A TUTORIAL ON PURE TONE AUDIOMETRY

(REGISTER NO. M 2K08)

An Independent project submitted in part fulfillment of the First year M.Sc (Speech and Hearing), University of Mysore, Mysore

ALL INDIA INSTITUTE OF SPEECH AND HEARING
MANASAGAXGOTHRI. MYSORE - 570006

MAY 2001

To,

Mamma, Dada

& Naanu………..

With all my love

Certificate

This is to certify that the Independent project entitled *"A Tutorial On Pure Tone Audiometry* " is the bonafide work done in part fulfillment of the degree of Master of Science (Speech and Hearing) of the student (Register No. M2K08).

Mysore
May 2001

Director
All India Institute of
Speech & Hearing
Mysore - 570006.

Certificate

This is to certify that the Independent project entitled *"A Tutorial On Pure Tone Audiometry"* has been prepared under my supervision and guidance. It is also certified that this has not been submitted earlier in any other University for the award of any Diploma or Degree.

Guide

Mr. Animesh Barman
Lecturer in Audiology
Department of Audiology
All India Institute of
Speech & Hearing
Mysore-570006.

Mysore
May 2001

Declaration

I hereby declare that this Independent project entitled *"A Tutorial On Pure Tone Audiometry"* is the result of my own study under the guidance of Mr. Animesh Barman, Lecturer in audiology, Department of audiology, All India Institute of Speech and Hearing, Mysore and has not been submitted earlier or in any other University for the award of any Diploma or Degree.

Mysore

May 2001 Register No. M 2K08

ACKNOWLEDGEMENTS

*My heartfelt thanks to **Mr. Animesh Barman,** Lecturer, Department of Audilogy, AIISH, Mysore, Sir, for being my guide, for always keeping my spirits up.... Words cannot truly express the gratitude I feel.*

*I would like to acknowledge and thank **Dr. M. Jayaram,** Director, AIISH, Mysore, for permitting me to undertake this project.*

*Sincere thanks to **Mr. Balasubramanyam** and **Ms. Sudha,** for your patience and dedication in helping to shape my work.*

*Dear **Rajalakshmi Ma'am** and **Yeshodha Ma'am,** - Your cheerful words of encouragement have never ceased to lift me up. For all that and so much more, thank you.*

*Thanks to all the **Library Staff** and the **Xerox Staff** for patiently bearing with all my "disobedient" and whacky ways.*

***Mr.Joby, Mr. Sameer, and Mr. Gopi,** for your support, your help and your best wishes, thank you.*

For never loosing faith in me for loving me the way I am. . . . .Thanking you would be an insult, so, ***Mamma and Dada,*** *I'll just say I love you .... instead.*

Dearest ***Naanu,*** *Nothing in this world compares to you. Wish you were here. . . . .Miss you.*

My very dearest ***Ammachie,*** *all my* ***uncles, aunts and cousins,*** *for all the support, love and affection - Thanks. . . . . .you make me believe that family and magic are synonymous.*

For you ***Uncle Percy,*** *I have no words. . . . . . . .will it suffice if I said you will always be my sweet heart. Thanks*

Tangu and Dodie*. . . . .for always pushing me and bringing sunshine my way. . . . . . . .oops ! and for tolerating my P.J's. . . . .No thanks.... its your privilege.*

For being there wheti I needed help the most. Thanks ***Rohini, Divya and Bhuva.***

Shivakami, Srivathsan, Prarthana, Sarah and all my B.Sc. classmates. *You're never far from my thoughts.*

Geeks, Bhumsie, Samamma, C-thu, Nega *- God really loves me ... that's why he sent you my way .... and I thank him for that.*

My ***guardian angels - Anju and Hia,*** *No one can take you place.......not now .... not never.....Watch over me always.*

Anjana, Puru, Deepa, Shereen, *-1 can be "Mommy" again and again and again_only if you'd be my daughters again and again and again ..... Thanks.*

Adirasam... *.....for the momentous memories we made together - Cheers ! "Lets grow old together" - Sounds familiar ?*

Mathew, Mukesh and Pressi dorling *- You guys brighten up my life just by being there - Thanks for all the fun, laughter and affection you shower on me.*

In the huge mysteries of time and space, I feel your hand in mine and am not afraid. For always being there for me, for walking beside me and for being my friend, Thanks ***Granpa Spice*** *with all my heart.*

J, M, P. For keeping me sane in those last maddening days I am for ever grateful........Hope you will be there next year too.

TABLE OF CONTENTS

LIST OF GRAPHS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The word "tutorial" as defined by scientific & english dictionaries refers to an "instruction book" or intensive instruction in some area". It aims at providing supplementary instruction in order to present better opportunities to students and concerned professionals to actively participate in the learning process and receive feedback. The information is carefully selected and organised in a standard manner. It also evaluates the user's knowledge through different types of questions which gives him/ her immediate feedback of the performance. It thus acts as an efficient guide for students and experts linked with the particular field.

An attempt has been made to construct a tutorial in pure tone audiometry

Among the great number of tests employed in the field of audiology, 'Pure tone Audiometry', is one of the most basic standard behavioural procedure for describing auditory sensitivity. 'Pure tone Audiometry' is used to determine if hearing loss is present or not. If present, the degree/ severity of hearing loss, the type of hearing loss and also the configuration of hearing loss including symmetry of the hearing loss or lack of it.

The concept of, 'pure tone Audiometry' has been cited in the late 19^{th} century in the more rudimentary form, by Arthur Hartman, who used a telephone receiver for the purpose of testing hearing. Following this, in 1972, Fowler and Wegel invented the 1^{st} commercially available vacuum tube audiometer, the Western Electric 1A Audiometer. This was followed by the rapid progress of pure tone audiometric techniques, procedures and instruments in quick succession.

Pure tone Audiometry specifies how well a range of frequencies are transmitted through the entire peripheral auditory system; outer ear, middle ear and inner ear. It also helps in identifying higher level pathologies. It includes two major procedures - Air conduction testing and Bone conduction testing.

Air conduction testing is done with headphones in a sound treated room with properly a calibrated audiometer. Bone conduction testing is done with a bone oscillator / vibrator which is placed on the mastoid process of the temporal bone (behind the pinna). The results of the test are recorded on an audiogram, which is a visual representation of a person's hearing capabilities i.e., the hearing thresholds as a function of frequency.

The application of pure tone audiometry is not limited to this alone. These procedures have been applied to all age groups of people for both screening and diagnostic purposes. It is of importance with regard to the procedure of selection of hearing aids and management. It is a helpful tool in the diagnosis of psychogenic deafness.

This procedure is now common not only in audiology clinics, but also, in ENT centers and other diagnostic units. In the present century when great importance is being given to early identification and intervention, this procedure helps in identifying reduced hearing sensitivity through the school screening programs.

From the above discussion it is clear that how important it is for students and professionals in this field to know about these measurement procedures in depth. The present tutorial has been developed keeping this in mind. The main topic Pure tone audiometry has been divided in to many more topics and subtopics in a simple and precise form. The main source of information has been collected from books, journals and other sources.

Each chapter will be followed by a set of questions of the following type :

- Fill in the blanks
- Multiple choice
- True or false
- Word grids
- Cross words
- Short answers
- Audiogram interpretation

The questions are neither too complex nor too simple. They provide the user with an opportunity to test the knowledge that he or she has gained through the tutorial. In order to cross check the results there are answers provided to all questions at the end of each section to give an immediate feedback of ones' performance.

Thus, this particular independent project has been developed to serve the following purposes:

1. Give intensive information about pure tone audiometry and its applications.
2. To test ones' knowledge of the topic.
3. To serve as a guide for students and other concerned professionals.
4. To train and evaluate trainees during a training program.

HISTORICAL ASPECTS

Historically considerable work has been devoted to the development of methodology for the clinical evaluation of human hearing. Much effort and attention were given to the establishment of tests intended to assess the type and to quantify the amount of hearing loss.

Although true diagnostic differentiation through various audiometric measures did have its beginning about half a century ago, attempts to test the power of hearing by using of instrumentation were made much earlier in the 1870's.

THE WHISPER TEST:

This was one of the earliest tests of hearing to determine whether the patient had normal hearing. The examiner used either spoken voice or whispered voice at a specified distance from the patient and determined whether the patient responded appropriately or not.

Disadvantages:

(i) Whispers have been measured from 20dB to 65dB SPL at 3 feet distance, depending on the talker,

(ii) It is not possible to determine which ear is responding to the whisper / spoken voice,

(iii) Frequency composition of the whisper was concentrated in the lower frequency region,

(iv) With increased advancement in technology, it became more important to determine extent of hearing loss and to differentiate site of possible pathology (ie EE/ME/IE).

THE WATCH-TICK & COIN CLICK TESTS

These were also some of the earlier tests administered to assess hearing. The physician holds his watch next to the patient's ear and asks the patient to inform him when he ceases to hear the tick, as the doctor moves the watch away. Hearing loss is expressed in terms of a fraction, of which, the distance in inches that the patient can hear the watch tick is the numerator and the distance the normal ear can hear the watch tick is the denominator.

Disadvantages:

(i) To administer such a test to a patient with any amount of hearing loss, the physician must posses a fairly noisy watch,

(ii) The information is obtained in a crude way.

The coin click test consists of the physicians' dropping a large coin, on a hard surface. The patient is instructed to report whether he hears the coin "ring" or only a dull thud. Hearing the coin "ring" indicates that the high frequency hearing acuity is normal, while, if he hears a thud he is presumed to have high-frequency hearing loss.

The disadvantages of this test were:

(i) It yields no information as to which frequencies are affected or the extent of loss,

(ii) It cannot be used successfully in monaural testing.

THE TUNING FORK TESTS

Reports concerning the use of tuning forks to test hearing appeared in the 19 century. Weber described the reference or lateralisation of response to the poorer ear with a tuning fork applied to the skull of the patient with unilateral conductive deafness. Later Rinne reported on comparisons of bone conduction (BC) and air conduction (AC) tuning fork responses to differentiate conductive from sensorineural (SN) deafness. Finally Schwabach related the results of comparing the length of time that a hearing impaired patient heard an activated tuning fork placed on the skull to the response time of those patients with normal hearing. These tuning fork tests serve as the foundation for basic audiological tests in their assessment of the air conduction and the bone conduction response, the comparison of these two responses, and the consideration of a given response to "normal".

1875-1914 THE TUNING-FORK AUDIOMETER

The credit for the development of the audiometer like many other scientific advancements, cannot be awarded to any one man of genius. In 1875, Clarence J Blake along with Politzer reported certain physiological investigations on hearing, which were vital to the development of the telephone. Later in 1878 by January, Arthur Hartman devised the "acoumeter" (German word : Hormesser) which utilized a telephone receiver for the purpose of testing hearing. Puretones were selected by placing a tuning fork in the primary circuit of an induction coil, interrupting the circuit at regular intervals. There were several variations that followed in the next 35 years but they were never in general clinical use by otologists.

In 1879, D.E. Hughes in England described an "Induction balance" originally used to analyze metals, but applied with a tuning fork to the testing of hearing. He called this instrument an "electric sonometer".

Other version of the "induction coil" audiometer using either tuning forks or a buzzer as a sound sources were Jacobson's audiometer (1885) and Cheval's audiometer (1890).

Seashore (1899) developed an audiometer, which represented an important advancement over earlier types in that he used a series of coils to provide inductance steps that increased the loudness in the receiver, according to the Weber-Fechner law.

The general disadvantages of these instruments were as follows:

(i) Early instruments were bulky and difficult to keep in running order.

(ii) They were limited in their diagnostic scope : only tuning forks with a frequency of 1000 c/s or less could be used effectively,

(iii) The output intensity had no psychophysical referent.

(iv) It told nothing about the hearing for speech and was therefore limited in diagnostic value.

1914-1919 - THE ELECTRIC GENERATOR

In 1914, AStefanini of Italy constructed an instrument ,which made the modern audiometer possible. It was an electric generator producing an alternating current with a complete range of frequencies. However, it was never applied clinically.

On the basis of Stefanini and his principles Lee W Dean and Cordia C Bunch applied the electric generator to the first clinically useful "Pitch range audiometer" in 1919. It was so called because it produced all the tones between 30 and 10,000 c/s. The intensity of tones could be varied from below threshold of audibility upto threshold of pain. However, it was never available commercially.

Schwartz in 1920, introduced the "otaudian" an electrical audiometer which had a series of controls for selecting the desired frequency and intensity along with a loud speaker arrangement.

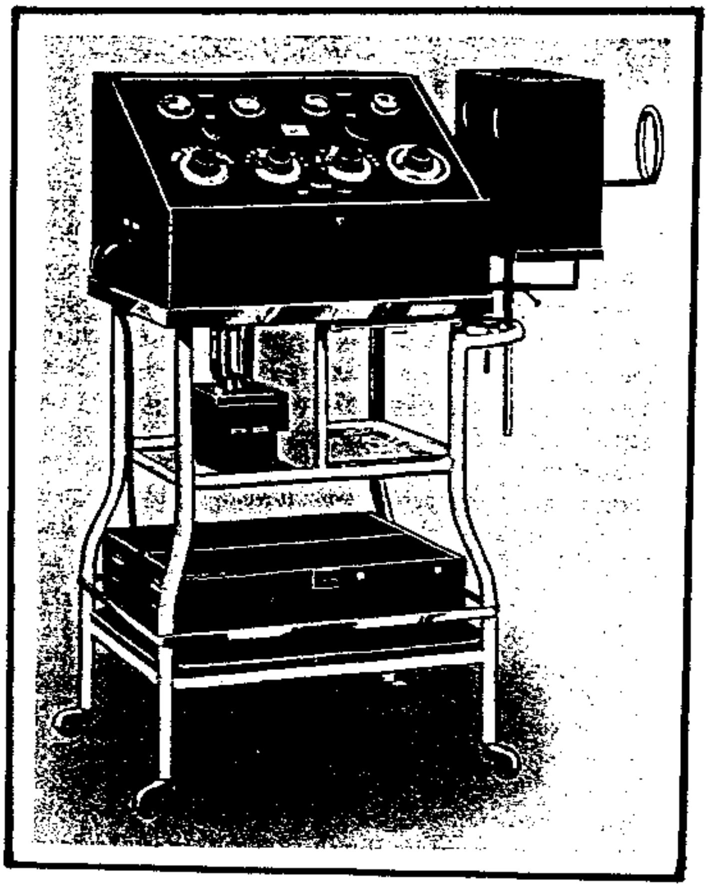


Figure 1 : The Otaudian (Schwartz 1920)

The advantages of these tests were:

1. They tested a wide range of frequencies.
2. There were controls which were specified.

The disadvantages of these instruments were:

1. They were not available commercially.

1921-1940 - THE VACUUM TUBE AUDIOMETER

After Dean and Bunch's contribution, it remained only for the application of the vacuum tube to make audiometers commercially feasible. The instrument hereafter utilized vacuum tubes to obtain oscillating electric currents of almost any desirable frequency.

The first commercial clinical audiometer was presented in 1922 by otologist Fowler and physicist Wegel, the Western Electric 1A, it generated 20 octave and semioctave frequencies from 32 through 16, 384 c/s and had a logarithmic attenuator, they also described charts called "audiograms" for plotting hearing sensitivity relative to a straight line for "normal hearing". The Western Electric 1A Audiometer was not widely used because of its prohibitive price of $ 1500.

The Western Electric 2A soon succeeded the 1A. Unlike the 1A which produced a sweep frequency output from 32 to 8192 c/s, the 2A presented only the octave frequencies from 64 to 8192 c/s. A further model, the 3A, used complex noise stimulus but never found favor among otologists.

The use of a bone-conduction receiver in connection with a pure-tone audiometer was reported by Jones and Knudsen (1924). Their "audioamplifier" used not only air conduction and bone conduction but also a speech circuit. Jones and Knudsen's audioamplifier was later modified and produced by the Sonotone corporation as the Sonotone Jones-Knudsen Model 1 Audiometer.

