an ectopic foci nearly always results in impulses being conducted over slower pathways within the heart, thereby increasing the time for depolarization and the duration of the QRS complex.

6.3.3 ST Segment

The isoelectric period (ST segment) following the QRS is the time at which the entire ventricle is depolarized and roughly corresponds to the plateau phase of the ventricular action potential. The ST segment is important in the diagnosis of ventricular ischemia or hypoxia because under those conditions, the ST segment can become either depressed or elevated.

6.3.4 T Wave

The T wave represents ventricular repolarization and is longer in duration than depolarization (i.e., conduction of the repolarization wave is slower than the wave of depolarization). Sometimes a small positive U wave may be seen following the T wave (not shown in figure 1). This wave represents the last remnants of ventricular repolarization. Inverted or prominent U waves indicate underlying pathology or conditions affecting repolarization.

6.3.5 QT Interval

The Q-T interval represents the time for both ventricular depolarization and repolarization to occur, and therefore roughly estimates the duration of an average ventricular action potential. This interval can range from 0.2 to 0.4 seconds depending upon heart rate. At high heart rates, ventricular action potentials shorten in duration, which decreases the Q-T interval. Because prolonged Q-T intervals can be diagnostic for susceptibility to certain types of tachyarrhythmias, it is important to determine if a given Q-T interval is excessively long.

6.4 Simulation

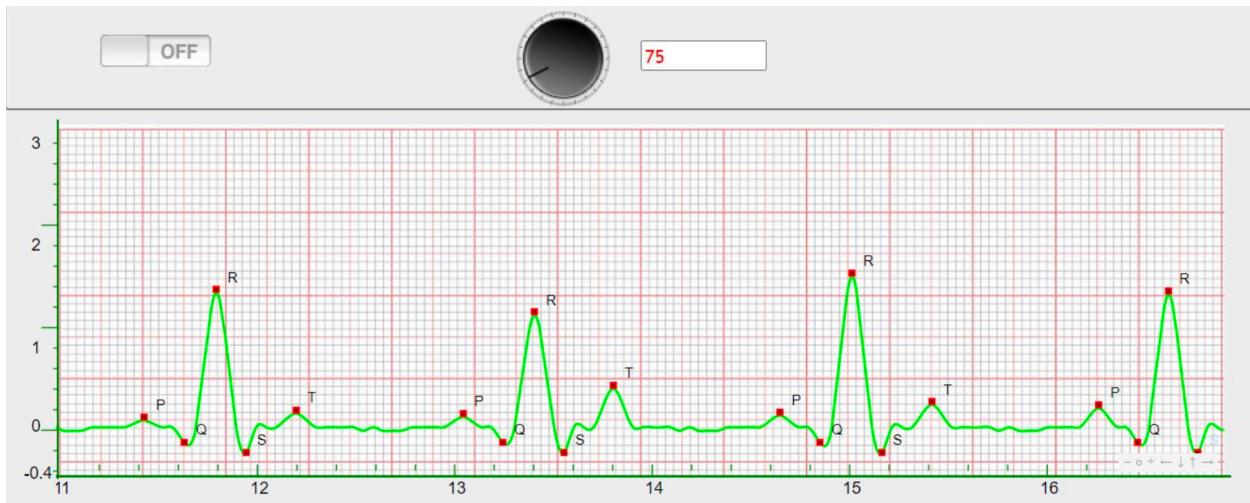


Figure 6.1: Normal ECG Waveform

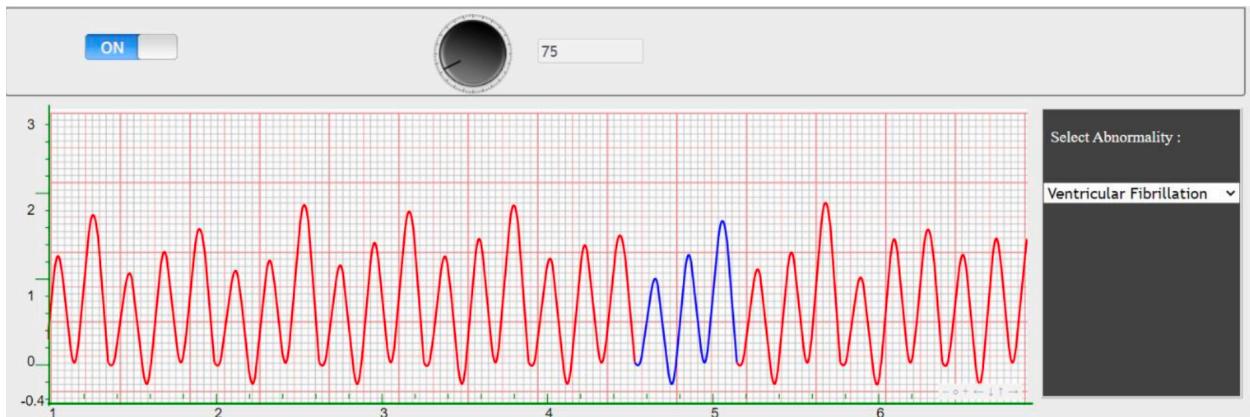


Figure 6.2: Abnormal ECG Waveform



Figure 6.3: Abnormal Moving ECG Waveform

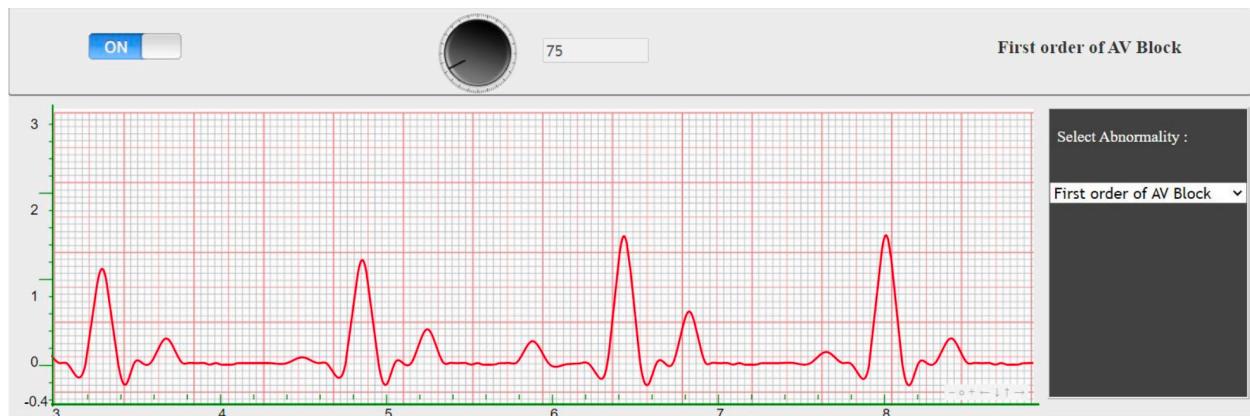


Figure 6.4: Abnormal ECG Main Plate

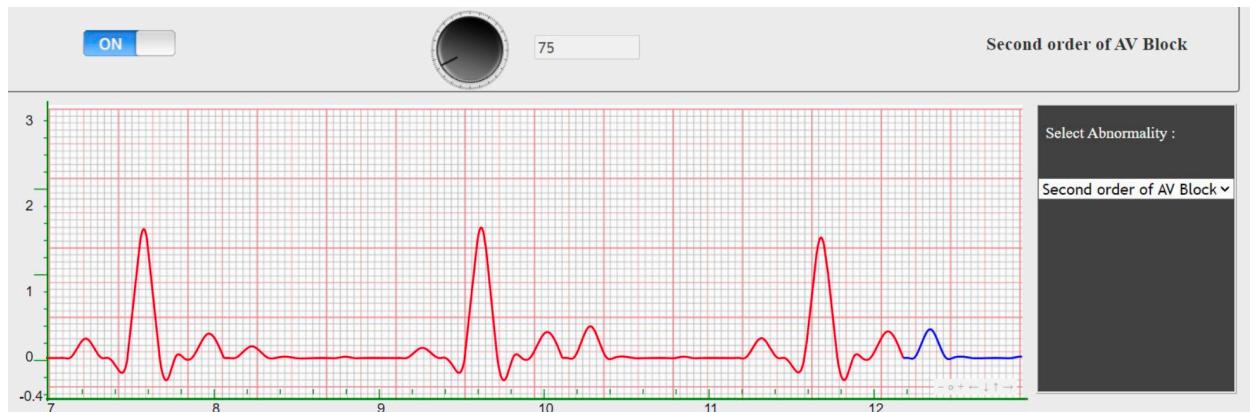


Figure 6.5: Abnormal ECG Main Plate: Moving waveform

6.5 Result

Thus, ECG Waveforms were simulated to observe the normal and abnormal patterns.

7 EEG Waveform Simulation

7.1 Aim

1. To understand normal EEG pattern.
2. To understand various abnormalities associated with EEG.
3. To assist in studying sleep patterns.
4. To assist in diagnosing mental disorders.