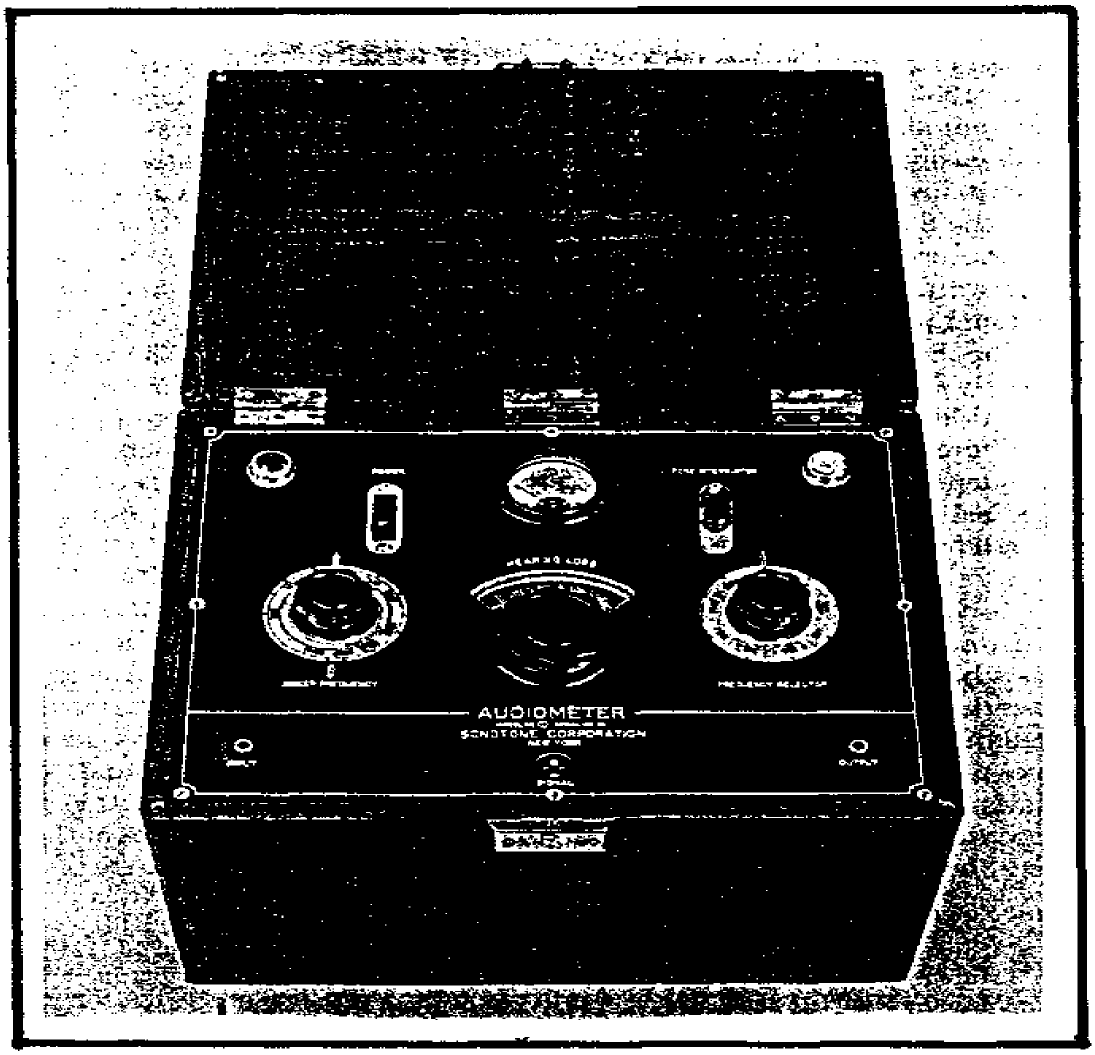


Figure 2: Sonotone Jones-Knudsen Model 1

The advantages were:

1. The introduction of the group audiometer.
2. These instruments were commercially available.
3. They provided more facilities & controls.
4. Speech audiometry was introduced.
5. It created a pathway for the diagnostic audiometer.

1940 ONWARDS

By the middle of the 20th century, audiometric testing included the use of both pure tones and speech. Towards the 1940's audiometers began to be available commercially. These advancements have been largely in the way of refinements of general principles and in the use of circuitry for test variations. In addition, transistors are currently replacing vacuum tubes in many instruments.

In 1947, Nobel Prize winner, Dr. Georg Von Bekesy introduced the automatic self-recording audiometer, in which the tone fluctuates around the threshold under the subject's control.

In 1950, German otologist B. Langenbeck used filtered bands of noise in experiments with noise audiometry.

QUESTIONS

I. Solve the word grid to find the names of 10 tests and instruments that have contributed to the history of pure tone audiometry.

Note : You may move in any direction

R	E	T	E	M	0	N	0	S	C	I	R	T	C	E	L	E
P	L	S	R	0	I	S	U	Q	W	Y	A	R	0	R	Z	R
K	E	A	Q	T	C	L	I	F	T	E	R	0	E	0	I	E
J	C	N	T	E	O	Z	I	B	A	N	G	T	R	W	M	T
T	T	T	W	H	I	S	P	E	R i	S	E	A	P	P	M	E
R	R	R	P	R	N	R	I	T	N	M	A	U	Q	I	E	M
G	I	0	S	B	C	T	0	S	U	Q	C	D	S	T	R	D
M	C	1	N	C	L	O	0	0	S	p	A	I	T	N	F	I
K	G	T	T	B	I	I	C	0	P	I	T	A	Z	A	F	D
T	E	E	A	D	C	A	A	P	R	Q	P	N	0	N	I	U
E	N	N	A	C	K	R	0	F	G	N	I	N	u	T	N	A
S	E	A	R	U	I	C	I	T	A	C	P	M	Z	I	I	E
L	R	C	U	L	F	G	H	L	T	R	U	T	p	0	T	B
0	A	U	D	I	0	A	M	P	L	I	F	I	E	R	A	V
M	T	P	L	R	E	T	E	M	0	R	A	G	A	I	E	T
N	0	O	C	R	E	A	T	I	C	A	C	E	M	T	Q	M
U	R	E	T	E	M	O	I	D	U	A	A	I	E	W	I	A
R	F	A	T	P	I	T	U	M	0	N	T	E	S	A	p	C
E	S	A	M	I	I	T	E	R	F	E	A	T	T	0	E	C
T	I	M	0	I	H	Y	Z	P	E	C	Z	O	K	I	T	E
A	M	F	E	A	R	F	E	L	0	K	I	T	E	N	A	V

II. Write in one sentence the contributions of the following persons:

(i) Bekesy:

(ii) Jones and Knudsen

(iii) Fowler and Wegel

(iv) Stefanini

(v) Arthur Hartman

III. Match the Following

[i] Whisper	[a] Air conduction versus bone conduction
[ii] Weber	[b] DE Hughes
[iii] Fowler and Wegel	[c]64c/s to 8192c/s
[iv] Electric sonometer	[d] Low frequency
[v] Pitch range audiometer	[e] Hormesser
[vi] Western electric 2A	[fj Lateralization
[vii] Rinne	[g] Otaudian
[viii] Acoumeter	[h] Jones and Knudsen
[ix] Schwartz	[i] Dean and Bunch
[x] Audioamplifier	[j] Audiogram
	[k]32c/sto8192c/s

IV. Who am I ?

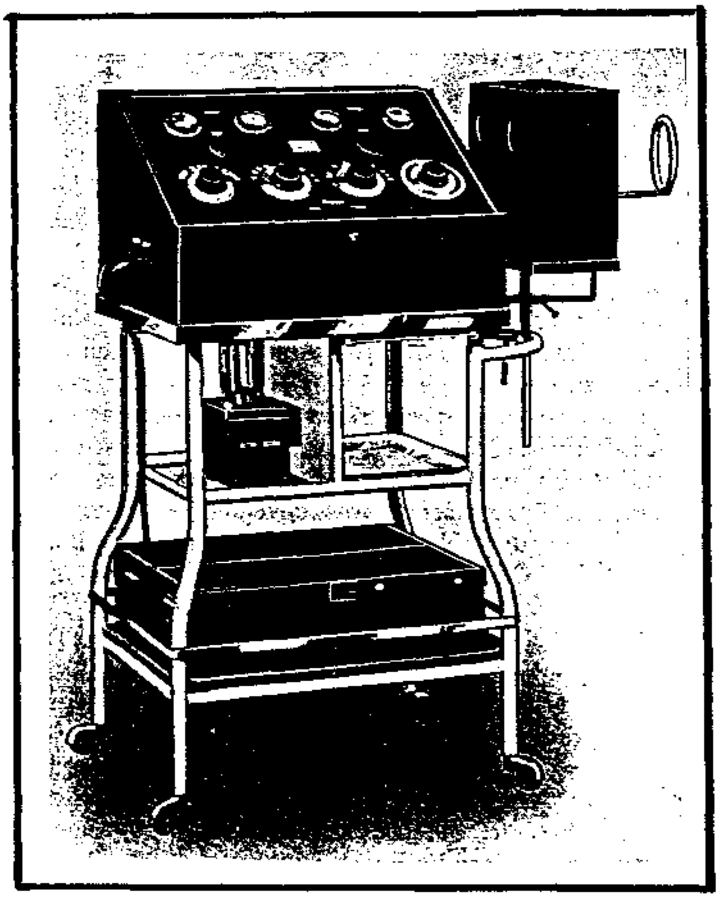
[i]. I was born in 1978 and Arthur Hartman made me.

[ii]. I work when an induction balance is applied with a tuning fork

[iii]. I was devised in 1919 and I can produce all tones between 30 & 10000 c/s

[iv] I was a modification of the audioamplifier.

[v] I was the first commercial audiometer and I was marketed in 1922.



[vi] I was born in 1920. Who am I ?

BASIC CONCEPTS RELATING TO PURE TONE AUDIOMETRY

INTRODUCTION

To understand the procedure of hearing evaluation by air conduction and bone conduction pure tone audiometry, it is first important to understand the basic concept related to it like the simple harmonic motion, the sine wave and its components like frequency, amplitude etc.

The following chapter throws light on some of these basic concepts:

SIMPLE HARMONIC MOTION

It may be defined as a symmetrical to and fro motion of a body over a rest position.

We know that vibration occurs when a body is disturbed by an external force so that it moves in a to and fro manner around its original point of rest. For this to take place the body must possess two important physical properties.

1. The property of elasticity :

This is the restoring force or the ability of the material to assume its original position once the force has been removed. Therefore, greater the elasticity, the greater the ability of the body to get back to its original shape.

2. The property of inertia :

V~ This is the tendency of a body to remain in motion once it is set in motion, or for the body to remain at rest if undisturbed i.e. The ability of a body to continue doing what it has been doing.

This elasticity and inertia interact with each other during the process of vibration.

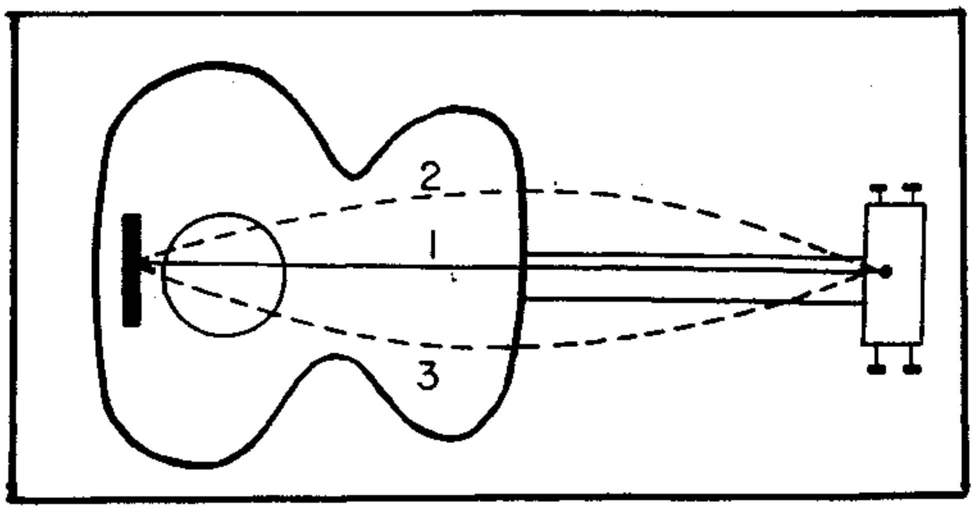


Figure 3 : A one-stringed guitar depicting interaction of elasticity and inertia.

Consider a one-stringed Guitar, if we do not touch the string, it will remain at its rest position (position 1) or in its equilibrium state. If we move the string to position 2 and release it the vibration process begins initially because of high elasticity it is displaced from its rest position. The restoring force causes the string to move back. Once the rest position is reached, the inertia is high and this causes the string to move through its equilibrium point and in the opposite direction. As the string moves away from the rest position, elasticity once again increases until its force exceeds the inertia at position 3; when this occurs the string will travel back towards the rest position again.

The most important point to be made here is that inertia and elasticity act opposite to each other in the process of vibration i.e. when inertia is high, elasticity is low and vice versa.

Although, vibration consists of back and forth motion, the manner in which this motion occurs over time may differ, it may be periodic or aperiodic. The motion of the guitar string is periodic, in that, the string moves over and over again in the same way and it takes the same time to complete each successive to and fro movement i.e. SHM. The most basic features of simple harmonic motion can be understood by the motion of a pendulum.

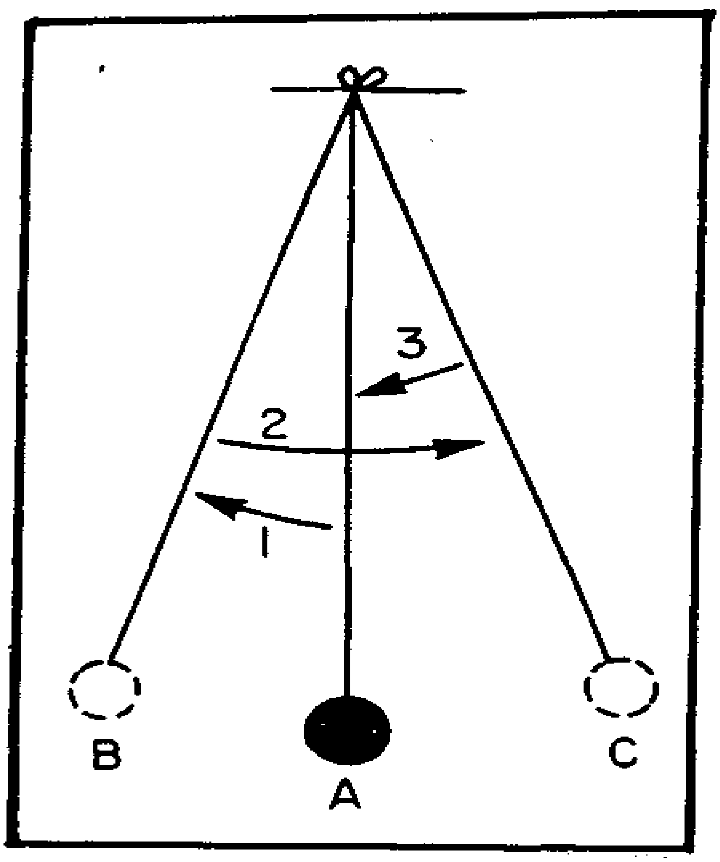


Figure 4 : It depicts the motion of a pendulum when set in motion.

The figure shows a pendulum. Once the pendulum is set in motion, the weight will swing back and forth in a repeatable manner, always taking the same time to complete one cycle. That is for the pendulum to move from A to B to A and then C and back to A in order to complete one cycle. The time it takes to complete one cycle remains unchanged as long as the pendulum remains in motion.

PURE-TONES

If the motion of the pendulum is graphed over time, we may be able to observe a graphical representation of a simple harmonic morion. Imagine that the ball of the pendulum will somehow leave a trail as it swings in its upward journey, the resulting pattern is a sine wave.

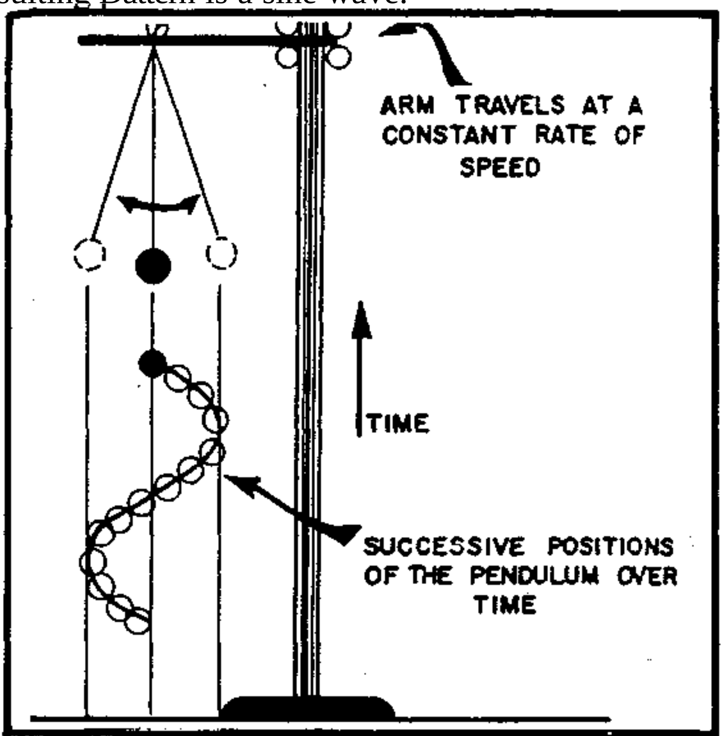


Figure 5 : A sine wave formed by the motion of a pendulum.

When a sinusoidal wave oscillates showing only one frequency of vibration with no tones superimposed on it, it is said to be a pure tone. The number of complete sine waves that occur within one second constitute the frequency of that wave. These pure tones have a definite tonal quality and can be represented in the horizontal plane as shown below.

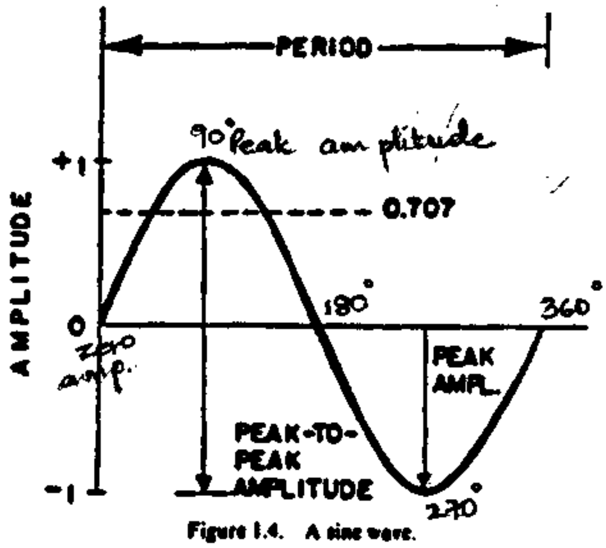


Figure 6 : A sine wave

These pure tones are extremely important in testing the hearing mechanism. They may be produced mechanically using tuning forks or they may be electronically generated. Sound is generated by vibration and is carried out through the air around us in the form of waves. It may be defined in terms of either psychological or physical phenomenon. In the psychological sense, sound is an auditory experience i.e., the act of hearing something. In the physical sense, sound is a series of disturbances of molecules within an elastic medium. Sound has 3 dimensions; frequency intensity and time, easily recalled by the acronym "FIT".

Frequency:

Frequency refers to the number of cyclic repetitions per second expressed as "cycle per second" (cps) or "Hertz" (Hz). Frequency is a physical unit and frequency information can be extracted from pure tones and from complex stimuli. The audible range of frequency for the human ear is from 20 Hz to 20,000 Hz.. Frequency is a physical entity. However frequency can also be expressed psychologically as pitch. Frequency is related to pitch but is not the same as pitch. Pitch is a perception that requires human observation. Therefore it can be considered as the psychological correlate of frequency, such that high frequency tones are heard as "high" pitched and low frequency tones are heard as "low" pitched. Pitch is measured in units called "mel".

There are many factors which may affect the frequency. They are :

1. Length

The length and frequency are inversely proportional i.e. As length decreases, frequency increases. Conversely as length decreases, frequency increases.

For example: Consider or imagine the swinging of an object suspended at the end of a string moving slowly back and forth. If the length of the string were suddenly shortened by holding it closer to the weight, the number of swings per second would increase causing the weight to swing back and forth more frequently.

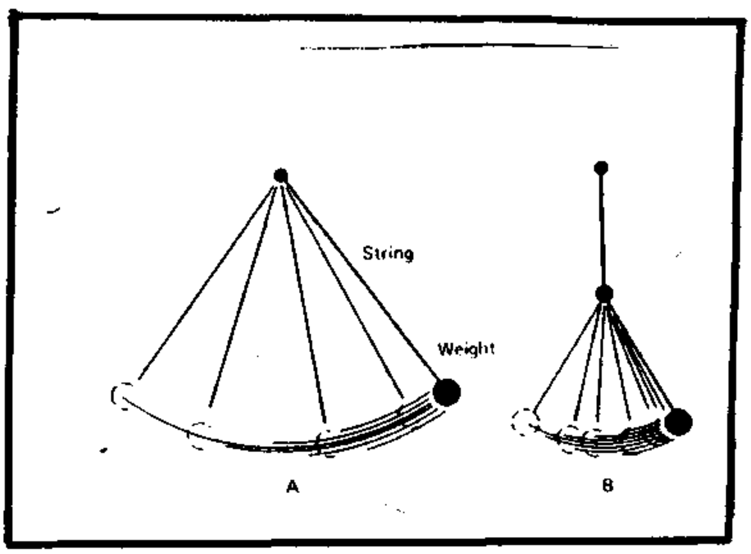


Figure 7 : Effect of length of a pendulum on frequency of vibration.

2. Mass

The mass of an oscillating system and frequency are inversely proportional i.e. As the mass is increased, the frequency of vibration is decreased. This is because the kinetic energy must be kept constant. Therefore greater the mass of an oscillating system there results a decrease in velocity.

3. Stiffness

As a body vibrates, it exhibits a certain amount of compliance which is the reciprocal of stiffness. As this compliance increases, the frequency at which the body is most easily made to vibrate i.e., the resonant frequency, decreases. Therefore systems that are stiffer and have more elasticity vibrate better at higher frequencies than at lower frequencies.

Intensity

The intensity of a sound refers to its physical magnitude, which may be expressed in such terms as its power or pressure. It represents the physical energy generated by a signal. The unit of measurement most commonly used is the decibel (dB). The psychological correlate associated with intensity is loudness. Generally speaking low intensities are perceived as "soft" and high intensities are perceived as "loud". However, there is not a simple one-to-one correspondence between the two. For example, one can find that loudness changes when "bass" and "treble" controls of a stereo amplifier are adjusted, even though the volume control itself is untouched. Loudness is measured in terms of "phons" and "sones".

The human ear is remarkable both in terms of its absolute sensitivity and in terms of the range of intensities to which it can respond. The loudest sound we can hear without damaging our ears is a level of about 120 dB above the faintest sound we can detect. This corresponds to a ratio of powers of 1000 000 000 000: 1.

Some of the factors that affect intensity are:

1. Energy

Energy and intensity are directly proportional. Greater the energy of a stimulus higher is the intensity.

3. Distance

Distance and intensity are inversely proportional .The relationship is given by the inverse square law ,where by, for every doubling of the distance the intensity decreases by half.

Intensity can be measured in terms of power and in terms of pressure.

The number of decibels (dB) for sound pressure values may be calculated using the formula

$$N_{dB} = 20 \log \left(\frac{Po}{PR}\right)$$

Where P_o = Sound pressure that is being measured

P_R = Recognised reference point which in terms of pressure is 0.0002 dynes / cm^2

In terms of power, it may be calculated using the formula

$$N_{dB} = 10 \log \left(\frac{Io}{IR}\right)$$

Where I_o = Sound intensity that is being measured

IR = Recognised reference point which in terms of power is $10"^{16}$watts/cm^2

Hearing Level

The lowest sound intensity that stimulates normal hearing has been varyingly called zero hearing loss and zero hearing level (HL). The human ear shows different amounts of sensitivity to different frequencies (being most sensitive in the 1000 to 4000 Hz range). Different amounts of pressure are required for zero HL at different frequencies. The pressure reference for decibels on an audiometer calibrated to ASA - 1951 specifications was therefore different at each frequency, but the hearing level dial was calibrated with reference to normal hearing called the "Audiometric zero".

Sensation Level

Another reference for the decibel may be to the auditory threshold of a given individual. It refers to the number of decibels of a sound above the threshold of a given individual is that number of decibels "sensation level"

Time

Temporal aspects of sound include duration, rise and fall time, phase, repetition rate and sequences of stimuli. Each temporal dimension interacts with frequency and intensity to generate unique and complex sound sensations.

Questions

I. State whether true or false

(i) When a sinusoidal wave oscillates showing only one frequency of vibration with no tones superimposed in it, it is said to be a pure-tone.

(ii) The unit of frequency is Hz / second

(iii) Pitch is the physical correlate of frequency.

(iv) The property of elasticity is also called the resonating force.

(v) In the process of vibration inertia and elasticity act opposite to each other.

II. Choose the right one

(i) Simple harmonic motion is a

(a) Sine wave

(b) Complex wave

(c) Saw tooth wave

(d) Square wave

(ii) The decibel, which is a unit of intensity, is denoted as

(a) dB

(b) DB

(c) Db

(d) db

(iii) The number of decibels in terms of sound pressure is given by

(a) $20 \log \left(\frac{Io}{IR}\right)$

(b) $10 \log \left(\frac{Po}{PR}\right)$

(c) $10 \log(\frac{Io}{IR})$

(d) $20 \log(\frac{Po}{PR})$

(iv) The threshold for my right ear is 20 dBHL. 10 dB SL with respect to my threshold is

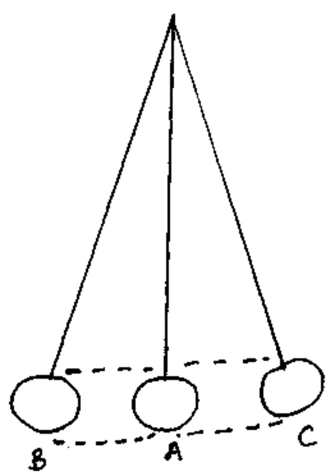
(a) 30 dBSPL

(b) 10 dBHL

(c) 30 dBHL %

(d) 25 dBSPL

(v) Look at the given figure and find out one complete cycle is represented by



(a) A-B-C

(b) A-B-A-C

(c) A-B-A-C-A

(d) A-B-A-C-A-B

(vi). If I am human what is my range of audible frequency

(a) 20 Hz-200 Hz
(b) 20 Hz - 20,000 Hz
(c) 20 Hz - 2000 Hz
(d) 20 Hz-200, 000 Hz

III. Fill in the blanks

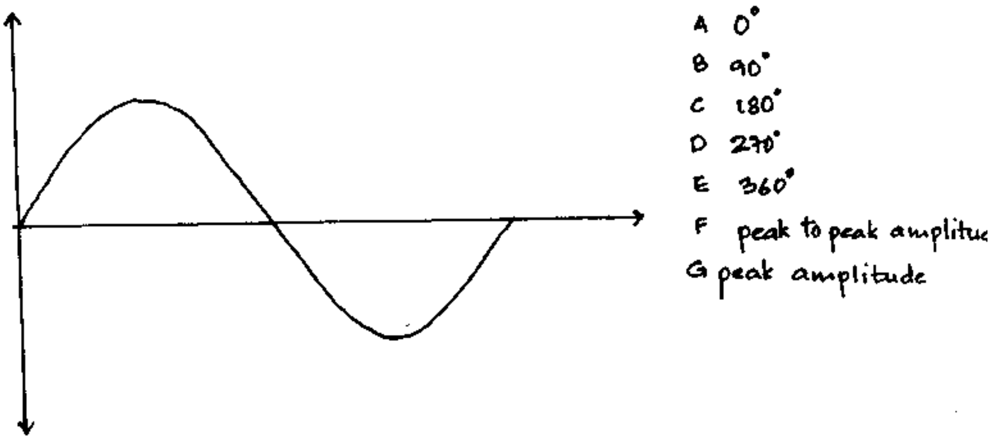
(i) For a body to be set into motion it must possess the property of———— &————————

(ii)——————————is the psychological correlate of intensity

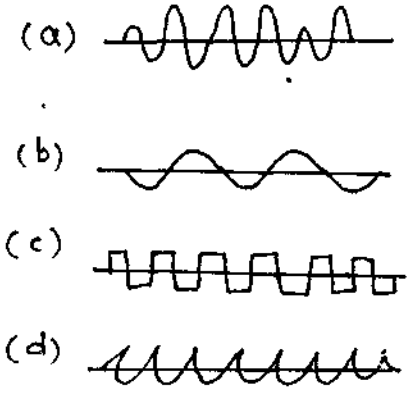
(iii) Length is————————proportional to frequency ; and mass is—————————proportional to it.

IV. Fun with figures

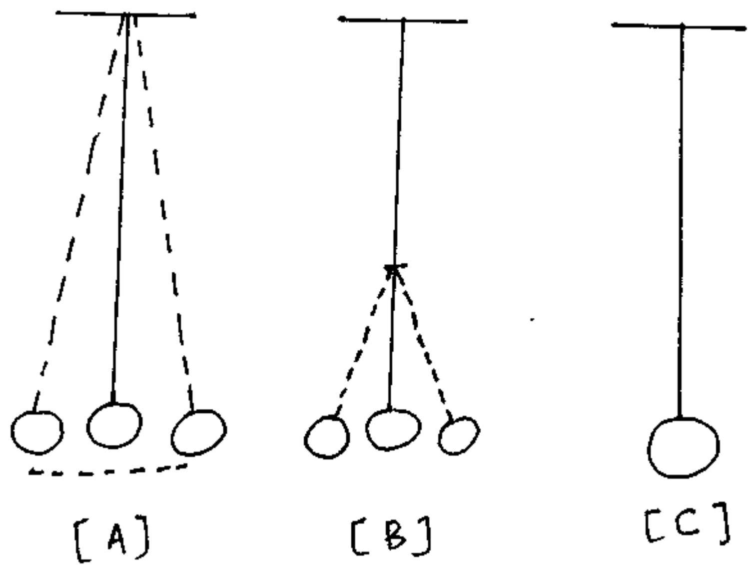
(i) I am a sine wave. Can you mark the different points with respect to phase on me.



(ii) Identify me. I am a sine wave.



(iii)



(A) I am a pendulum in vibration

(B) What would happen to my frequency if I were shortened

(C) What would happen to my frequency if I were heavier

V. Unscramble the words and find them in the maze

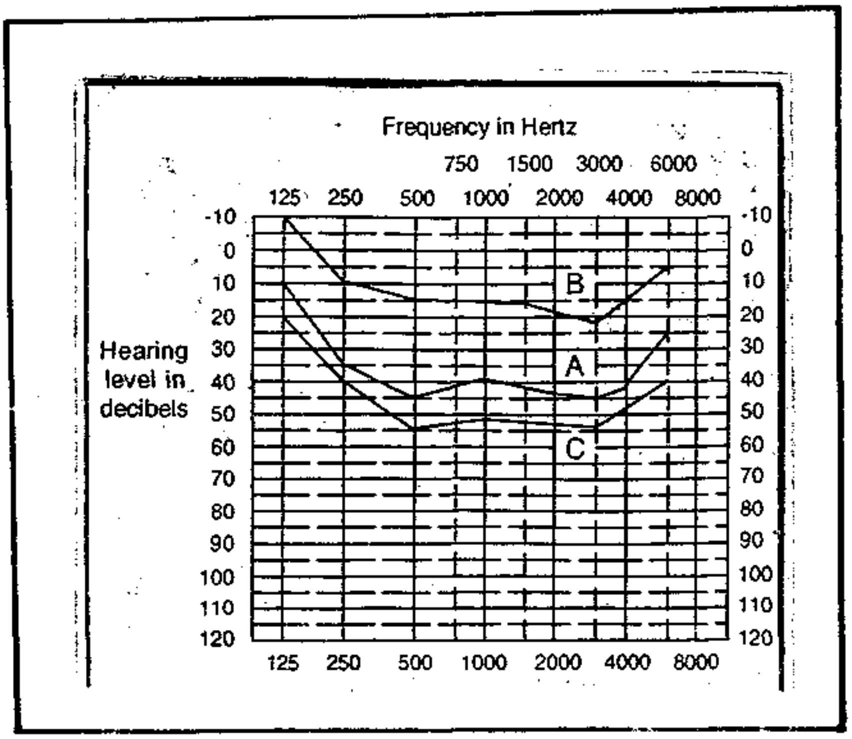
1. ycquerenf
2. riynients
3. lediceb
4. lme
5. chipt
6. snedsulo
7. eponerut

E	P	L	L1	E	M	D	T	I	I	I	L
L	0	F	0	T	E	R	S	A	M	E	R
U	J	R	F	E	T	R	Q	P	B	0	L
S	S	E	N	D	U	0	L	I	L	I	A
A	p	Q	A	T	M	0	C	E	I	Y	T
E	Q	U	E	I	A	E	P	N	M	Z	0
A	A	E	0	C	D	I	L	0	E	P	M
I	I	N	T	E	N	S	I	T	Y	0	R
T	Z	C	T	E	P	0	L	E	S	E	E
0	R	Y	A	M	E	T	I	R	T	0	T
0	N	E	0	T	I	Q	0	U	T	A	S
N	A	L	I	H	C	T	I	P	M	0	P

PURE TONE AIR AND BONE CONDUCTION TESTING

RATIONALE USED FOR THE FREQUENCY RANGE OF PURE-TONES USED IN PURE-TONE AUDIOMETRY

The range of frequencies for air conduction testing is generally 250-8000Hz while that for bone conduction testing is 250-4000Hz. Any sound, however complex can be shown to be a combination of pure-tones, including speech. The overall intensity level of conversational speech is approximately 65-70 dB SPL. Pascoe (1978) determined the sensation level with respect to the minimum sound pressure level for audibility of the speech stimulus at the 3 rd octave bands centered at 125;250,1000,2000,4000, & 8000 Hz. The study was done on normal-hearing listeners, so the sensation level can be considered equivalent to hearing level.



Graph 1 : Speech spectrum on an audiogram format.

As can be seen from figure, the hearing level for speech at each frequency when the speech has an overall level of 65 dB SPL is approximately 20 dB at 125 Hz, 40 dB at 250 Hz, 55dB at 500 Hz, 52dB at 1000 Hz, 55dB at 2000 Hz, 50 dB at 4000 Hz & 40dB at 8000 Hz.

Audibility of the entire speech range is not essential for good speech-recognition ability in quiet. However, normal-hearing listeners would have to utilize high frequency sensitivity in noisy situations when low frequency hearing is masked by the noise. Persons with high frequency hearing loss on the other hand cannot efficiently utilize their high frequency hearing in noisy situations (Hirsh et al, 1954). In a study by Skinner & Miller, (1983) highest speech recognition score was obtained with the widest bandwidth (266-6000 Hz). Thus, frequencies above 4000 Hz are important for hearing-impaired listeners in quiet & noise as well as for normal hearing listeners in noisy situations.

- Another rationale for testing 250 Hz &500 Hz is the detection of many conductive pathologies yielding a stiffness-loaded middle ear or outer-ear system as in the case of otosclerosis & otitis media.
- Testing 4000 & 8000 Hz is to assist in differentiating between noise induced & other high frequency sensory neural hearing losses.
- Also, these tests are often used in suggesting site of lesion or general anatomic location of the pathogenic condition.

Thus although people are seldom called upon to listen to pure tones it is" reasonable to use such stimuli to test hearing.

AIR CONDUCTION MEASUREMENT

The air conduction route i.e., the AC route comprises of the outer ear, the middle ear & the inner ear. The total auditory system, including the conductive portion & the sensory neural portion (i.e., the outer & middle ear, the cochlea & eighth cranial nerve respectively) are involved in air conduction testing. The stimuli for this test are delivered through earphones or insert receivers or in sound field through speakers.

Purpose of Air Conduction Testing:

(1) To determine the type of hearing loss present by comparison of the air & bone conduction thresholds

(2) To determine the magnitude of hearing loss

(3) To detect the presence of functional hearing loss by comparison of the pure-tone average with the speech-recognition threshold.