7.2 Pre Requisites

- Understanding of Central Nervous System
- Tools like NI LabVIEW and MATLAB

7.3 Theory

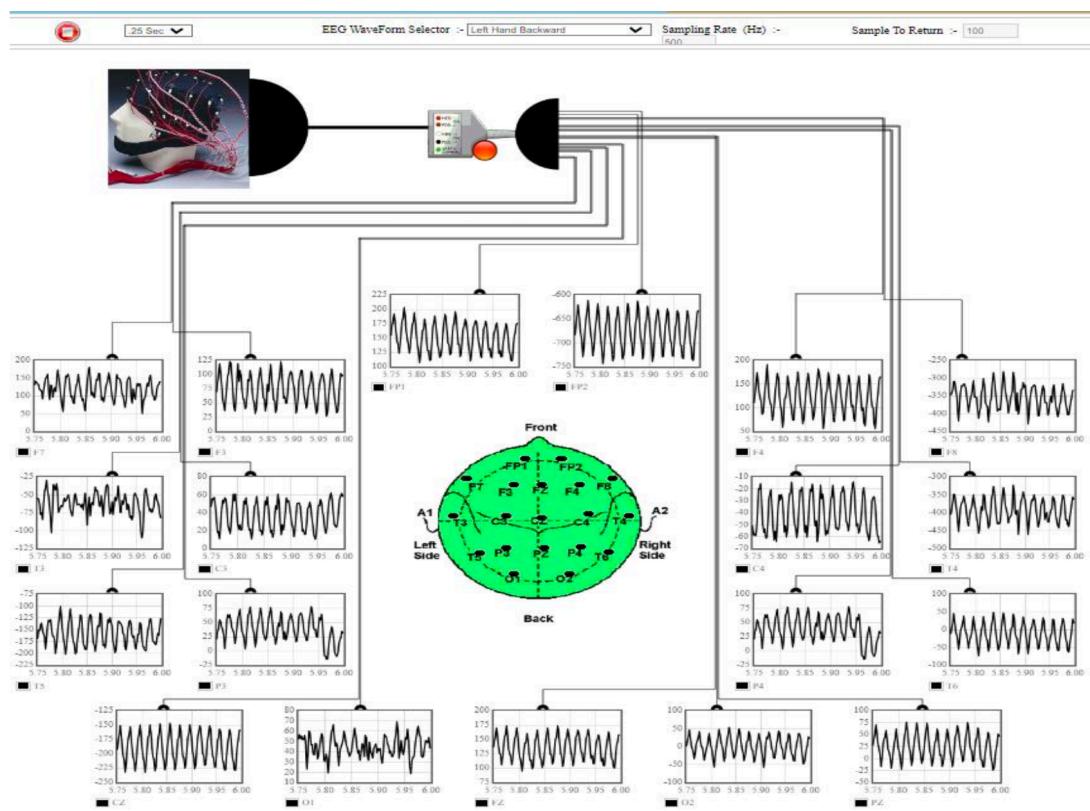
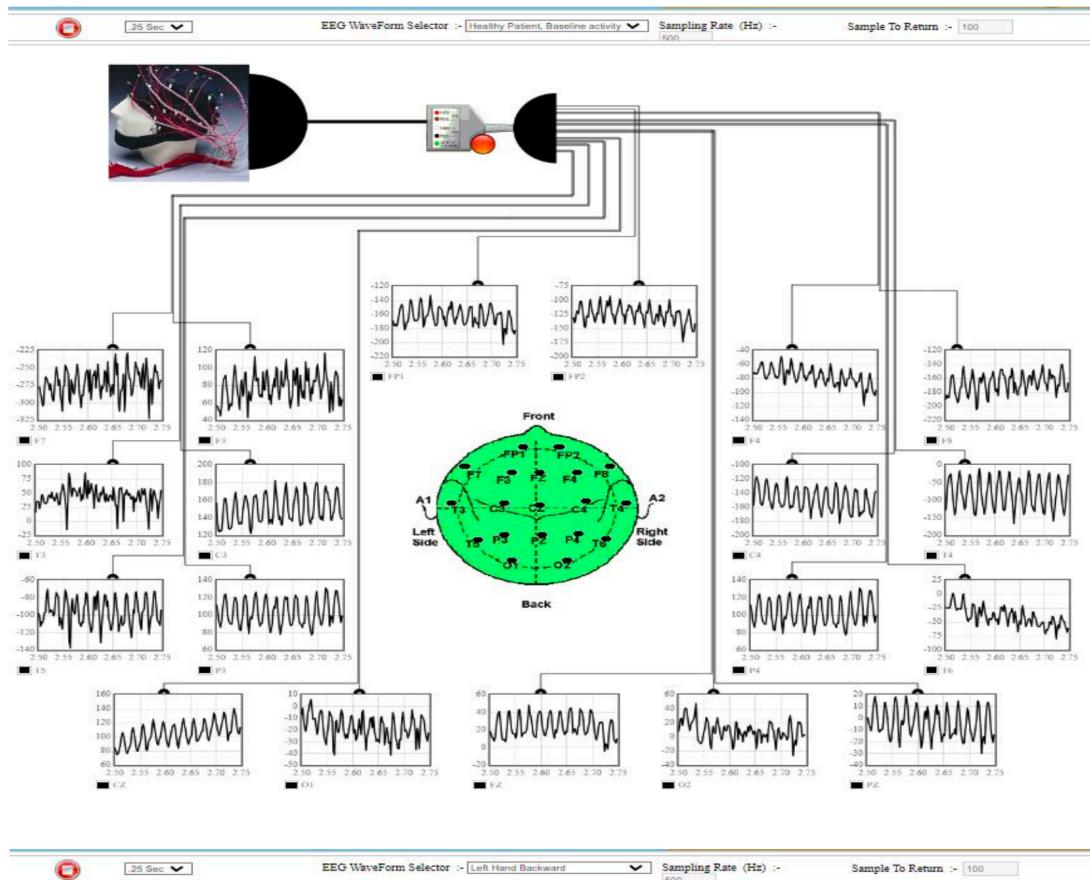
The electroencephalogram (EEG) is a unique and valuable measure of the brain's electrical function. It is a graphic display of a difference in voltages from two sites of brain function recorded over time. Electroencephalography (EEG) involves the study of recording these electrical signals that are generated by the brain.

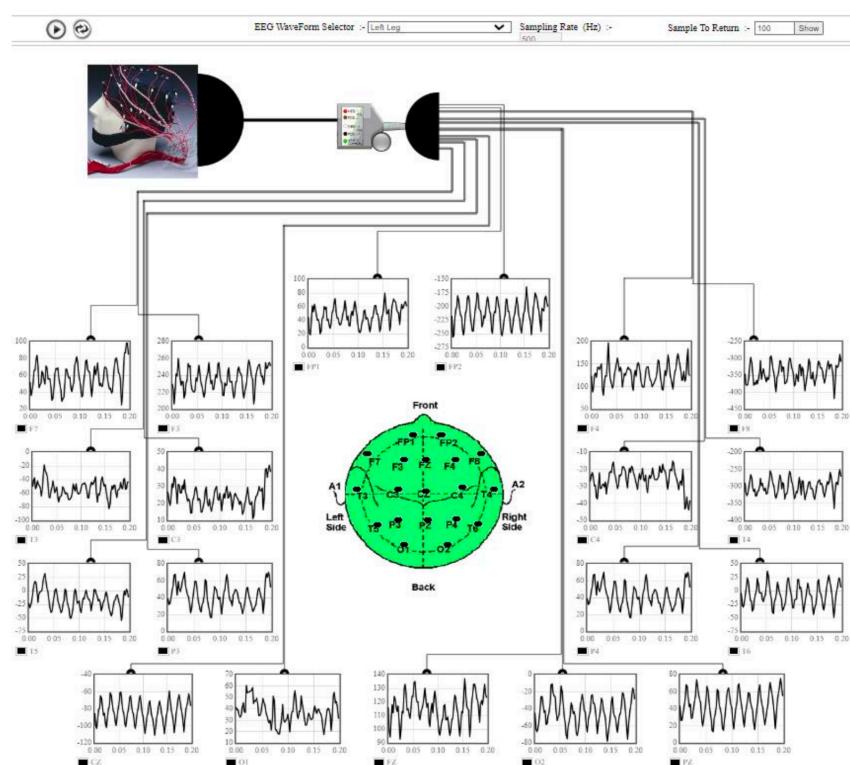
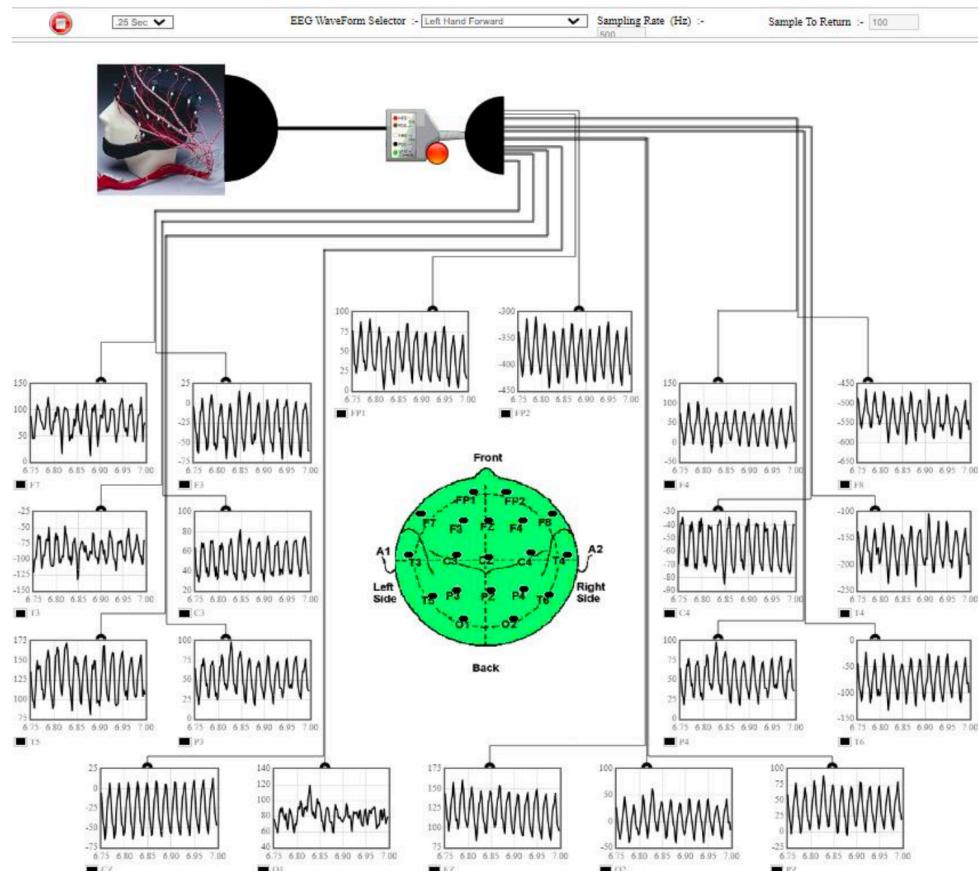
7.3.1 10-20 Electrode Positioning:

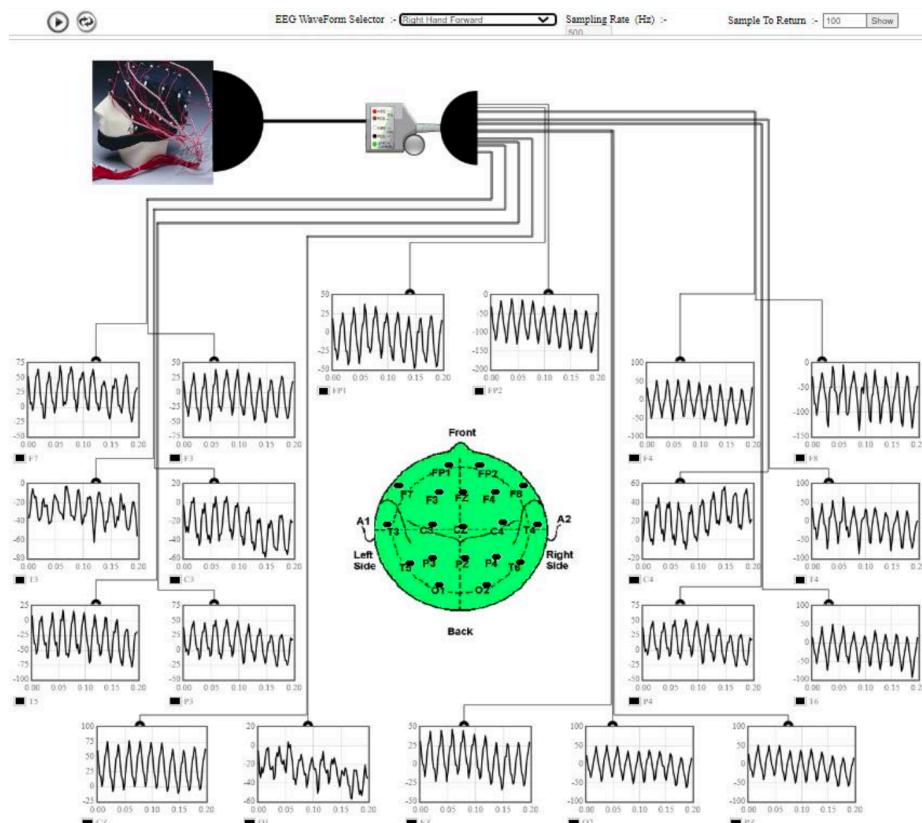
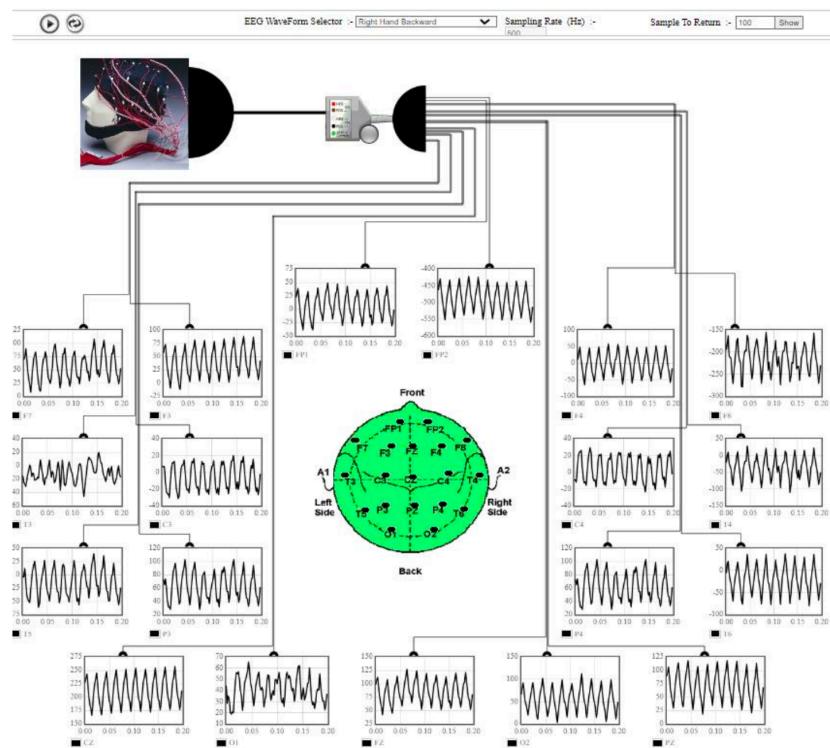
The 10-20 system avoids both eyeball placement and considers some constant distances by using specific anatomic landmarks from which the measurement would be made and then uses 10 or 20% of that specified distance as the electrode interval. The odd electrodes are on the left and the even ones on the right.

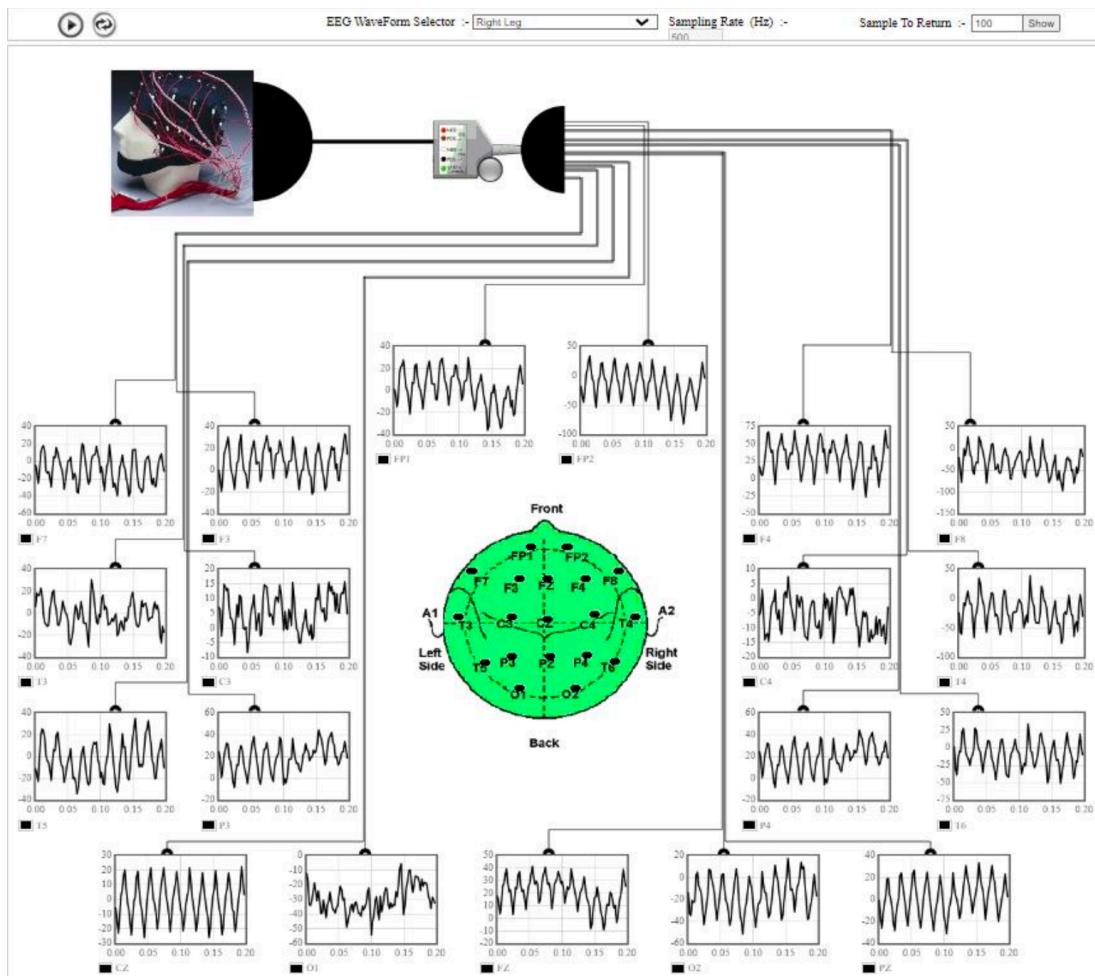
There are five major brain waves distinguished by their different frequency ranges. These frequency bands from low to high frequencies respectively are: delta (δ), theta (θ), alpha (α), beta (β) and gamma (γ).