(4) To monitor the effectiveness of medical intervention by comparing pre & post treatment AC thresholds.

(5) To predict auditory handicap & phoneme-recognition ability.

(6) To assess the need for & the benefit from amplification.

BONE CONDUCTION MEASUREMENT

Bone-conduction threshold measurement is an integral part of basic audiological evaluation. In bone-conduction testing an oscilator or vibrator is positioned on the masteoid process of the temporal bone or on the middle of the forehead. Electrical energy is delivered to the oscillator to drive it into vibration against the skull thereby causing the skull bones to vibrate. The vibrational energy is transmitted directly to the cochlea, bypassing the outer and middle ear, which make up the conductive portion of the auditory system. The bone conduction threshold assesses the integrity of the cochlea & eighth cranial nerve, which represent the sensory neural portion of the auditory pathway.

Bone conduction hearing from airborne sound does not occur until the intensity of the sound exceeds the air-conduction threshold by at least 60 dB (Dirks, 1985)

The purpose of bone conduction testing is:

(1) To determine the type of hearing loss present by comparison of the air & bone conduction thresholds.

(2) Bone conduction testing measures the sensorineural sensitivity.

CONVENTIONAL PURE TONE THRESHOLDS

According to the American National Standards Institute (ANSI, 1973), the threshold of hearing is the threshold of audibility which can be obtained under two conditions denoted by the minimum audible pressure (MAP) & minimum audible field (MAF). This threshold is defined as the "minimum effective sound pressure level of the signal that is capable of evoking an auditory sensation in a specific fraction of trials" (ANSI S3.20-1973) i.e., to say if 3 trials are given & there is a positive response twice, then the minimum level at which there is consistency in the two positive responses out of 3 trials is considered the threshold.

There are many psychophysical methods based on which thresholds are obtained. Some of them are:

I. Method of limits

II. Method of adjustment

III. Descending run method

IV. Method for clinical determination of pure tone threshold measurement.

[A] Hughson-Westlake(1944)

[B] Carhart-Jerger modified Hughson-Westlake (1959)

[C]ASHA (1978a) Guidelines for manual pure tone threshold audiometry,

[D]ANSI (S3.21-1978) Method for manual pure tone Audiometry.

I. Method of limits:

It was given by Fechner in 1860 & is one of the classical psychophysical methods for measurement of threshold. Series of stimuli that are either ascending or descending in intensity are presented. This is done because the threshold varies as a function of the direction of the run/ trial. The amount of increase (i.e., increment) in intensity is fixed or equal.

Instructions:

1) The patient is instructed to respond whenever & as soon as the tone comes on regardless of how faint it is & to stop responding as soon as the tone goes off. The subject is also instructed that first one ear & then the other ear will be tested.

2) The mode of response can be any of which is overt, for example, raising and lowering the finger, hand or arm, pressing & releasing a signal light switch.

3) A spoken response, however, is the least acceptable as silence is desirable in the test environment.

Method:

1. Ascending run: Sound is first presented at a level known to be below threshold & then is increased in fixed, equal increments until the subject perceives the sound (i.e., a first positive response is obtained).

2. Descending run: Sound is initially presented at a level known to be well above the threshold, & then is decreased in fixed, equal increments until the subject no longer perceives the sound (i.e., a first negative response is obtained)

3. The descending and ascending runs are alternated and a minimum of at least 6 runs is administered.

4. Each run is initiated & terminated at a different intensity in order to prevent the subject from standardizing the response by counting the number of stimuli given before changing the response.

Calculation:

The absolute threshold is determined for each run by calculating the series of transition points denoted by (t), which is the midpoint between the last negative and the first positive response in an ascending run or the last positive & first negative response in a descending run.

The over all threshold is the average of the T values (for at least 6 runs)

Disadvantage

Errors of anticipation & habituation may constitute the persistence effect.

1. Anticipation: Subject changes response before applicable e.g. In ascending run the subject may say "no" for the first few stimuli & then say yes before the stimulus is heard because it is anticipated.

2. Habituation: Subject continues to respond to the stimuli in the same manner, even when response is no longer applicable e.g. In descending series subject says "yes" out of habit, even when stimulus is no longer heard.

Altering the direction of runs & using large no of runs minimizes the effect.

II. Method of adjustment:

In this, the testee has control of the intensity of the stimulus by depressing/ releasing a switch, which will increase or decrease the intensity. He has to adjust the intensity of the stimulus until it is just barely audible. He is instructed to manipulate the switch so that the continuously changing stimulus varies between just audible & just not audible. A mid point of these two values is usually taken as threshold.

III. Descending method:

The instruction is similar to that used for the method of limits, the tester presents a stimulus that is easily heard & serially decreases the intensity with each tonal presentation until the testee no longer reports hearing the tone. The process is repeated several times & the lowest level at which the observer reports hearing the tone 50% of the total time is taken as threshold of hearing at that frequency.

A. Hughson-Westlake Method (1944):

It is similar to psychophysical "Methods of limits" in that it represents only the ascending version.

Instruction: Same as that for method of limits.

Method: The stimulus is presented in ascending order from a level where sound is inaudible to the lowest level where sound is audible.

Calculation: Threshold is defined as the lowest level at which the sound is audible in more than half of the ascending trials.

[B] Carhart-Jerger Modified Hughson-Westlake (1959):

Carhart & Jerger (1959) revised the Hughson-Westlake method.

Instruction:

The instruction is the same as mentioned earlier.

Method:

A tone is presented well above threshold, i.e., at 30-40 dBHL, if the subject appears to have normal hearing sensitivity, & at 70dBHL if a moderate hearing loss appears to be present.

If the initial level still yields a negative response, then the intensity is increased in 10-15 dB steps until a positive response is obtained.

The duration of pure-tone stimuli is 1-2 s & the stimuli are separated by toneless intervals.

After the first response, the intensity is decreased in 10-15 dB steps until response is obtained.

When inaudibility is reached, the threshold search is begun. The intensity is then increased in an ascending series of 5 dB steps until a response is obtained.

When a response is obtained, the intensity is decreased 10-15 dB & another ascending trial of 5 dB increments is begun.

Interpretation:

The criterion for threshold is the lowest intensity at which 3 positive responses are obtained on an ascending run.

Advantages:

5-dB increments in ascending run increase the reliability since moment to moment fluctuations (i.e., changes) in auditory sensitivity are generally less than this increment size [Carhart & Jerger (1959)]. /

The brief tonal duration enhances reliability by maximizing "on effect" phenomenon & minimizing adaptation [Carhart & Jerger (1959)]. /

"On effect": Refers to the fact that the auditory system responds most vigorously at the onset of a tone.

Adaptation: For a sustained tone when there is a reduction in responsiveness (either due to perceived decrease in loudness or change in tonality) even when the tone is not intense enough to yield fatigue.

Separation of stimulus by toneless intervals permits full recovery from adaptation, if present.

[C] ASHA (1978a) GUIDELINES FOR MANUAL PURE-TONE THRESHOLD AUDIOMETRY

The ASHA guideline for manual pure tone threshold audiometry is essentially based on the recommendations of Carhart & Jerger (1959) & Reger (1950). The guidelines indicate that variations in procedure may be necessary for **difficult -to -test populations.** The procedure is as follows:

1. Instructions: Instructed to respond whenever & as soon as the tone comes on regardless of how faint it is & to stop responding as soon as the tone goes off. The subject is also instructed that first one ear & then the other ear are tested.

2. The mode of response can be any which is overt, for example, raising & lowering the finger, hand or arm pressing & releasing a signal light switch.

3. A response should not be considered as one unless the latency of the response is consistent & the subject responds approximately to the termination and initiation of a tone. If the latency of the response to the first tone in an ascending run is delayed, the response to the tone that is 5 dB higher should be with out hesitation.

4. Subjects should be instructed if false-positive responses or false negative responses are obtained. False positive responses cm be minimized by

varying the interval between audible stimuli, employing pulsed on warble tones, or by having the subject report the number of pulsed tones presented at a given level.

5. The subject is familiarized with the tone by one of the two methods. In the first method, the attenuator is set at lower limits & the intensity is slowly & continuously increased until a response occurs. In the second, the tone is presented at 30 dBHL & at 50 dBHL if no response occurs at 30 dBHL. If there is no response at 50 dBHL, the tone is increased in lOdB steps until a response occurs.

6. The duration of tone is l-2seconds

7. The inter stimulus interval is varied but is never less than the duration of the stimulus.

8. After the first response, the tone is decreased by 10 dB whenever the subject responds & increased by 5 dB whenever the subject fails to respond.

9. The threshold is defined as the lowest intensity at which the subject responds at least half the times & at least 3 times on ascending runs.

10.Variations in technique should be recorded on the audiogram, for example, descending method, pulsed tone, warbled tones, substituted.

11. The audiometers & earphones must meet the specifications in ANSI S3.6-1969.

12. The ambient noise levels in the test environment must meet the specifications in ANSI S3.1-1977.

13. The tester should check for cerumen blockage or collapsed canals with or without earphones. The tester should place the headphones, so that the grid is directly over the entrance to the ear canal. Hair should be manipulated so that it is not trapped underneath the headphones & other obstacles such as earrings should be removed.

14. Diagnostic testing should be done at the following octave frequencies: 250, 500, 1000, 2000, 4000, 8000 Hz. Testing is also done at 125 Hz when a low frequency hearing loss is present. The interoctave frequency is tested whenever the difference in threshold between two adjacent octave frequencies is at least 20 dB

15. The better ear should be tested first. The order of test frequencies employed should be

(a) 1000, 2000, 4000 & 8000, retest at 1000, then 500, & 250 Hz or

(b) 1000, 500, & 250Hz retest at 1000 then 2000, 4000 & 8000 Hz respectively.

[D] ANSI S.3.21-1978- METHOD FOR MANUAL PURE TONE AUDIOMETRY

The ANSI is only slightly different from ASHA (1978 a).

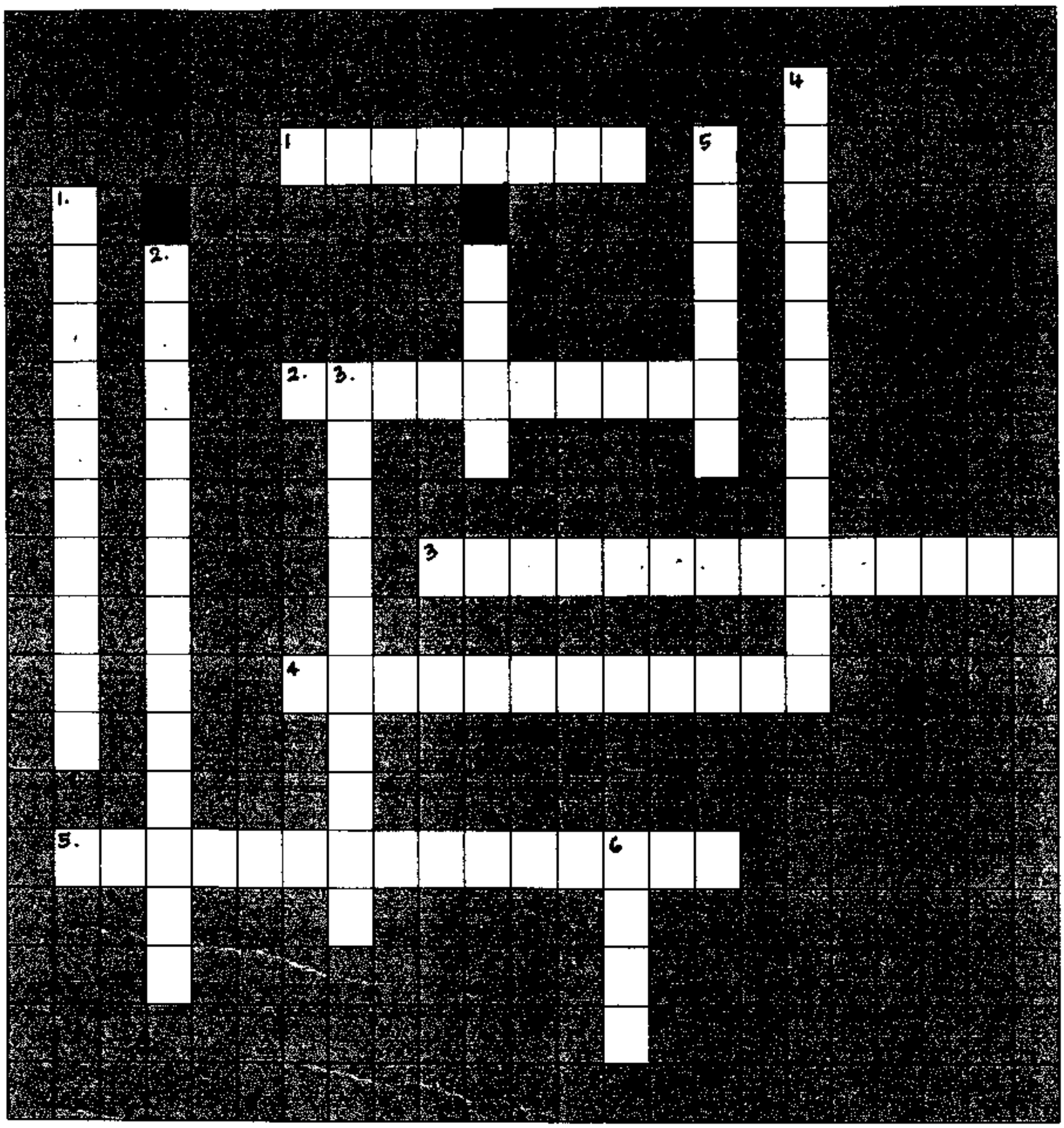
It initially recommends presentation of tone at 30 dBHL for every one; if no response occurs increase by 20 dB & by lOdB there after until a response occurs. An Alternative method is setting the attenuator at the lowest intensity level & then slowly & continuously increasing the intensity until a response occurs. The tone is then turned off for at least 2s & then presented again at the same intensity.

If no response occurs when the tone is presented again, the complete procedure is repeated again.

Yantis (1985) According to him this method is preferred by many audiologists Since this approach is less time consuming, the intensity range around threshold is decreased & some of the behavioral characteristics associated with **functional hearing loss & loudness recruitment may be detected more easily.**

Questions

I. Solve the crossword with the help of the clues:



Across

1. I am an effect. I respond most vigorously at the onset of a tone.
2. l a m a method in which the testee has control over the intensity of the stimulus.
3. A stimulus is absent, yet I respond, I am a response.

4. I am an error. I am caused when I change my response before it is appropriate for me to do so,

5 I am the ascending version of the "Method of limits".

Down

1. I am a phenomenon. I cause a reduction in responsiveness even when the tone is not intense enough to yield fatigue.
2. I am the modified Hughson-Westlake method.
3. I am a method in which a stimulus is presented well above the threshold.
4. I am an error. I continue to respond to the stimulus in the same manner, even when that response is no longer applicable.
5. I am a method, which consists of a minimum of 6 alternately ascending & descending runs.
6. I am based on the recommendations of Carhart & Jerger (1959) & Reger (1950).
7. I am an authority on standards for audiometry

II. State true or false:

(i) The over all intensity for conversational speech is 65-70 dBHL.

(ii) ANSI (1978 a) recommends an initial presentation of tone at 30 dBHL for every one.

(iii) In the ascending method the tester presents a stimulus at a very high intensity that is easily heard &serially decreases the intensity with each tonal presentation.

(iv) Speech can be shown to be a combination of pure tones.

(v) In the method of limits the ascending runs are presented continuously followed by a set of descending runs.

(vi) Many conductive pathologies yielding stiffness-loaded middle ear or outer ear system can be detected by testing for 250 Hz & 500Hz.

(vii) The bone conduction mode bypasses the middle ear

(viii) The bone conduction hearing from airborne sounds occurs at any intensity above the bone conduction threshold.

III. Choose the right one

(i) Differentiating between noise induced & other high frequency sensorineural hearing losses requires testing in these frequencies

(a) 500 - 2000 Hz. (b) 8000 - 16000 Hz.

(c) 4000-8000 Hz. (d) 1000 - 3000 Hz.

(ii) The comparison of air and bone conduction thresholds gives

(a) Type of hearing loss (b) Pattern of hearing loss

(c) Degree of hearing loss (d) All of the above.

(iii) The duration of a pure tone stimulus as per the ASHA (1978 a) requirements is

(a) 1-5 s (b) 1-3 s

(c) 1-2 s (d) 1-4 s

(iv) As per ASHA (1978 a) guidelines, method for pure tone threshold measurement, threshold is defined as the lowest intensity at which the subject responds at least half the time or

(a) At least once an ascending run (b) At least twice an ascending run

(c) At least thrice an ascending run (d) At least four times an ascending run

5. In determining the pure tone average threshold ,the different audiometric frequencies usually used are

(a) 250, 500, 1000 Hz (b) 1000, 2000, 3000 Hz

(c) 500, 1000, 2000 Hz (d) 250, 1000, 4000 Hz

IV. Fill in the blanks

(i)__________________measures the sensorineural sensitivity.

(ii) The threshold of hearing or the threshold of audibility can be obtained under two conditions__________________&_________________.

(iii) The main purpose of air conduction testing is to determine the _____________of hearing loss.

(iv) Bone conduction hearing from airborne sound does not occur until the intensity of the sound exceeds the air conduction threshold by at least

(v) The hearing level for speech with an overall spectral level of 65 dBSPL at 2000 Hz is_____________dB.

Table 1 : Classification of audiometers according to IEC.