7.4 Simulation









7.5 Result

Thus, EEG Waveforms were simulated. Patterns were observed for movement of different body parts.

8 Defibrillator Waveform Simulation

8.1 Aim

1. To simulate the Defibrillator output waveform
2. To understand energy levels generated by defibrillator
3. To understand the necessity and applications of defibrillator
4. To understand various controls associated with defibrillator
5. To understand various configurations and types of defibrillator

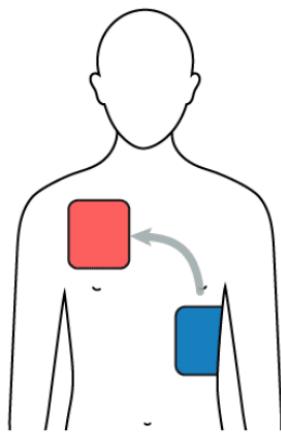
8.2 Pre Requisites

- Knowledge of various cardiac arrhythmias
- Tools like NI LabVIEW and MATLAB

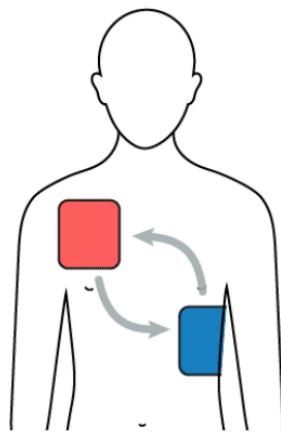
8.3 Theory

The instrument for administering the shock is called a defibrillator. Electric shock by defibrillator is used to reestablish normal activity. The shock can be delivered to the heart by means of electrode placed on chest of the patient.

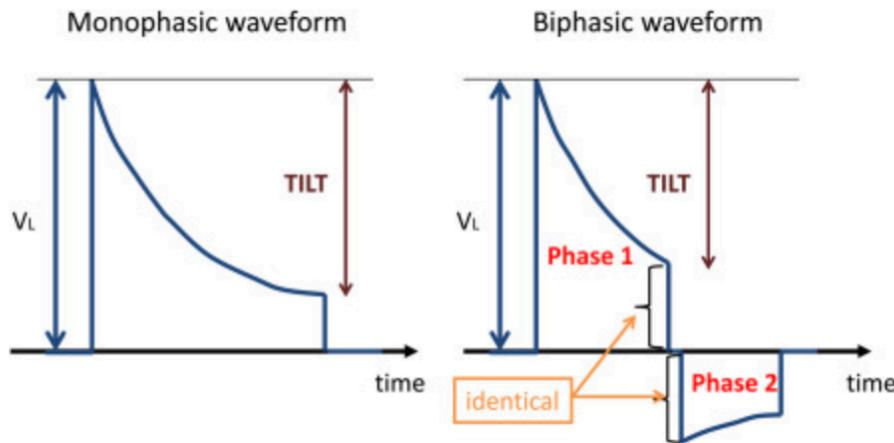
Ventricular fibrillation is serious cardiac emergency resulting from asynchronous contraction of heart muscle. This uncoordinated movement of ventricle walls of the heart may result from electric shock or from abnormalities of body chemistry. Main problem of fibrillation is continuously stimulation of adjacent cells of heart muscle fibers so there is no synchronized succession of events that follow heart action. This Fibrillation leads to loss of cardiac output and irreversible brain damage or death if not reversed within 5 minutes of onset.



Monophasic Defibrillation

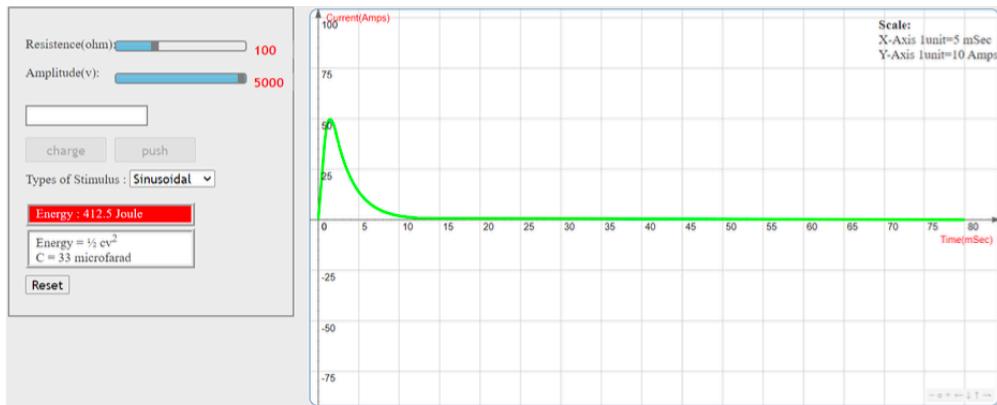


Biphasic Defibrillation



- Monophasic pulse width is typically programmable from 3.0 to 12.0 msec.
- Biphasic positive pulse width is typically programmable from 3.0 to 10.0 msec, while the negative pulse is from 1.0 to 10.0 msec
- Studies suggest that biphasic pulses yield increased defibrillation efficacy with respect to Monophasic pulses
- Monophasic pulse width is typically programmable from 3.0 to 12.0 msec.
- Biphasic positive pulse width is typically programmable from 3.0 to 10.0 msec, while the negative pulse is from 1.0 to 10.0 msec
- Studies suggest that biphasic pulses yield increased defibrillation efficacy with respect to Monophasic pulses

8.4 Simulation



8.5 Result

Thus, the output waveform of defibrillator was simulated. Monophasic and Biphasic waveforms were observed and understood.

9 Asynchronous and Synchronous Pacemaker Waveform Simulation

9.1 Aim

1. To simulate the pacemaker output waveform
2. To understand various energy levels generated by pacemaker
3. To understand the necessity and applications of pacemaker
4. To understand various types and configurations of pacemaker
5. To understand various controls associated with the pacemaker

9.2 Pre Requisites

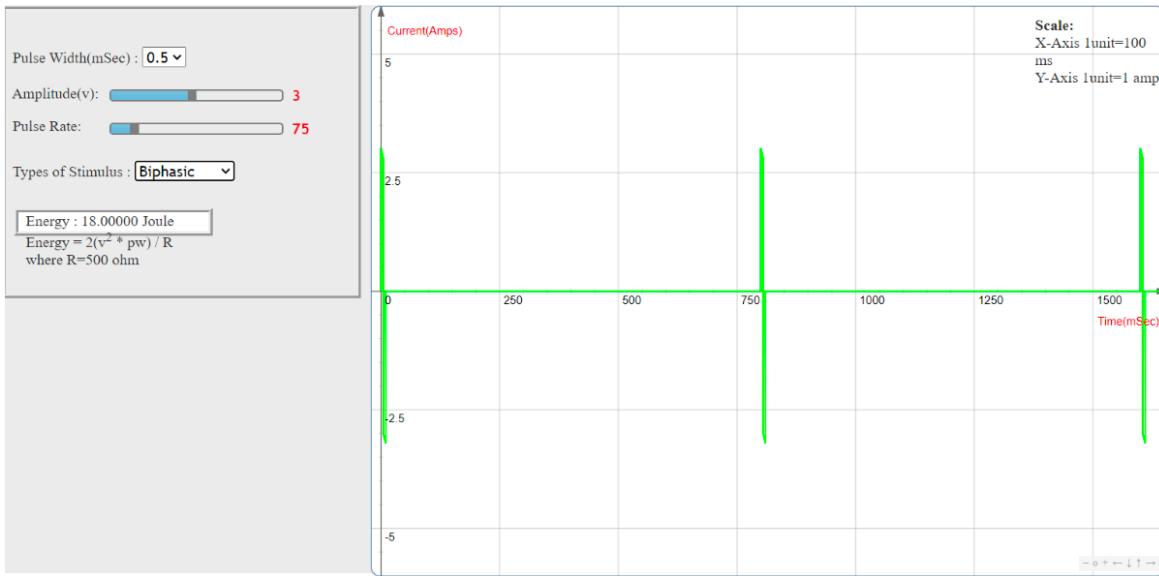
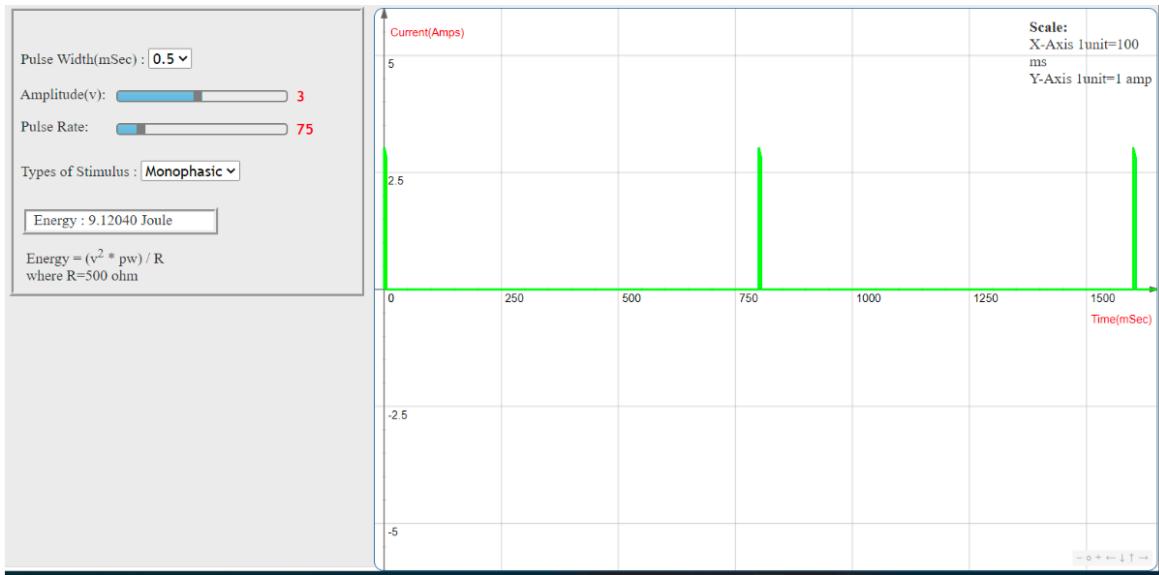
1. Knowledge of cardiac arrhythmias
2. Tools like NI LabVIEW and MATLAB