SI. no	Parameters	Typel	Type2	Type3	Type4	Type5
1	Intensity Range					
	Maximum	120 dB	HOdB	100 dB	70 dB	70 dB
	Minimum	-10 dB	-10 dB	-lOdB	-10 dB	-10 dB
2	Frequency Range					
	Lowest	125 Hz	125 Hz	Exclusion of 125 Hz, 750 Hz & 1500 Hz	500Hz	
	Highest	8kHz at octave interval frequen -cies of 750 Hz.	8000 Hz with aditional 1500 Hz 3000 Hz & 6000 Hz.(IEC 29C)		6 kHz. others 1000, 2000, 3000, 4000 Hz.	
3	Noise					
	Transducer for masking noise facility	Contralateral earphone Ipsilateral earphone & bone vibrator		Masking noise available through earphones only	Not provided for masking noise.	
	Type of masking noise.	Narrow Band and Broad band		Narrow Band only		
4	Transducer					
	Earphones:	2 earphones mounted in Supra/circum aural cushions				Single earphone
	Bone vibrator	Available			No bone vibrator	

(IS:9098-1979) classified audiometers as pure tone audiometers & diagnostic audiometers. The pure tone audiometer has the facility to test using pure tones whereas the diagnostic audiometer has both, speech and pure tone testing facility.

According to ANSI (1969), the specifications for audiometer covers two major types of instruments-Pure tone audiometers & speech audiometers. Audiometric instruments are further categorized into wide, limited, &narrow range devices.

(I) The wide range device is defined as one, which covers a major portion of the human auditory range in both frequency & Sound pressure level. It is similar to the diagnostic audiometer. It includes one or two earphones, a bone vibrator & provisions for masking of the non-test ear.

(II) Limited Range: It is restricted in frequency & output & could be compared to a screening audiometer. Facilities for testing bone conduction & for masking may be omitted.

(III) Narrow Range: It is further restricted to perhaps only 2-3 frequencies at just few sound pressure levels. They are for screening purposes.

The speech audiometer is defined as an instrument that enables the monitoring of spoken material at controlled sound pressure levels. The speech source may be live voice, disc or tape.

According to Newby,(1972). Pure tone audiometers can vary from simple portable models for school testing to elaborate 'research' type audiometers, with which it is possible to administer all kinds of speeial advanced tests, in addition to the standard measures. According to him, they are of two main types: discrete frequency & sweep frequency. The former provides tones only at octave & mid-octave steps as the frequency dial is turned; the latter type provides a tone that is continuously variable in frequency.

Pure tone audiometers

A common type of audiometer, which is sometimes portable, tests hearing sensitivity by air conduction & by bone conduction. The testable frequencies for these audiometers include 125, 250, 500, 750, 1000, 1500, 2000, 3000, 4000, 6000, & 8000 Hz. The range of intensities begin at -10 dB & goes to 110 dBHL at frequencies between 500 & 6000 Hz & slightly lower maxima at 125, 250 & 8000 Hz. Usually only the range from 250 through 4000 Hz may be tested by bone conduction. The maximum testable hearing level for bone conduction is considerably lower than for air conduction, not exceeding 50 dB at 250 Hz & 70 or 80 dB at 500 Hz & above. **The Maximum output for BC is lower than that for AC because the power required to drive a bone conduction vibrator is greater than for an air conduction ear phone.** Additionally when the bone conduction vibrator is driven at high intensities, harmonic distortion takes place, especially in the low frequencies. A masking control is also provided for introduction of noise to the non-test ear during masking.

Automatic Audiometers

These are audiometers that allow a patient to track his or her own auditory threshold while it is automatically recorded in the form of a graph on a special form. During automatic audiometry, patients hold a switch that they press whenever they hear a tone. The tone is automatically increased in intensity for as long as the switch is released. The tones may be in the form of discrete or sweep frequency steps.

Computerised Audiometer

A computer may be programmed to control all aspects of administering puretone air & bone conduction stimuli, recognize the need for masking, determine the appropriate level of masking, regulate the presentation of the masker to the non test ear, analyze the subjects responses in terms of threshold determination criterion & present the obtained threshold values in an audiogram format at the conclusion of the test computerized audiometry may be performed on a device that is microprocessor- controlled which allows it to be remotely operated by a computer.

Stach (1988) states that it is used successfully to a great extent for military, industrial & educational applications than for individual diagnostic purposes.

Further classification of audiometers can be on the basis of

(i) Screening Vs Diagnostic

Screening audiometer

It is used for the purpose of identifying hearing loss. It has got facility for only AC testing with limited range for frequency & intensity. It may be individual or group Type.

Diagnostic Audiometer:

It is more versatile. It has got facility for both pure tone & speech testing & in its more elaborated form includes facility for special tests. It has primary meant for diagnostic test in clinical & medical settings.

(ii) Individual Vs Group:

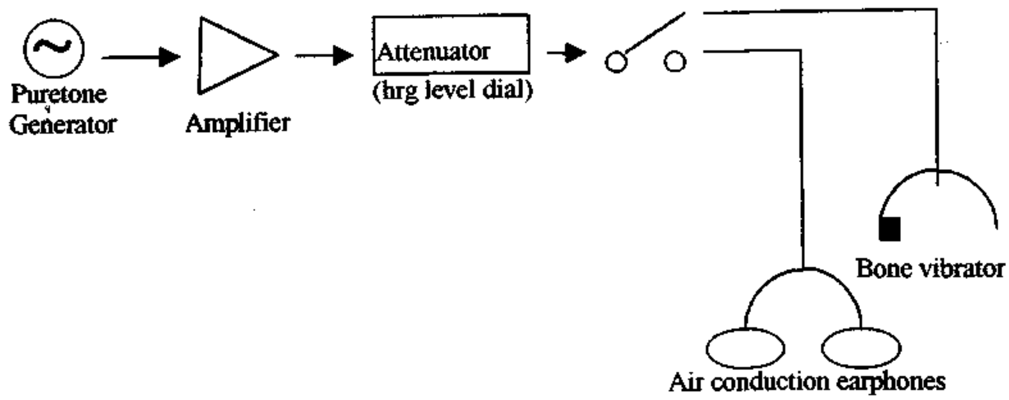
Individual Audiometer:

hi this type one can test only one subject at a time. It provides a more accurate result than the group audiometer but the procedure is more time consuming.

Group Audiometer:

This is capable of testing a group of persons simultaneously, using a procedure in which reliable information is obtainable from each individual.

Figure 8 : Block Diagram Of A Pure tone Audiometer



PARTS OF THE AUDIOMETER

(l) On/Off switch

An audiometer may receive the power supply either by AC or DC. Some have facilities for both. Battery operated audiometers are also available. Currently most commercial audiometers come with a provision of uninterrupted power supply (for a certain duration of time). The switch may have markings like on/ off, AC, DC, Batt, Power etc.

(2). Attenuator

The attenuator or hearing level dial indicates the level of the stimuli-pure tone or speech & the level of noise being presented, hi a screening audiometer where facility for masking is not provided, there may be a single attenuator to control the intensity of the tone being presented. For audiometers equipped to provide masking noise two attenuators are provided, one to control the level of the tone & one to control the level of the noise, so that the simultaneous presentation of the 2 tones may be controlled independently of each other.

For audiometers having two channels, two attenuators to control the level of the signal in each channel are provided.

" Normally, the attenuator is marked in hearing level in dB ranging from -10 dB to 100 dB or 120 dB, -10 dB being indicative of the signal or noise at its softest & 100 dB or 120 dB being indicative of the loudest signal or noise that the instrument is capable of producing.

The hearing level control may be graduated in steps of 1,2 or 5dB i.e., the level of the signal pure tone or speech, can be increased from 0 to 5 to 10 to 15 to 20 etc. when 5 dB steps are set up to the maximum

It is more important to note that for the range from the lowest to the upper most limits i.e. -10 dB to +100 dB or 120 dB, the attenuator is applicable to the pure tones in the range of the middle frequencies such as 500 Hz to 4000 Hz. At higher (6000, 8000 Hz) & lower (125Hz, 250 Hz) the range is more limited. Similarly compared to the range available for air conduction testing, the range for bone conduction testing is more limited. The effective level for masking noise may be indicated on the attenuator so that the tester is aware of the noise level required to mask a pure tone at threshold level.

The attenuator linearity (i.e. if there is a corresponding change in output values consequent to the manipulation of the attenuator) is in the clockwise &

anticlockwise direction through out the full range and is an important aspect of calibration. To check the output SPL, the attenuator is kept constant at the recommended level i.e., 60 dBHL or 70 dBHL (ANSI 1969) (IS: 9098-1979)

3. Frequency Dial:

Every audiometer has the facility to choose the test tone for presentation to the testee. The range of frequencies provided depends upon the type of audiometer.

The frequency range listed above is normally the same irrespective of whether the signal is a continuous tone, pulsed tone or warble tone. However a high frequency audiometer can have a facility to check hearing acuity upto 20 kHz at octave and mid octave frequencies

For calibration purposes, the deviation of the indicated frequency must be checked. The permissible error is ± 3% for all except the 2 or 3 frequencies at the extremes (250, 6000, 8000 Hz) which can have an error of ± 4%(ANSI-1972. In addition, harmonic distortion, 2^{nd} & 3^{rd} & higher harmonics must be checked.

(4) Tone Switch:

To present the signal, a tone switch is provided. When the switch is depressed the selected pure tone is fed through the earphone & the bone vibrator. The tone switch in recent audiometers are normally of the 'off type i.e., unless it is depressed, no signal will be presented. In earlier audiometers the tone switch was called as the tone interrupter since when the switch was depressed, the tone which was normally 'on' was interrupted.

The tone switch has to meet certain requirements. It must not produce any audible clicks, it must be easy to operate.

(5) Masking Noise

Audiometers have provision for masking noise to be presented to the non test ear when ever there is a likely hood of the test signal crossing over the non test ear from the test ear. Facilities for presenting the masking may be through the contralateral earphone, through the bone vibrator. Types of masking noise may be one or more of the following, broad band noise, or narrow band noise, speech spectrum noise.

(6) Ear phone:

Each audiometer is equipped with 2 earphones, one marked red to be used for the right ear & the other marked blue to be used for the left ear. The two earphones are mounted in supra/circum aural ear cushions and are comiected by means of an adjustable headband. The two earphones must be matched.

The earphone frequency response must be flat through out the frequency range of interest. Also, impedance must match that of the audiometer.

(7) B.C. Vibrator:

Audiometers are equipped with B. C. vibrators. For both single channel & dual channel audiometers, a single B. C. vibrator attached to a head band are provided. The vibrator must meet certain requirements. It should have a circular contact tip area of 1.75 ± 25 mm^2 (ANSI-1972, IEC 373-1971). The headband must exert a force of 5.4 N. The B. C. vibrator must be calibrated periodically.

(8) Output selector switch

By means of this switch the signal may be presented through the red / blue earphone through the BC vibrator, insert receiver or free field.

Discussed above, are the parts of an audiometer that are common to almost all audiometers. In addition to the above, the more versatile clinical diagnostic ones are provided with the following:

(a) Test signal indicating device

(b) Patient signal indicating device (Talk back)

(c) Auxiliary output for loudspeakers

(d) Input for external signal

(e) Reference tone for alternate / Simultaneous presentation

(f) Communication / between tester and the testee.

(g) V.U. meter.

Given below is a table summarising the various parts of the audiometer and their functions

Table 2 : Summary of the various parts of an audiometer and their functions

Control	Purpose
1. Power switch	Activates device
2. Frequency selector	Selects frequency for test
3. Hearing level control	Selects test level
4. Output selector	Selects desired Transducer
5. Interrupter control	Turns signal 'on' & 'off
6. Mode selector	Select pulsed/continuous
7. switch for masking	Turn on masking noise
8. Attenuator for masking	Controls level of masking

QUESTIONS

I. Match the following

1. On/ Off switch	(a) Signal presentation
2. Attenuator	(b) 125-8000 Hz.
3. Masking Noise	(c) Flat frequency response
4. Frequency dial	(d) Circular contact tip area
5. Tone switch	(e) Monitoring of speech output
6. Output selector switch	(f) Bone,tone switch
7. VU meter	(g) Power supply
8. Earphone	(h) Narrow band noise
9. BC vibrator	(i) Hearing level dial
	(j) Type 1 Audiometer

II. Fill In The Blanks

1. The International Electrotechnical Commission (IEC:1976) classifies audiometers as___________,______________,____________,____________,

2. The Bureau of Indian Standards classifies audiometers as___________and

3. The American National Standards Institute classifies audiometers as

4.______________audiometers allow a patient to track his or her own auditory threshold.

5. The_____________audiometer is capable of testing a group of persons simultaneously.

III. Which would you choose?

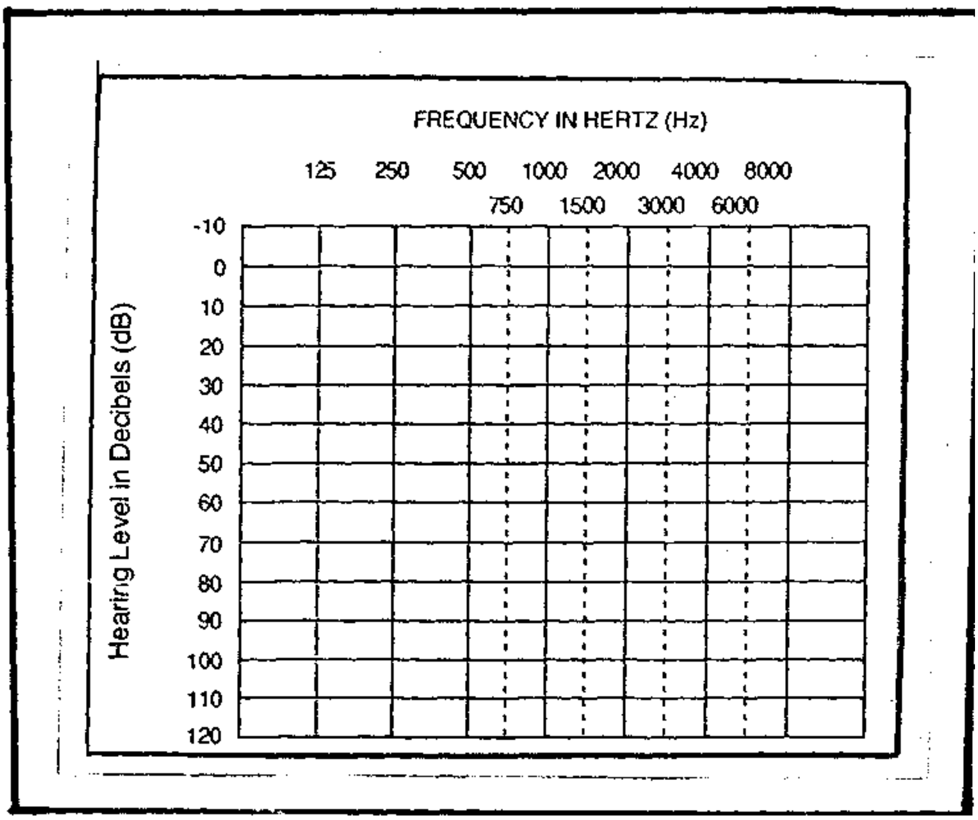
1. If you wanted to select a 1000 Hz tone
2. If you wanted to present noise
3. I am a transducer with a headband and a circular contact tip area, what am I?
4. If you wanted to present a 1000 Hz tone
5. If you wanted a signal of 45dBHL
6. I may be red/blue in colour and mounted on cushions, Who am I?
7. If you wanted to turn me on?

IV. True or False:

1. The Type 4 and Type 5 audiometers have provision for air conduction & bone conduction testing.
2. The attenuator is marked in hearing level in dB ranging from 0 dB to 150dB
3. Discrete frequency Audiometers provide tones only at octave & mid octave frequency.
4. The maximum testable hearing level for bone conduction is considerably less than for air conduction.
5. A diagnostic audiometer has no provision for masking.