9.3 Theory

A pacemaker is an electronic device that provides an electrical signal to make the heart beat when it's own, built-in pacemakers fail. The anatomical, built-in pacemakers provide what is called the “intrinsic” rhythm, and they can be disrupted by various conditions - ischemia for example, or by an MI. It is prosthetic device for the heart, first conceived in 1932 by Albert S. Hyman, an American cardiologist. In 1952 the pacemaker was used clinically by Paul M. Zoll as an external device.

Abnormality in cardiac normal rhythm is called cardiac arrhythmia. There are various types of cardiac disorder. Some of them are Bradycardia and tachycardia. In bradycardia heart rate goes down from normal rate (i.e. below 60) and in tachycardia heart rate is higher than normal rate.

9.4 Simulation of Asynchronous Pacemaker Output Waveform



9.5 Simulation of Synchronous Pacemaker Output Waveform



9.6 Result

Thus, the waveform of the asynchronous and synchronous pacemaker was simulated, its configurations and controls were understood.

10 Simulation of Hemodialysis Machine

10.1 Aim

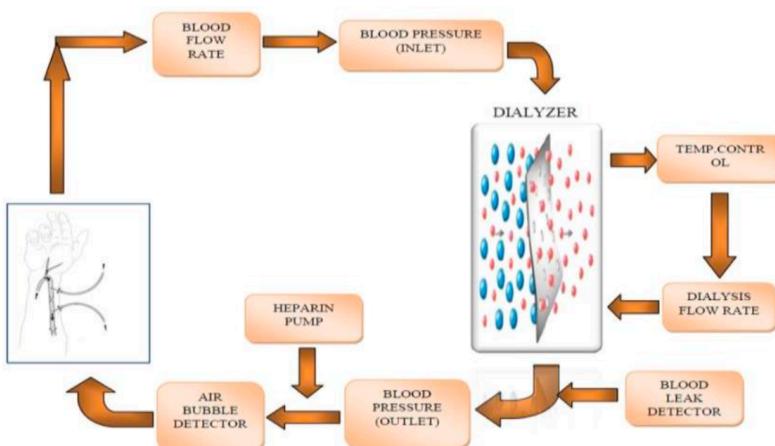
1. To understand the block schematics / modules involved in Haemodialysis Machine
2. To understand various measurement and control involved in Haemodialysis Machine
3. To understand overall functionality of Haemodialysis Machine

10.2 Pre Requisites

1. Knowledge of physiology of Kidney
2. Tools like NI LabVIEW and MATLAB

10.3 Theory

Hemodialysis means the process of filtering blood. In hemodialysis, the filtering process takes place in a machine outside the body. Hemodialysis is a method for removing waste products such as creatinine and urea, as well as free water from the blood when the kidneys are in renal failure. When the kidneys do not work well, dialysis is needed to remove extra fluid and waste products from the body. Hemodialysis is a type of dialysis that uses a machine with an artificial filter to remove waste and extra fluids from the blood.



10.3.1 Blood flow

The blood pump takes and returns the blood from the patient via the arterial and venous needles respectively. The blood is confined to the disposable plastic tubing and doesn't come in contact with any part of the machine. The blood coming from the pump flows to the dialyzer and the blood that leaves the dialyser returns to the patient through the venous needle. The pump speed, and the resulting blood flow rate, is adjustable from zero to about 600 cc/min. While pump speed is controlled, blood flow rate is displayed. These two usually go hand in hand, but not always. The blood flow rate is calculated based on the pump RPM (revolution per minute), and the diameter of the tube. The calculated blood flow is displayed. The control doesn't check the real blood flow. It displays blood flow even if the pump turns without the plastic tube installed.

The real blood flow may differ from the display because of:

- *Internal reverse leak:* the rollers never squeeze the tube completely so not all the blood is pushed forward, a little goes backward.
- High arterial and/or venous pressure reduces the ability of the pump to suck or to deliver.
- Any speed above some low value gradually reduces the blood flow. For a display of 600 cc/min the actual blood flow is 500 or less. In addition to the inherent features of the pump, a human error that may reduce blood flow is the way the plastic tube is installed in the pump. If the plastic tube inside the pump is too tight it cannot expand to its full volume, so the suction is reduced, and the pump delivers less blood flow than the display indicates.

10.4 Blood pressure

The blood pressure is measured both when it taken out from the limb and also when it is returned.

10.4.1 Arterial & Venous Pressure

These pressures are the result of the blood forced to flow through the plastic tubing, the dialyzer, and the needles.

10.4.2 Arterial pressure

When the blood flow rate increases the arterial pressure becomes more negative. If it is too negative the red blood cells may break down. This is called hemolysis. To be on the safe side never let the arterial pressure go below -220 mmHg. If it goes below that the pump speed should be reduced. If your blood count is low you may notice that the pump speed should be reduced as your blood count goes up.

10.4.3 Blood flow rate

The effect of blood flow is easy to follow - any change in pump speed is immediately reflected on the pressure displays. The higher the flow the higher the pressure.

10.4.4 Dialysis Process

Concerning the blood, dialysis performs 2 different functions that are normally done by healthy kidneys:

- Removing excess fluid.
- Removing waste like urea, and excess electrolytes (chemicals) like potassium, magnesium, sodium, etc.

The dialysis is performed inside the dialyzer, which is a plastic cylinder, in which the blood enters from the top, flows through thousands of extremely thin hollow fibers and leaves from the bottom. At the same time the dialysate enters from the bottom, flows around and in between the fibers, and leaves from the top. The fibers are semi permeable membranes, that is, smaller molecules in the blood stream can pass through them into the dialysate and bigger molecules as well as blood cells cannot. Dialysate is a water-based solution and its purpose is to absorb from the blood all that should be removed and nothing else.

Waste and electrolytes move from the blood into the dialysate because their concentration in the blood is higher. This process is called diffusion. The dialysate flow ensures that fresh dialysate is present at all times so that the dialysate doesn't become saturated, and the process never ends.

Fluid is removed from the blood in the same way the kidneys do it - by blood pressure. This process is called Ultra Filtration (UF) and is similar to Reverse Osmosis (RO). With RO, the membrane pore size is very small and allows only water to pass through the membranes. In UF, the membrane pore size is larger, allowing some bigger molecules to pass through the pores with the water.

The rate at which fluid is removed from the blood is called UFR (UF Rate). There is higher pressure in the blood passing through the dialyzer and lower pressure in the dialysate. This pressure difference is called TMP (Trans Membrane Pressure). The higher the TMP the higher the UFR.

The rest of the machine takes care of supplying the blood and the dialysate to the dialyzer, controls the flow and the pressures, and provides visual indication and alarm when something goes wrong.

10.4.5 Dialysate

The dialysate is a water-based solution. With all contemporary machines, the dialysate concentrate is fed into the machine, water is fed from a water tank and a marvelous pump mixes them to the desired concentration. - Calcium (Ca) can be 3.5, 2.5, 2 mEq/L, depending upon the patient's calcium. (US units; Ca 3.5 mEq/L equal 1.75 mmol/L). - Potassium (K) can be 4, 3, 2, 1 mmol/L, or zero (free-K). (US units, used internationally).

10.4.6 Dialysate flow

The dialysate pump, in addition to mixing the concentrate with water, moves the dialysate through the dialyzer. This pump has an adjustable flow rate. For regular dialysis at blood flow up to 250 cc/min the dialysate flow should be 500 cc/min. For more efficient dialysis, called high flux, the blood flow is 400-500 cc/min, and the dialysate flow is 800 cc/min. In addition to controlling the flow, this multi-function pump controls the pressure of the dialysate as to achieve the desired TMP and hence the desired UFR.

10.4.7 UF and UFR

In modern dialysis machines either UF or UFR can be set. When UF is set it is called Goal; that's how many grams or cc of fluid to remove. Treatment time should also be entered so the control can calculate the UFR and the TMP. This is the way it is done in most centers. The control is sophisticated enough to recalculate the UFR if the goal is changed during the treatment.

10.4.8 Blood Leak

Blood may leak inside the dialyzer because of ruptured fibers. This may happen even with a new dialyzer. There could be a minor leak, which is invisible, or a major leak in which blood can be seen in the dialyzer. In both cases the machine stops and sets the alarm. To resume dialysis the dialyzer should be replaced.

10.4.9 Heparin Pump

This pump delivers heparin to the blood tubing. The pump is a regular syringe that is pushed by a controlled motor. On all machines the rate can be adjusted. Usually an initial dose of heparin is given when the treatment begins, then the pump delivers heparin until one hour before the end. All patients need continuous heparin.

In case of a patient after surgery or another kind of bleeding, heparin is used sparingly or not at all. To avoid clotting in the dialyzer it is rinsed with 100 cc saline every hour or so. In spite of that, the blood in the dialyzer may clot, but unless the patient has a very low blood count no treatment is required (of course the heparin dose should be increased when possible).

10.4.10 Temperature

To make it more convenient for the patient, the dialysate temperature can be set to a desired value, so the blood returning to the patient will not be too cold. For most patients a setting of 37 C (98.6 F) is ok.

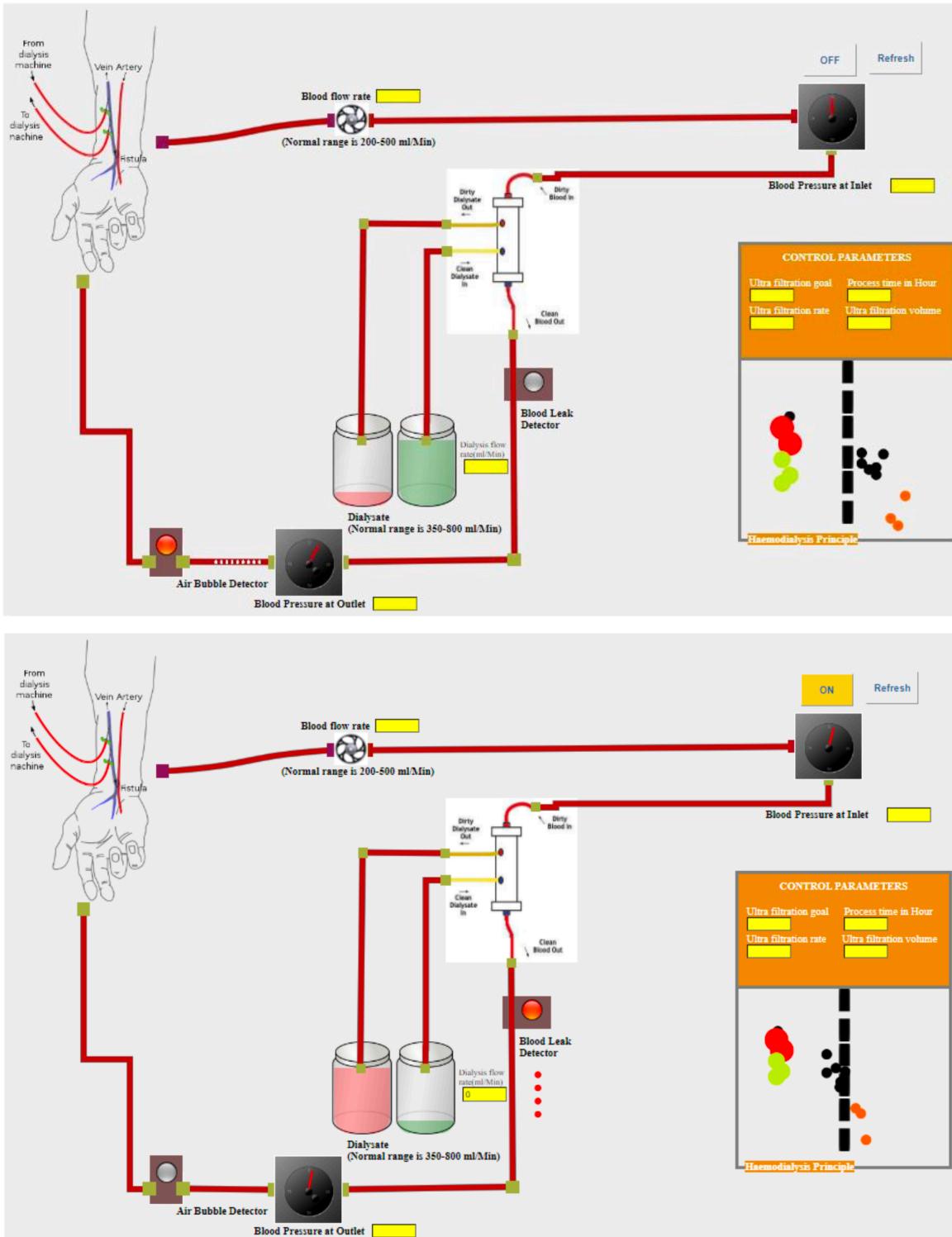
10.4.11 Treatment Time

Each treatment takes about 4 hours and is done three times each week. Moreover, depending upon the patient's clinical history the treatment may vary.

10.4.12 Alarm

There is a red alarm light. There are many reasons for the machine to alarm: the reason is either Air bubble detection or Blood leak detection.

10.5 Simulation



10.6 Result

Thus, the simulation of the hemodialysis machine is working, and the output was studied.

11 BMS Hospital Visit

11.1 Defibrillator¹

Delivers controlled electric shock | disrupts the chaotic electrical activity of abnormal heartbeat | restores a normal heart rhythm

- General use case: unconscious and not breathing
- Specific use case: Arrhythmia² → Ventricular Fibrillation & Tachycardia

Feature	Ventricular tachycardia (VT)	Ventricular fibrillation (VF)
Heart rate	Very fast, typically between 120 and 250 beats per minute	Chaotic and unmeasurable
Electrical activity	Regular, but the heart is beating too fast	Chaotic and uncoordinated
Symptoms	Chest pain, shortness of breath, lightheadedness, or fainting	Sudden loss of consciousness and no breathing
Treatment	Medication, electrical cardioversion, or an ICD	Immediate defibrillation

Figure 11.1: Untitled

- Types:

Feature	AED	ICD	WCD
Type	Portable device	Implanted device	Wearable device
Use	By laypersons	By healthcare professionals	By patients or caregivers
Treatment	Delivers an electric shock to the heart	Delivers an electric shock to the heart	Delivers an electric shock to the heart
Power	Less powerful than an ICD	More powerful than a WCD	Less powerful than an ICD
Indications	Cardiac arrest	Life-threatening heart arrhythmias	Life-threatening heart arrhythmias
Duration of use	Single use	Permanent	Short-term

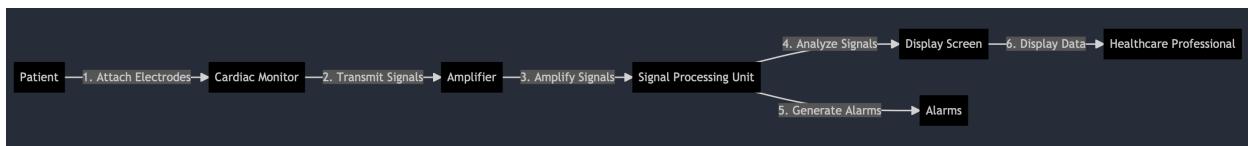
¹<https://www.nhlbi.nih.gov/health/defibrillators#:~:text=Defibrillators%20are%20devices%20that%20send,also%20help%20it%20beat%20again>.

²<https://www.nhlbi.nih.gov/health/arrhythmias>

11.2 Cardiac monitor

Displays real-time electrical activity of elec signals generated by heart.

- Electrodes (small, adhesive patches with conductive gel) → connected to leads (Colour coded: b, g, r, y) → attached to chest, limbs or both.
- Data output: Heart rate | ECG | BP | SpO₂ | Respiratory rate



11.3 Nebuliser

Medication in form of mist → into the lungs

- Use case: Patient in trouble coordinating breaths using inhalers.
- Types of medications: bronchodilators, corticosteroids, antibiotics.

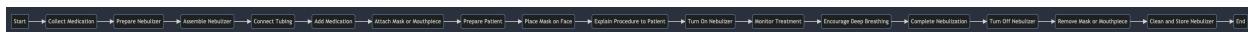


Figure 11.2: Handling a Nebuliser and its process

Handling a Nebuliser and its process

11.4 Ryles tube³

aka Nasogastric tube (NG tube): to deliver food, medicine, fluids to stomach, remove stomach contents → via securing to patient's nose.

- Use case:
 - providing nutrition when unable to eat or drink on their own
 - Gastro-esophageal reflux disease (GERD) and pyloric stenosis

Injuries associated: injury to nose, risk of infection, vomit, stomach distension..

11.5 Nasal Prongs

aka nasal cannulas: 2 small prongs into patient's nostrils → delivering O₂

³<https://www.gpcmedical.com/317/DIS137/ryles-tube-nasogastric-tube.html>

11.6 IntraVenous lines

Intra → Inside, Venous → veins: tubes that deliver medications, fluids, directly into bloodstream

11.7 Hemodialysis

Instructor: Bhaskar [Dialysis technician]

Device: Fresenius Medical Care 4008S

- Acid and Bicarbonate conc → 13.5 - 14.5
- AntiCoagulant → Heparin
- 120L - 150L of purified water per Dialysis
- Saline inlet: for Fluid balance, Hydration, Optimal electrolyte conc.