THE AUDIOGRAM

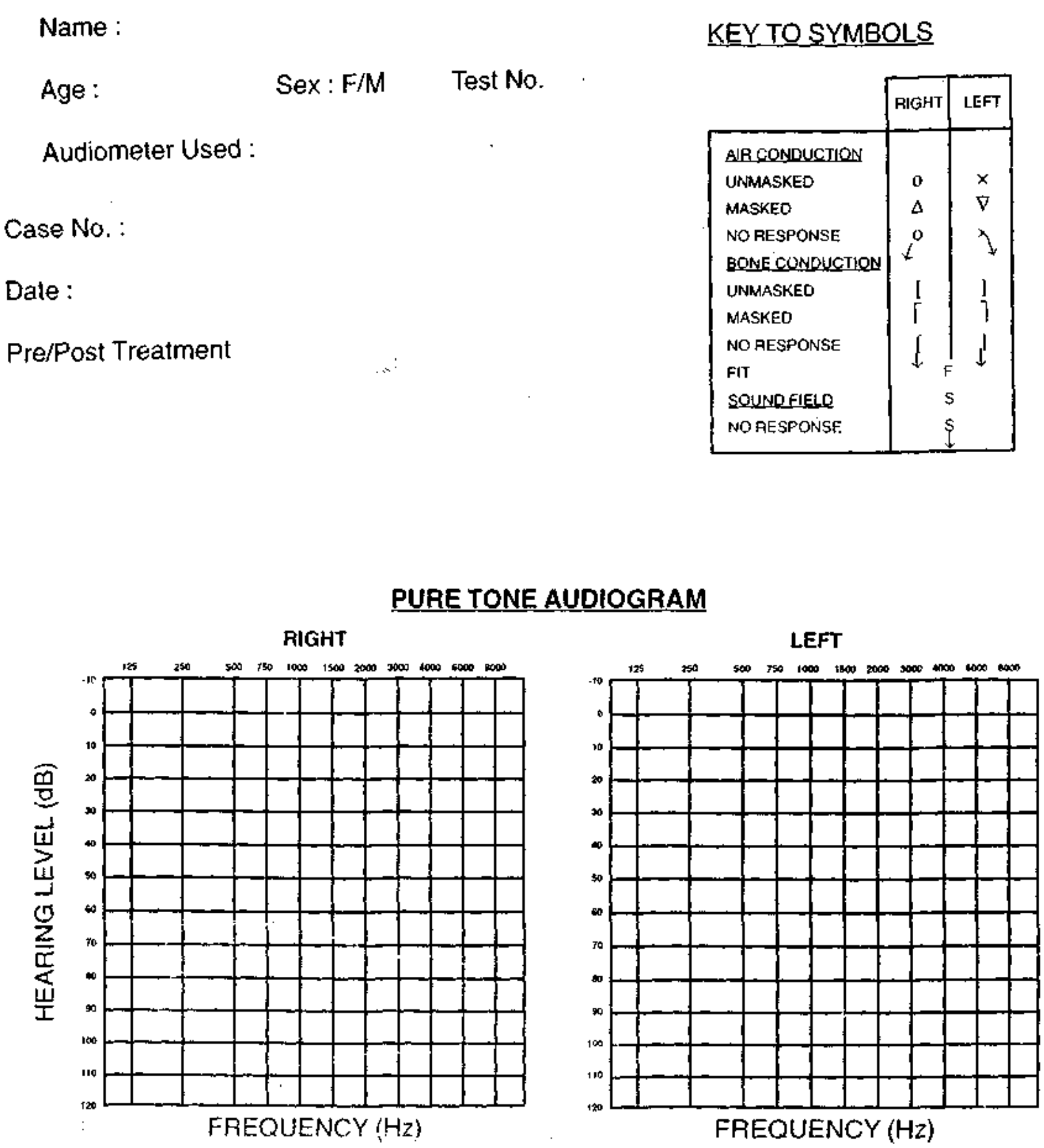
Pure-tone sensitivity can be measured by air conduction and by bone conduction. The audiogram is a graph showing the hearing sensitivity for air and bone conducted sounds of an individual. Thus an audiogram can be defined as the graphical representation of an individual's hearing sensitivity, the results of which can also be recorded numerically. The graph has two dimensions; the frequency of the tone in Hertz (Hz) or cycles per second (cps) is represented along the abscissa and hearing threshold level (HTL) in decibels (dB) along the ordinate. The figure below is an example of a graph, which is used to plot an individual's threshold



Graph 2: An Audiograph depicting frequency along the abscissa and intensity along the ordinate

Specifications of an Audiogram

An audiogram form consists of identifying information such as name, age and sex of the testee, registration number, audiometer used, symbol keys and also provision for recording other test batteries such as speech audiometry and special test results in addition to the graph.



Graph 3: An Audiograph with specifications like Key to the symbols, personal information etc.

Construction of the graph

A graph of frequency versus intensity is drawn to record the test results. ASH A (1974) recommended that frequency be represented by the horizontal line (i.e. the abscissa) and hearing level by the vertical Line (i.e., the ordinate). The digit of the hearing range in the audiogram corresponds to the digit range given in the intensity dial of the audiometer. The same holds true for frequency also.

The size of one octave on the frequency scale should be equivalent to 20 dB on the hearing level scale (ANSI S3.6 - 1969, ASHA 1974) Also it is recommended that the lines representing octave interval of frequency scale and 10 dB interval of hearing level scale have equal darkness and thickness. The lines used for interoctave frequency should be finer and lighter than that of octave frequencies (ASHA 1974).

Symbols Used

The symbols used in the audiogram form , should, as far as possible, conform to a standard specification to prevent any discrepancy. Additionally, a key to the symbols should be provided whenever possible so that there is no confusion regarding the interpretation.

Standard symbols are used to indicate HTL's for each ear at the appropriate 5 dB step, separate symbols being used for air conduction and bone conduction thresholds. Also, different colors can be used to differentiate between the ears, red denoting the right ear and blue the left.

Table 3: Audiometric symbols recommended by ASHA (1990).

Modality	Response			No Response		
	Ear			Ear		
	Left	Unspecified	Right	Left	Unspecified	Right
Air conduction earphones						
Unmasked	X		O	X↘		↙O
Masked	□		△	□↘		↙△
Bone conduction-mastoid						
Unmasked	>	^	<	>↘	^↓	↙<
Masked	]		[	]↘		↙[
Bone conduction-Forehead						
Unmasked		v				
Masked	┌		┐			
Air conduction- sound field	*	S	Ø	*↘	S↓	↙Ø
Acoustic-reflex Threshold						
Contralateral						
Ipsilateral						

The above figure shows a typical audiograph form with the symbols being approved by the American Speech-Language Hearing Association (ASHA, 1990)

A combination of both masked and unmasked symbols can be used depending on, for which frequencies' masking was actually employed, but it is customary not to include unmasked symbols if these results were repeated with masking. Thus, the symbols shown should represent true hearing sensitivity.

If the patient does not respond by air-conduction or bone conduction to the maximum hearing level at a given frequency, an arrow is drawn pointing towards the specific direction from the appropriate symbol at he hearing level, as shown. For example

Customarily, solid lines of the appropriate color connect the air-conduction symbols, which mark the points of hearing threshold level across the audiogram. The bone conduction thresholds may not be connected by lines or may be connected by dashed lines (Newby,1972). However, universal agreement does not exist concerning the direction or placement of some symbols and no-response arrows. Some authors believe that the direction of the symbols should be reversed from the way they appear on the sample audiogram i.e., for bone conduction thresholds of the right ear, the no-response arrows and brackets should appear to the right of the frequency line and point to the right. Others, however, believe that the no response arrow or bracket should head to the left for the right ear and to the right for the left ear. The logic for this backward use of symbols is that the arrow or bracket represents the pinna of the patient and that as the patient sits facing you, the right pinna is to your left; therefore the symbol for the right ear should be to the left of the frequency line on the audiogram and the no response arrow should point downward towards the left. This logic, however, does not hold well, if the patient sits with his back to the examiner.

Interpretation

There are two aspects where the interpretation of the audiogram is important. They are:

A. AS AN AID TO DIAGNOSIS

B. AS A GUIDE TO REHABILITATION

A. AS AN AID TO DIAGNOSIS

The audiogram provides information about the person's air and bone conduction sensitivity. Based on this information we can further classify the hearing loss as

(i) Type of hearing loss
(ii) Pattern of Hearing loss
(iii) Degree of Hearing loss

(I) Type of Hearing loss

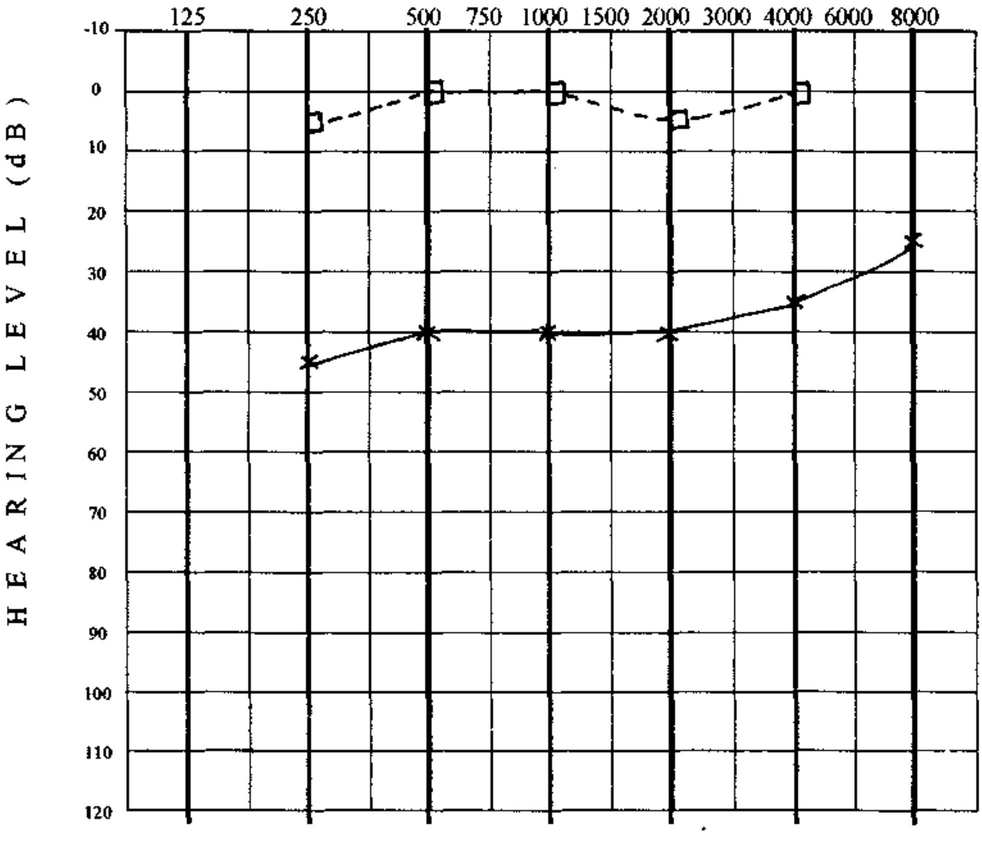
Hearing loss can be diagnosed as conductive, sensory-neural or mixed in type. The course of treatment prescribed will be based on this diagnosis and it depends not only on the hearing test results but also on the results of the physical examination and the patient's medical history.

a. Conductive Loss

A patient with a conductive hearing loss should show losses by air conduction but normal hearing by bone conduction. The existing air-bone gap must be at least 10 dBHL. If such an air bone gap (ABG) exists when both air conduction (AC) and Bone conduction (BC) thresholds are within normal limits, it is termed as minimal conductive hearing loss. AC loss generally does not exceed 60 dBHL (Feldman, 1963) because beyond this level, the whole skull brates resulting in direct stimulation of the cochlea. Thus, if the threshold level exceeds 60 dBHL, the problem cannot be purely conductive.

Generally in a conductive impairment the air conduction losses will be fairly equal at all frequencies, with perhaps slightly greater loss for lower frequencies. However, diagnosis should be made by comparing the AC and BC curve.

In conductive hearing loss damage to either the middle ear, which transmits sound energy efficiently, or the Eustachian tube, which maintains equal air pressure between the middle ear cavity and the external canal, could result in a mechanical defect in sound transmission. In pure conductive hearing loss there is no damage to the inner ear or the neural pathway.

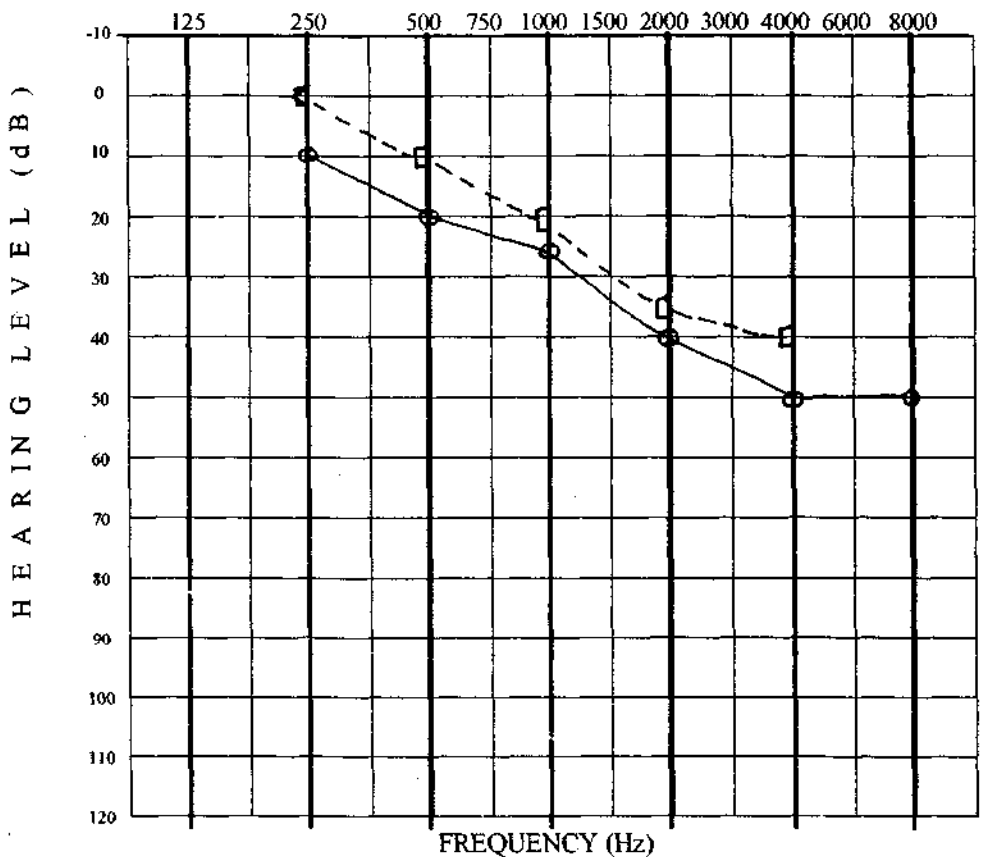


Graph 4: An Audiogram depicting conductive hearing loss.

b. Sensorineural Loss

A sensorineural (SN) hearing loss is present if the bone conduction thresholds are outside the normal limits. The air bone gap does not exceed 10 dB and the air conduction thresholds are outside the normal limits i.e., greater than 25 dBHL. Thus a SN loss is characterised by poor bone conduction thresholds, and essentially ,equally poor air conduction thresholds.

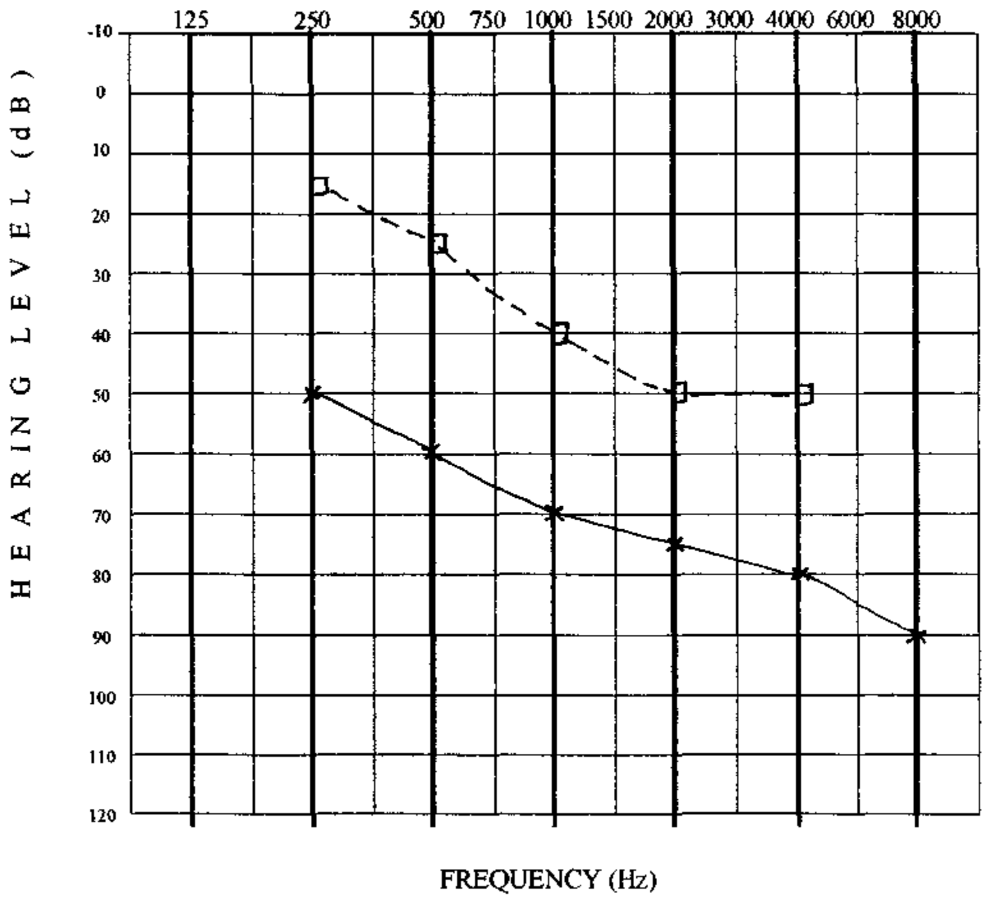
The term sensorineural has dual character and suggests two separate areas, which may be affected. The "sensory" hearing loss is applied when the damage is localised in the inner ear. "Neural" hearing loss is the correct term to use when the damage is in the auditory nerve.



Graph 5: An audiogram depicting sensori neural hearing loss.

c. Mixed hearing loss

A mixed hearing impairment is present if the bone conduction thresholds are outside the normal limits, i.e., greater than 15 dBHL, significant air bone gaps exceeding 10 dB are present, and the air conduction thresholds are outside the normal limits signaling a problem in the outer/or middle ear in addition to the problem in the sensorineural mechanism, indicated by the poor bone conduction thresholds.