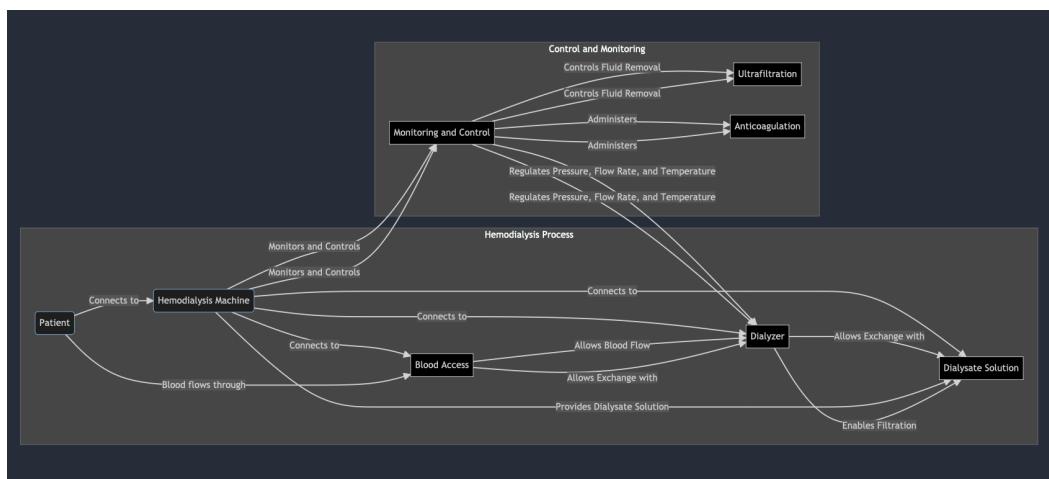


Figure 11.3: Duration: 4hrs

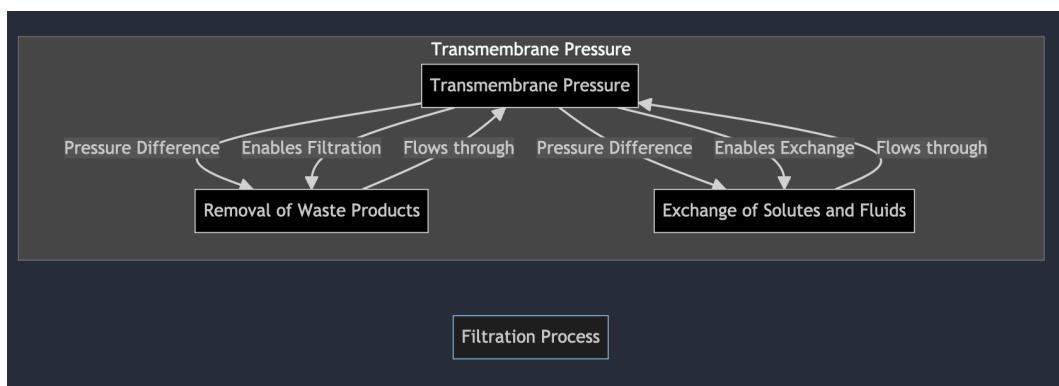


Figure 11.4: Role of TMP

Role of TMP

Composition of Dialysate solution (in mili-equivalents per litre):

- $Na^+ \rightarrow 130-140$
- $K^+ \rightarrow 1-4$ depending on the patient's needs.
- $Ca^{2+} \rightarrow 1.25-1.75$
- $Mg^{2+} \rightarrow 0.5-1.0$
- $HCO_3^- \rightarrow 25-35$
- $Cl^- \rightarrow 95-110$
- Acetate $C_2H_3O^{2-}$ → as a buffer

Steps:

1. Cleanse the patient's access site with an antiseptic solution
 2. Connect the tubing set to the patient's access site and allow blood flow
 3. Enter the patient's weight into the machine
 4. Verify the dialysate solution is properly mixed & at req temp
 5. Periodically check machine's display to adjust parameters like blood flow rate, UF ..in the machine.
- Auto Rinse everyday

11.8 Laboratory

11.8.1 Hematology

Device: Horiba Yumizen

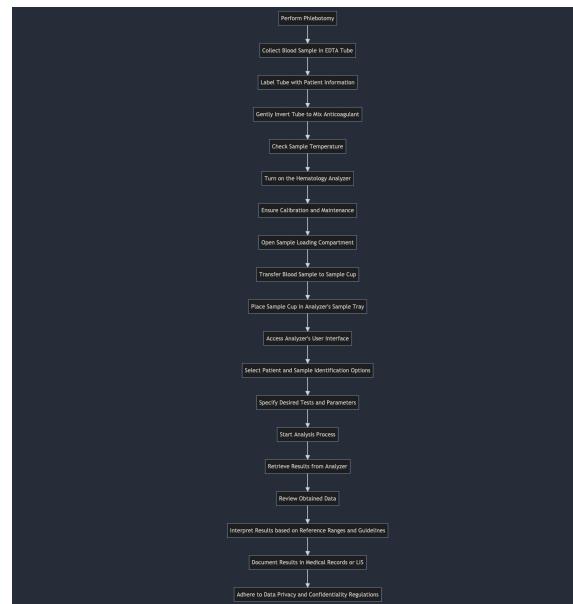


Figure 11.5: Instructions on operating Horiba Yumizen Hematology Analyzer

Analysis results:

1. Complete Blood Count (CBC) Parameters:

- Hemoglobin (Hb) concentration
- Hematocrit (Hct) value
- Red Blood Cell (RBC) count
- Mean Corpuscular Volume (MCV)
- Mean Corpuscular Hemoglobin (MCH)
- Mean Corpuscular Hemoglobin Concentration (MCHC)
- Red Cell Distribution Width (RDW)
- White Blood Cell (WBC) count
- Platelet count

2. Red Blood Cell (RBC) Indices:

- RBC histogram
- RBC distribution width

3. White Blood Cell (WBC) Parameters:

- Total WBC count
- Differential WBC count (percentage or absolute values of different types of WBCs, such as neutrophils, lymphocytes, monocytes, eosinophils, and basophils)
- WBC histogram
- WBC scattergram
- Absolute Neutrophil Count (ANC): Number of neutrophils per volume of blood.

4. Platelet Parameters:

- Platelet histogram
- Mean Platelet Volume (MPV)
- Mean Platelet Component (MPC): Average content of platelet granules.
- Platelet Distribution Width (PDW)
- Plateleterit (PCT)

5. Red Blood Cell Morphology:

- Evaluation of red blood cell shape, size, and abnormalities (e.g., presence of target cells, spherocytes, schistocytes)

6. White Blood Cell Morphology:

- Evaluation of white blood cell morphology, including the presence of abnormal cells or immature forms (e.g., blast cells)

7. Other Parameters:

- Reticulocyte count
- Reticulocyte Hemoglobin Content (CHr): Amount of hemoglobin in reticulocytes.
- Erythrocyte sedimentation rate (ESR)
- Coagulation-related parameters (e.g., prothrombin time, activated partial thromboplastin time)
- Immature Granulocytes: Percentage or absolute count of immature granulocytes in the white blood cell population.
- Nucleated Red Blood Cells (NRBCs): Presence or count of nucleated red blood cells.

11.8.2 Biochemistry

Device: Erba Mannheim EM200

- Fully automated, 10-12 mins duration per test with large no of sample capacity

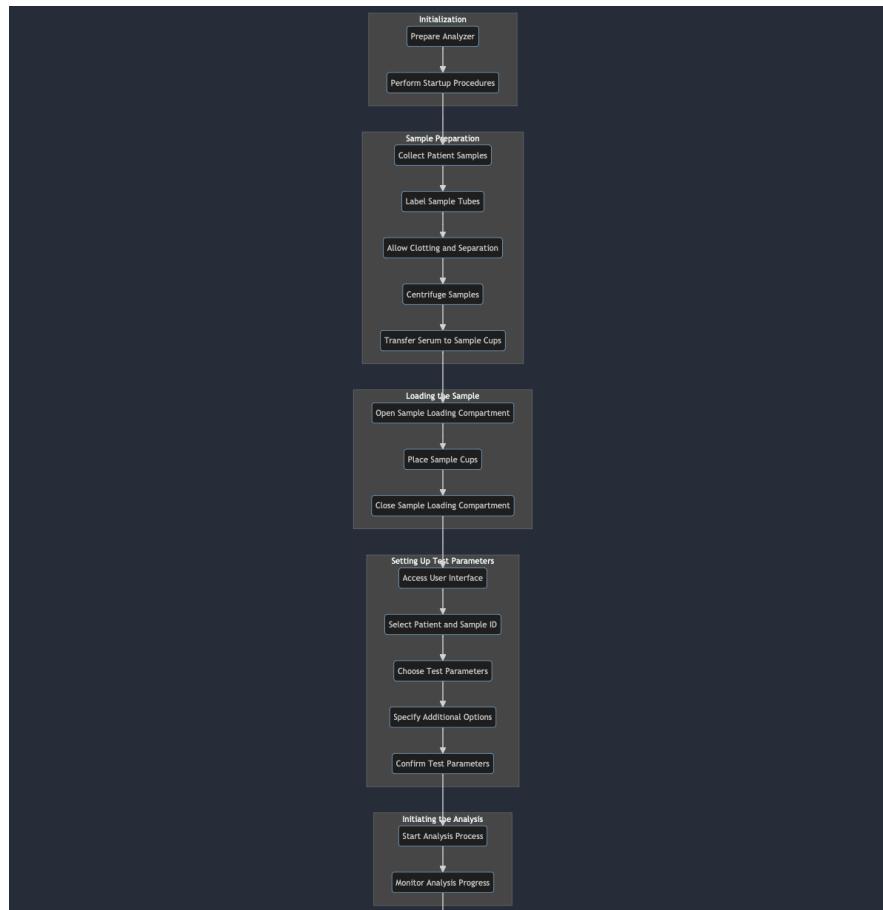


Figure 11.6: Instructions for operating the Chemical analyser

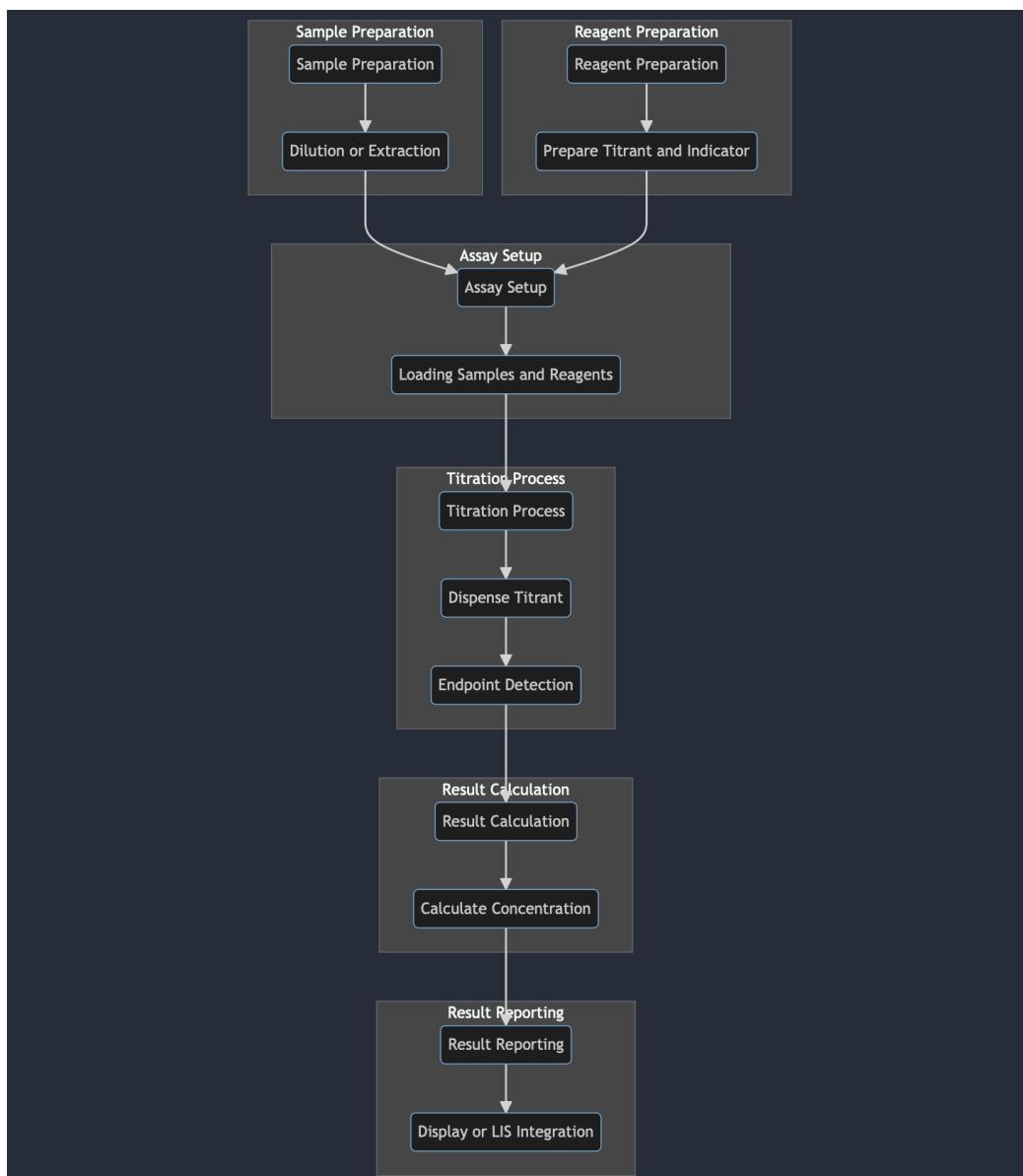


Figure 11.7: PDTA method

Analysis results:

1. Enzymes:

- Alanine Aminotransferase (ALT)
- Aspartate Aminotransferase (AST)
- Alkaline Phosphatase (ALP)
- Gamma-Glutamyl Transferase (GGT)
- Lactate Dehydrogenase (LDH)
- Creatine Kinase (CK)
- Amylase
- Lipase

2. Liver Function Tests:

- Total Bilirubin
- Direct Bilirubin
- Total Protein
- Albumin
- Globulin
- Albumin/Globulin Ratio

3. Kidney Function Tests:

- Blood Urea Nitrogen (BUN)
- Creatinine
- Uric Acid
- Estimated Glomerular Filtration Rate (eGFR)

4. Lipid Profile:

- Total Cholesterol
- Triglycerides (TGL)
- High-Density Lipoprotein Cholesterol (HDL-C)
- Low-Density Lipoprotein Cholesterol (LDL-C)
- Very Low-Density Lipoprotein Cholesterol (VLDL-C)

5. Glucose:

- Fasting Blood Glucose
- Random Blood Glucose
- Oral Glucose Tolerance Test (OGTT)

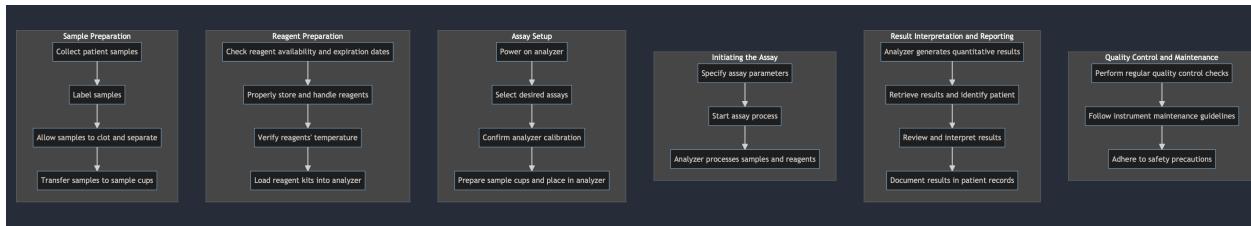
6. Other Parameters:

- Total Protein
- C-Reactive Protein (CRP)
- Iron
- Transferrin
- Thyroid Stimulating Hormone (TSH)
- Free Thyroxine (FT4)
- Free Triiodothyronine (FT3)

11.9 Endocrinology

Device: Mini VIDAS

- Quantitative analysis of hormones: T3, T4, TSH..
- No liquid input only Dry input, 45-60 mins per test session



11.10 Microfluid Analyser

Device: Afinion Abbott

- Utilises ‘Microfluidic LabCard’ technology - point-of-care system
- Analysis output: blood glucose, HbA1c (glycated hemoglobin), lipid panel, and ACR (albumin-to-creatinine ratio)

11.11 Electrolyte analyser

Device: ST200 - Sensa Core Medical Instrumentation Pvt. Ltd

- Uses Ion Selective Electrode technology
- Analysis output: sodium, potassium, chloride, calcium, and pH

11.12 Centrifuge

Device: REMI R8C

- 5250 RPM

11.13 ICU

- Syringe pump - 50ML capacity, single digit rate

Feature	Syringe Pump	Infusion Pump
Volume	Delivers small volumes of fluids or medications, such as those used in chemotherapy or pain management.	Delivers large volumes of fluids or medications, such as those used in intravenous (IV) therapy.
Portability	Portable, making them ideal for use in mobile settings, such as ambulances or doctor's offices.	Stationary, requiring a power source and a dedicated workspace.
Complexity	Simple to operate and maintain.	More complex to operate and maintain, requiring training and expertise.
Features	Variable rate delivery, multiple fluid delivery.	Variable rate delivery, multiple fluid delivery, alarms, safety features.
Applications	Chemotherapy, pain management, research.	IV therapy, patient-controlled analgesia.

11.14 BiPAP - Bilevel Positive Airway Pressure

To increase O_2 levels in blood, assists with inhalation & provide positive pressure to keep the airways open.

- Inspiratory positive airway pressure (IPAP): This is the pressure level when breathing in.
- Expiratory positive airway pressure (EPAP): This is the pressure level when breathing out.
- Use case: sleep apnea, COPD, obesity-hypoventilation syndrome.

11.15 Differences in BiPAP and Mechanical Ventilator

Feature	BiPAP	Maquet Servo S
Intended use	BiPAP is a home-use device for the treatment of obstructive sleep apnea (OSA) and other respiratory conditions.	Maquet Servo S is a hospital-grade ventilator that is used to treat a variety of respiratory conditions, including acute respiratory distress syndrome (ARDS), pneumonia, and chronic obstructive pulmonary disease (COPD).
Modes of ventilation	BiPAP offers two modes of ventilation: CPAP (continuous positive airway pressure) and BiPAP (bilevel positive airway pressure).	Maquet Servo S offers a variety of modes of ventilation, including pressure control, volume control, and SIMV (synchronized intermittent mandatory ventilation).
Settings	BiPAP allows users to adjust the pressure settings for CPAP and BiPAP.	Maquet Servo S allows users to adjust a wide range of settings, including pressure, volume, respiratory rate, and inspiratory and expiratory times.
Monitoring	BiPAP does not offer any built-in monitoring features.	Maquet Servo S offers a variety of built-in monitoring features, including respiratory rate, tidal volume, and peak inspiratory pressure.
Cost	BiPAP is typically less expensive than Maquet Servo S.	Maquet Servo S is a more expensive device than BiPAP.