Graph 6: An audiogram depicting mixed hearing loss.

d. Functional Hearing Loss

The patient may neither seem to hear or respond; yet the handicap may not be caused by any organic pathology in the peripheral or central auditory pathways. The hearing difficulty may have an entirely emotional / psychological etiology, or it may be superimposed on some mild organic hearing loss, in which case it is called a functional or psychogenic overlay. In some cases it may be feigned or simulated and the patient is conscious of the deception. It is commonly encountered with a background service, social circumstances involving a pension, rejection for enlistment, compensation in a legal action or social maladjustment

e. Central Hearing Loss

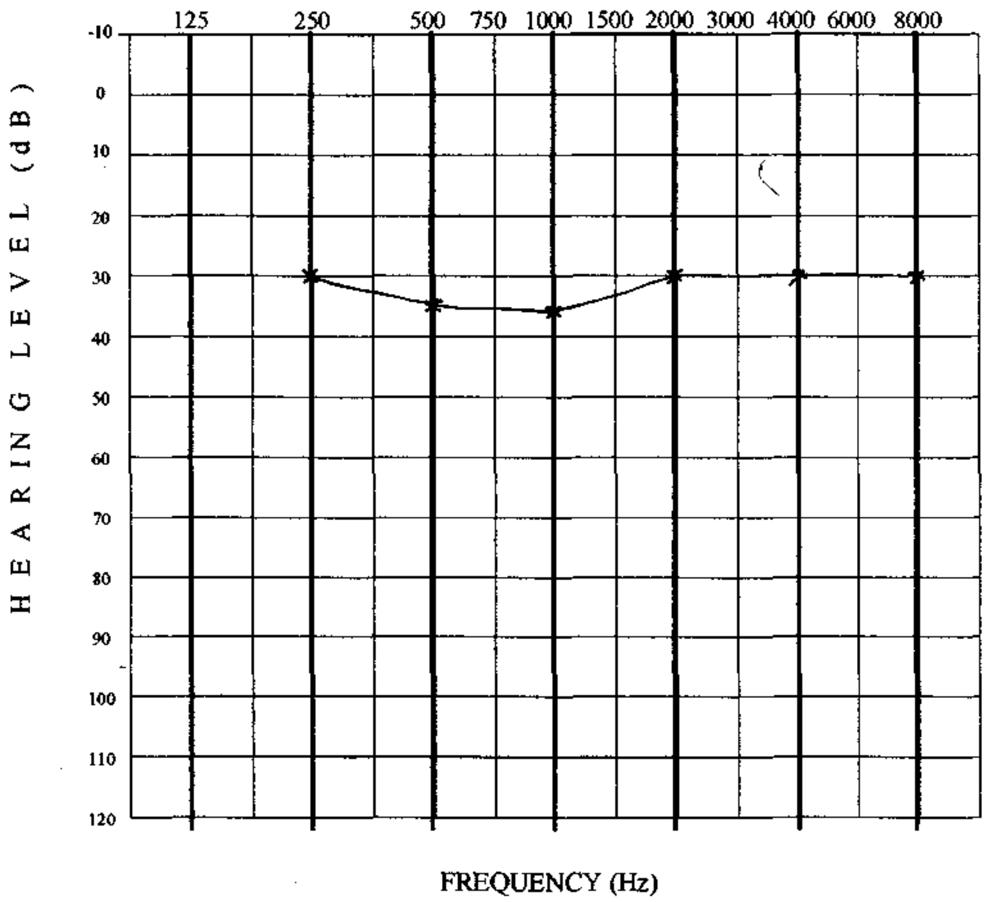
Some patients cannot interpret or understand what is being said and that the cause of the difficulty is not in the peripheral mechanism but some where in the central nervous system. In this loss, the problem is not in lowered pure tone thresholds but in the patient's ability to interpret what he hears.

(ii) Pattern of Hearing Loss

The Audiometric configuration with respect to the positive or negative slope of the air conduction threshold i.e., classified as flat, gradually sloping, sharply sloping, precipitously sloping, rising, trough, saucer, notch, corner and miscellaneous type.

a. Flat Audiogram

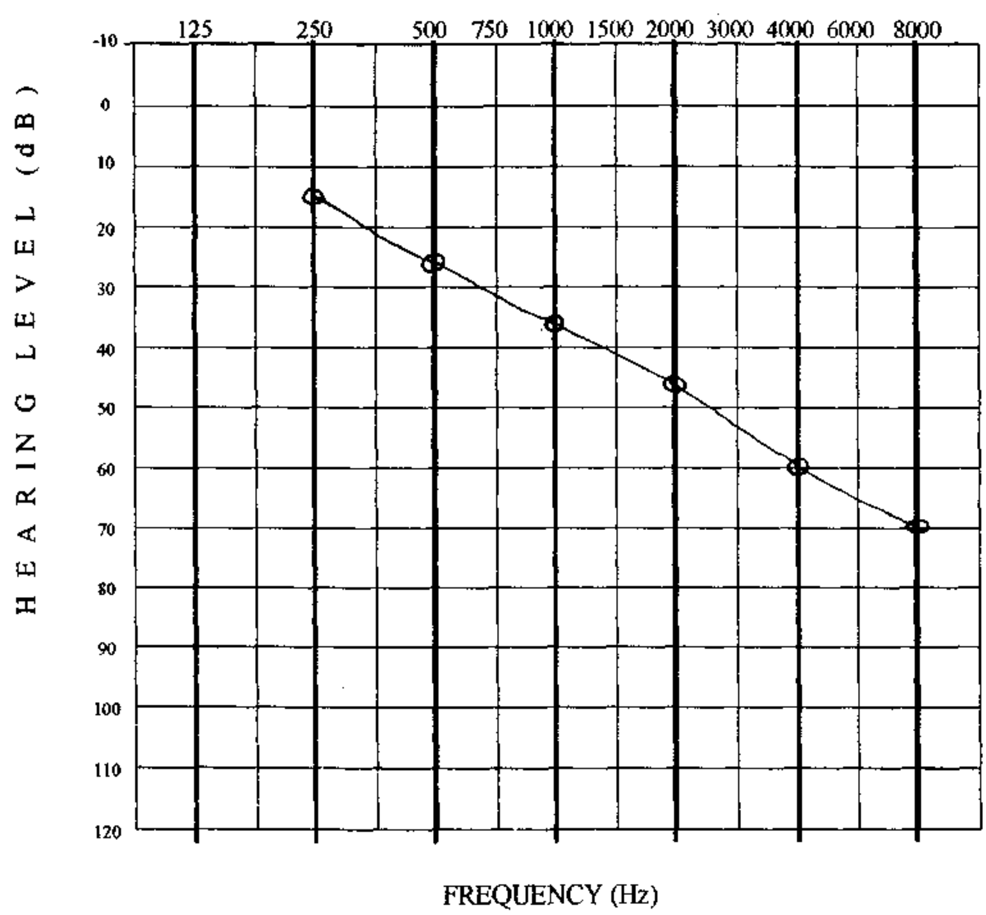
In this there is approximately equal degree of hearing in all test frequencies, the magnitude of difference not exceeding 5-10 dB (Johnson, 1966 ; Davis, 1998). It is usually associated with conductive hearing loss such as Serous Otitis Media, Collapsed Ear Canal, Moderately advanced condition of Meniere's Disease.



Graph 7: An Audiogram depicting a flat pattern

b. Gradually sloping Audiogram

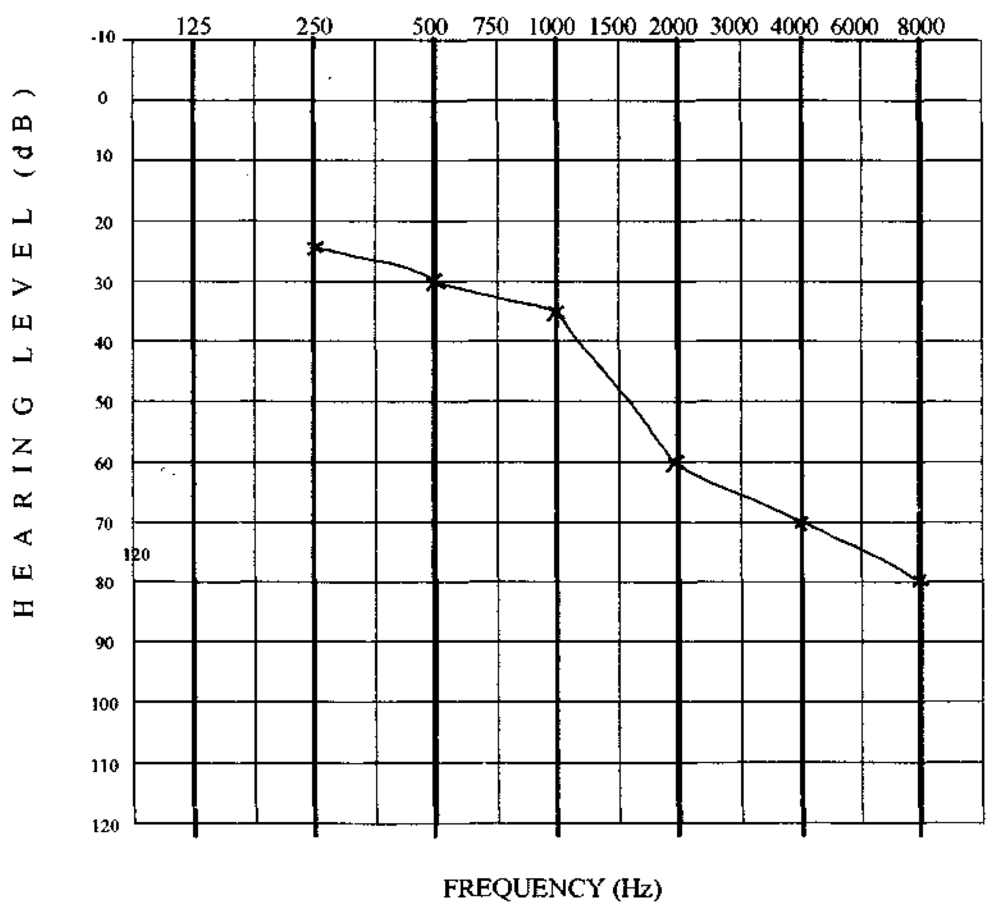
In the gradual type, the loss begins at low frequency with a gradual increase in the high frequency. At 500 Hz, a threshold of 25 dBHL or greater with an increase in threshold of around 5-12 dB per octave. The difference between the highest and the lowest being no more than 35 dB (Stephens and Rintelmann, 1978).



Graph 8: An Audiogram depicting a gradually sloping pattern.

c. Sharply sloping Audiogram

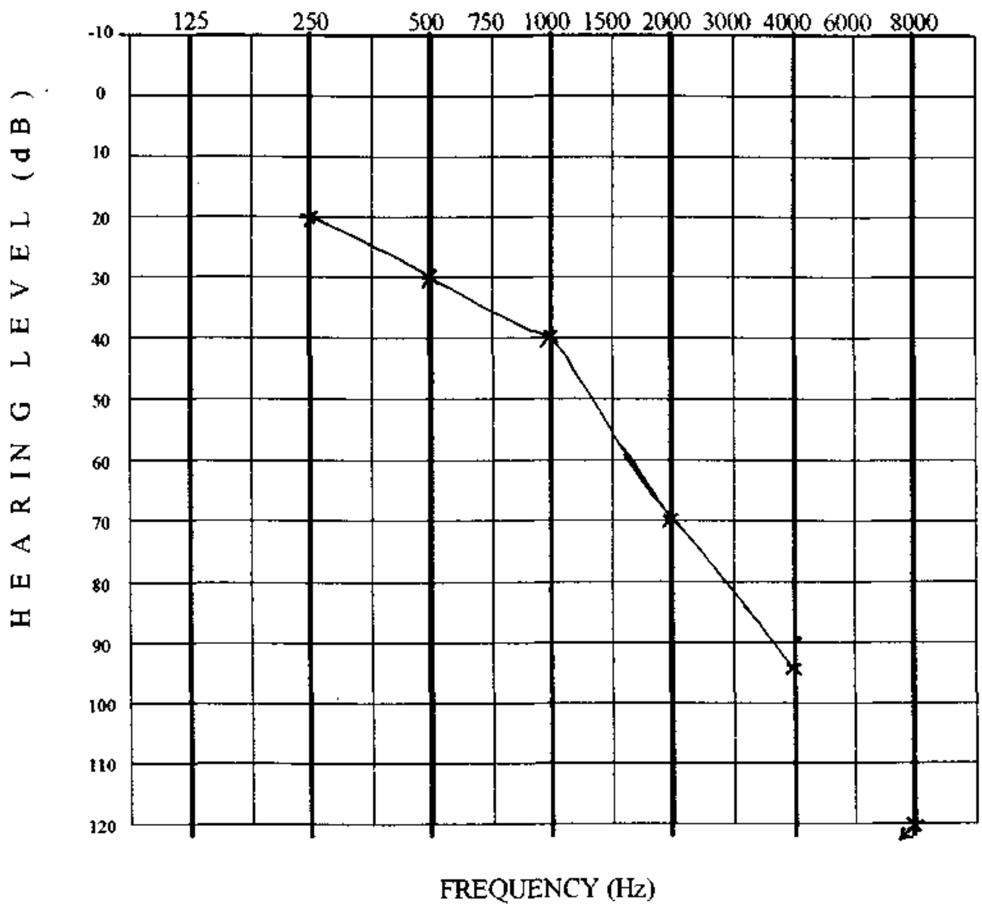
It is characterised by normal or near normal hearing in the low frequency with a threshold of 30 dBHL or better at 500 Hz. Between 500 and 1000 or 1000 and 2000 there is a drop in threshold of at least 20 dB and the difference between the highest and lowest thresholds is greater than 40 dB (Stephen and Rintelmann, 1978).



Graph 9:An Audiogram depicting a sharply sloping pattern.

d. Precipitous sloping Audiogram

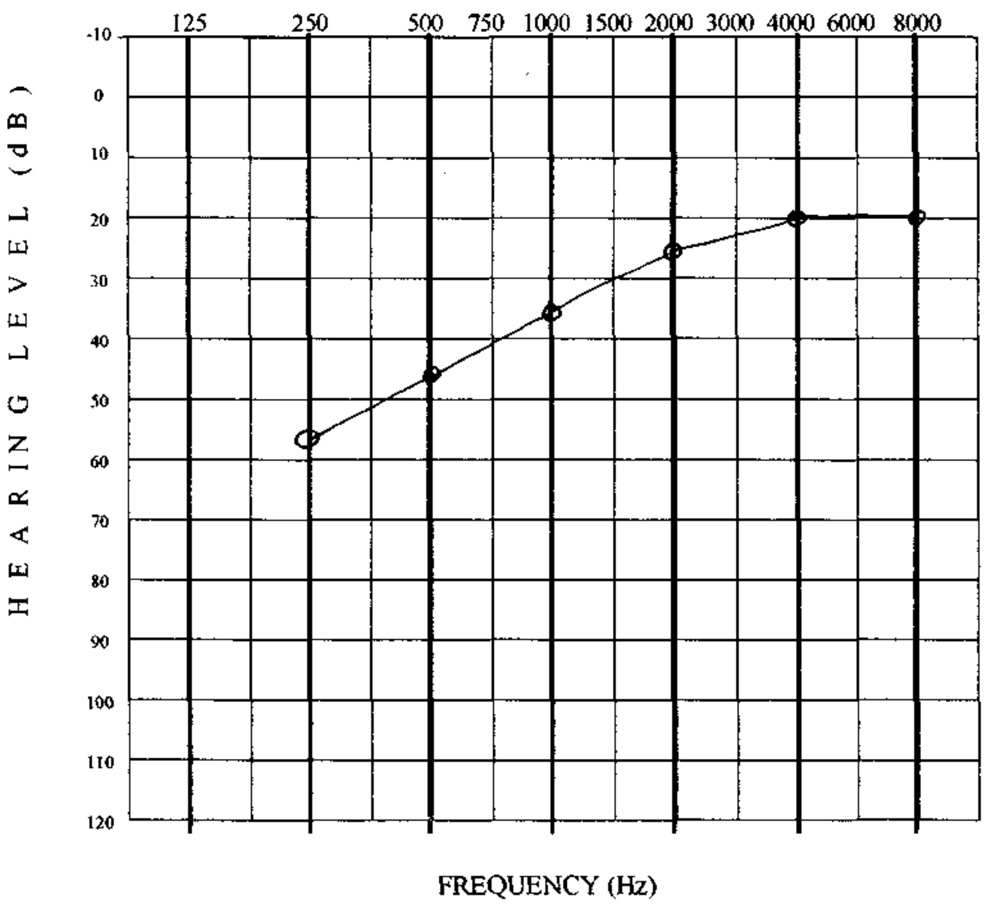
This initially shows a flat or gradually sloping pattern with the threshold suddenly increasing at the rate of 25+ dB per octave.



Graph 10:An audiogram depicting the precipitously sloping pattern

e. Rising Audiogram

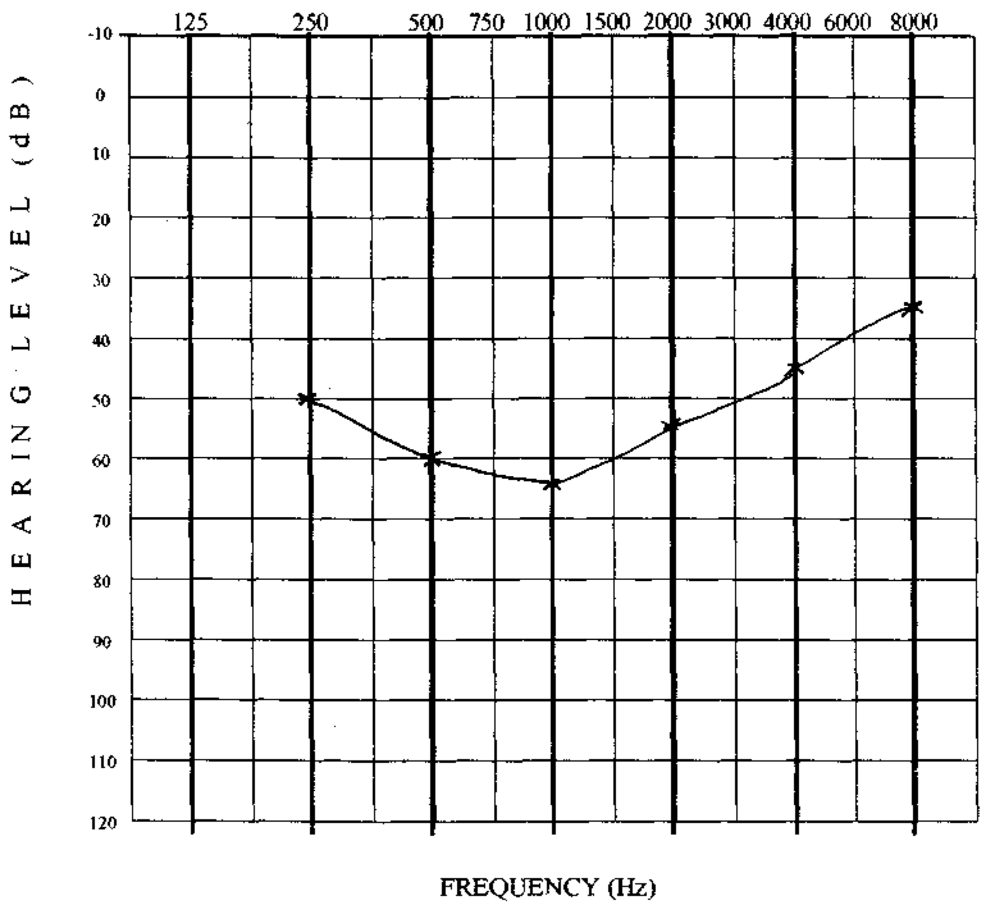
This audiometric pattern shows significant loss at low and mid-test frequencies with relatively normal or near normal hearing in the high frequency region (Ross and Matkin, 1967 ; Davis and Johnson, 1966). It is usually seen in conductive hearing loss cases but it may be seen in some SN loss conditions such as Meniere's disease at an early stage.



Graph 11: An Audiogram depicting a rising pattern

f. Trough Audiogram

In this pattern there is greater loss at the mid frequencies of around 20 dB or greater than at the extreme frequencies. It is typically seen in some children with Rubella.

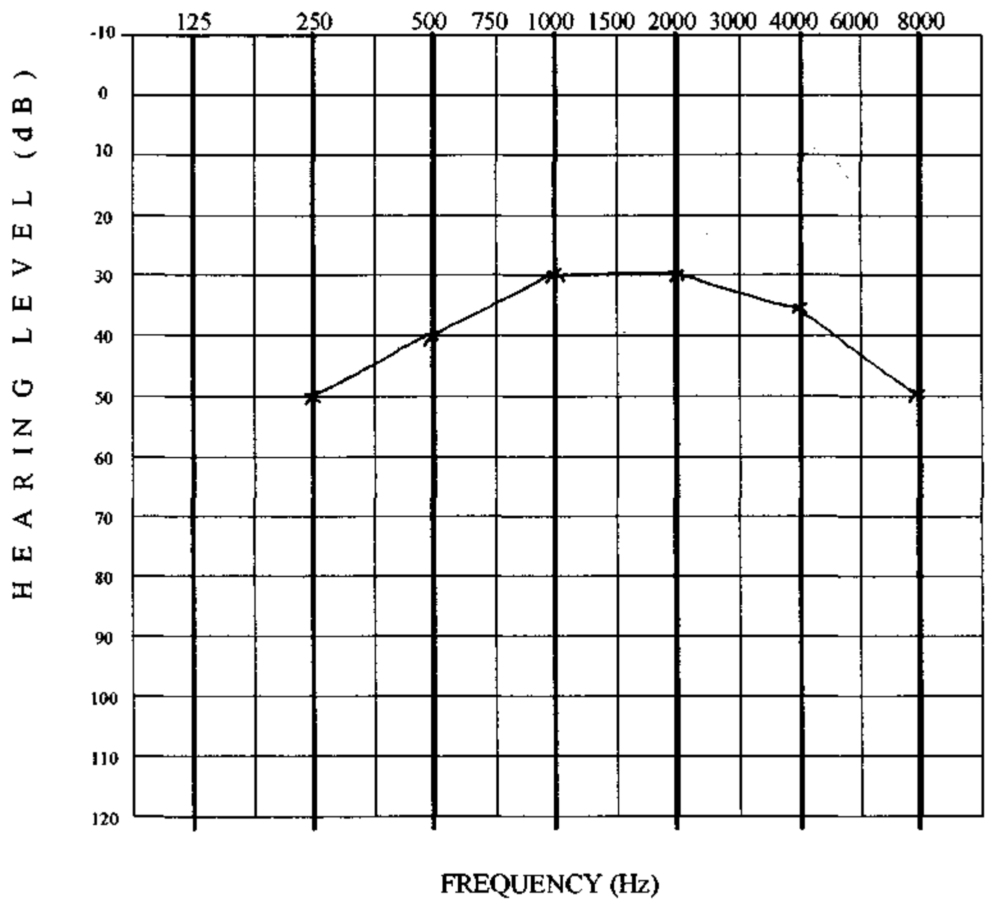


?

Graph 12:An Audiogram depicting a trough pattern

g. Saucer Audiogram

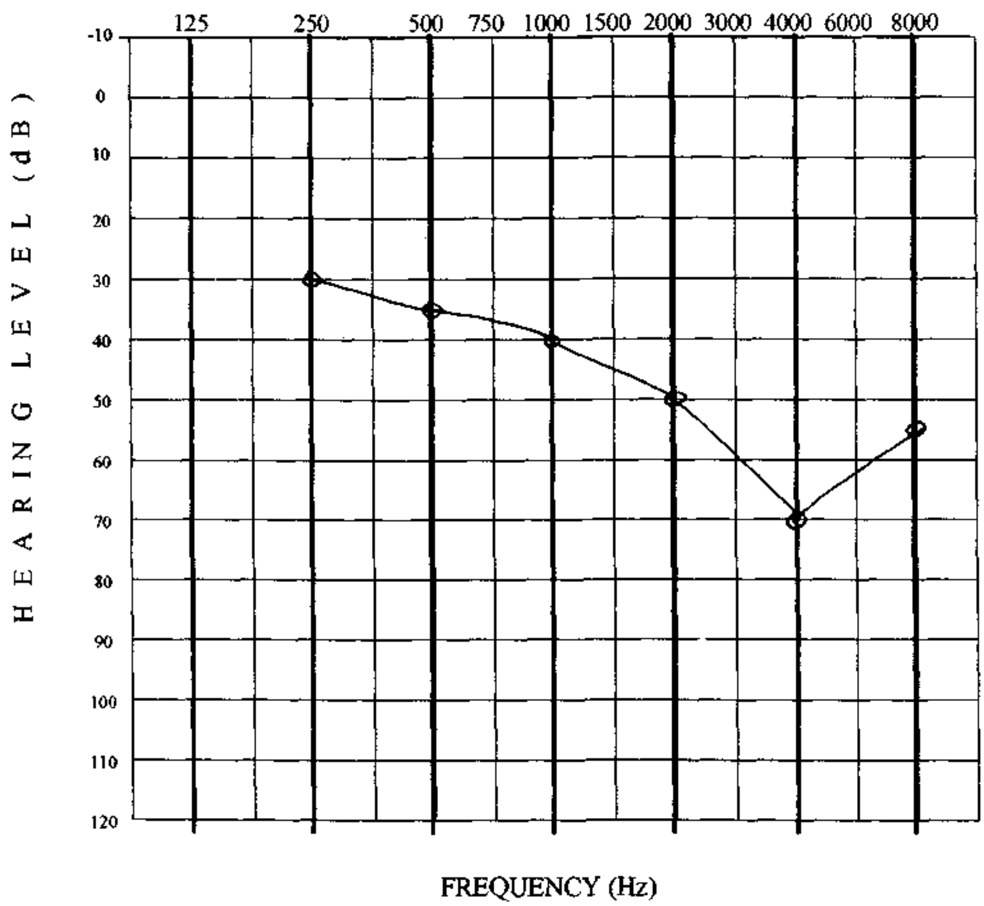
This is the opposite of the trough pattern in that there is 20 dB or greater loss in extreme frequencies than at the mid frequencies. It is often associated with malingerers.



Graph 13:An Audiogram depicting a saucer pattern

h. Notch type Audiogram

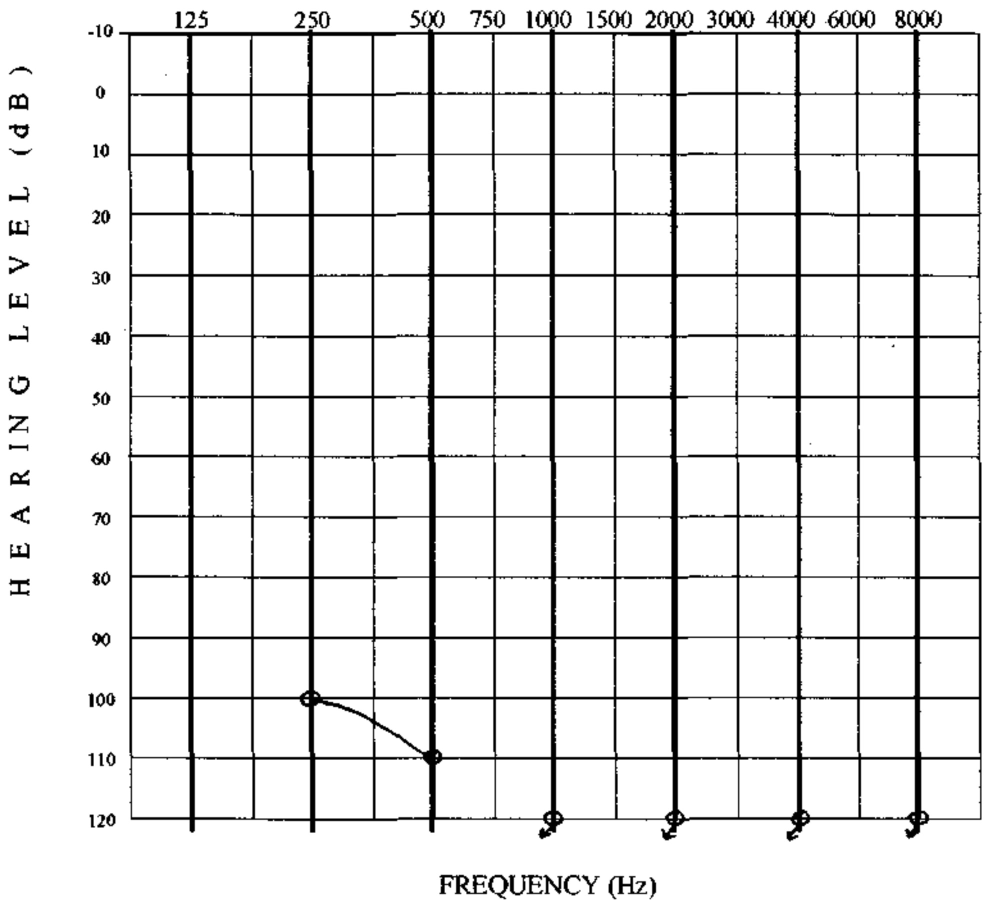
This type is characterized by a sharp dip at a single frequency withrecovery at the immediately adjacent frequencies. A notch at a high frequency is usually associated with noise exposure or head trauma etc.



Graph 14: An Audiogram depicting a notch pattern

i. Corner Audiogram

This pattern occurs in profound deafness. It is characterised by the presence of a response to only low frequencies such as 250 Hz or 500 Hz when presented at very high levels.



Graph 15: An Audiogram depicting a corner pattern

j. Irregular/ Miscellaneous Audiogram

The audiogram does not fit into any of the above categories (Hodgson, 1980).

(iii) Degree of hearing loss

Degree of hearing loss indicates to some extent the degree of difficulty experienced in communication by the individual. It is usually obtained by comparing AC threshold value with that of standard norms. Although audiometric zero level is considered as the average response of a normal young adult; there are individual variations in the normal hearing range.

Classification of hearing loss can be made on the basis of magnitude of hearing impairment. Goodman (1965) prepared a scale of hearing impairment, which relates the hearing threshold level with degree of hearing impairment.

Hearing Threshold Level	Degree Of Loss
0 to25	Normal
26 to 40	Mild
41 to 55	Moderate
56 to 70	Moderately severe
71 to 90	Severe
90 & above	Profound

Table 4: Classification of degree hearing loss by Goodman (1965)

Clarke (1981) then modified the Goodman's classification, & this classification more or less follows that adopted by ANSI.

Average Threshold Level (dB)	Suggested Description
- 10 to 15	Normal hearing
16 to 25	Slight hearing loss
26 to 40	Mild hearing loss
41 to 55	Moderate hearing loss
56 to 70	Moderately severe hearing loss
71 to 90	Severe hearing loss
90 & above	Profound hearing loss

Table 5: Classification of degree hearing loss by Clarke (1981) (Modified Goodman)

o 10 20 30 40 50 60 70 80 90 100 110 120

	Profoundly deaf					Clarke (1957)
	Slight deafness	Partial deafness	Severe deafness	Profound deafness		Dale (1962)
Class A: Not significant	Class B: Slight	Class C: Mild	Class D: Marked	Class E: Severe	ClassF: Extreme	Davis and Silverman (1970)
Normal	Mild	Moderate	Severe	Profound		Paul and Hardy (1953)
Normal	Mild	Moderate	Moderately severe	Severe	Profound	Goodman (1965)
Normal	Classl: Mild losses	Class2: Marginal Losses	Class3: Moderate losses	Class4: Severe losses	Class 5: Profound losses	Streng etal. (1955)
Normal	Hard of hearing	Educationally or partially deaf	Deaf			Streng etal. (1955)
Hard of hearing						Van Uden (1957)

Table 6: Hearing level (loss) in dB re: ANSI-1969.

A classification of the degree of hearing impairment, which classifies hearing loss in terms of percentage, was given by the World Health

Organization. Based on this, the ministry of health and welfare notification no.4.2/83 HW dated 06.08.86, gave a classification as follows.

Sl.no.	Category	Classification	dB level	Speech & Discrimination	%of hearing loss
1	I	Mild hearing impaired	26-40 in better ear	80-100% in better ear	Less than 40%
2	II	Moderate Hearing Impaired	41-55	50-80%	40 - 50%
3	III	Severe hearing impaired	56-70	40-50%	50 - 75 %
4	IV	a.Near total deafness	91dB& above	No discrimination	100 %
		b.Profound hearing loss	71-90 dB	Less than 40%	75-100 %
		c. Total deafness	No hearing	No discrimination	100 %

Table 7: Classification of percentage of hearing loss given by the ministry of health and welfare (1986).

B. AS GUIDE TO REHABILITATION

The audiogram may be interpreted as a guide to rehabilitative needs. It is useful in pointing to the need for rehabilitative measures such as a hearing aid. It helps to differentiate between children who are deaf and need full time special education and children who are hard of hearing who can fit in to the framework of regular a classroom.

Hearing level dB 1951 ASA reference	Hearing level dB 1964 ISO reference	Probable handicap and needs
Less than 30 dB	Less than 40 dB	Has difficulty hearing faint or distant speech; needs favorable seating and may benefit from lip-reading instruction.
30 to 45 dB	40 to 55 dB	Understands conversational speech at a distance of 3-5 feet; needs hearing aid, auditory training, lip-reading, favorable seating, speech conservation and speech correction
45 to 60 dB	55 to 70 dB	Conversation must be loud to be understood there is a great difficulty in group and classroom discussion; needs all of the above plus language therapy, and may be special class for hard of hearing.
60 to 80 dB	70 to 90 dB	May hear loud voice about 1 foot from the ear, may identify environmental noises, may distinguish vowels but not consonants; need special education for deaf children with emphasis on speech, auditory training and language, may enter regular classes at a later time.
More than 80 dB	More than 90 dB	May hear loud sounds, does not rely on hearing as a primary channel for communication; needs special class or school for deaf; some of these children eventually enter regular high school.

Table 8: indicating relations between hearing level in dB and probable handicapped and their needs.

The magnitude of hearing loss can also be expressed in terms of percentage; there are two basic methods to compute percentage of hearing loss

(i) AMA method
(ii) AAOO method

(i) AMA method

It was published under the aegis of the American Medical association, hi the AMA method, only 4 frequencies on the audiogram are given consideration: 500, 1000, 2000 and 4000 cps. These frequencies are weighted in their importance to the total speech-hearing function, as follows: 500 cps 15%, 1000 cps= 30%, 2000 cps= 40% and 4000 cps=15%. Losses in dB at each of these frequencies are assigned percentage values according to a chart which is used in conjunction with the pure tone audiogram. Losses for each ear are converted to percentages, and a formula is applied for computing binaural percentage loss.

Disadvantages

1. It speaks little about the person's communicative ability.
2. It also does not shed any information on the ability to compensate for his loss by means of a hearing aid.

(ii) AAOO method

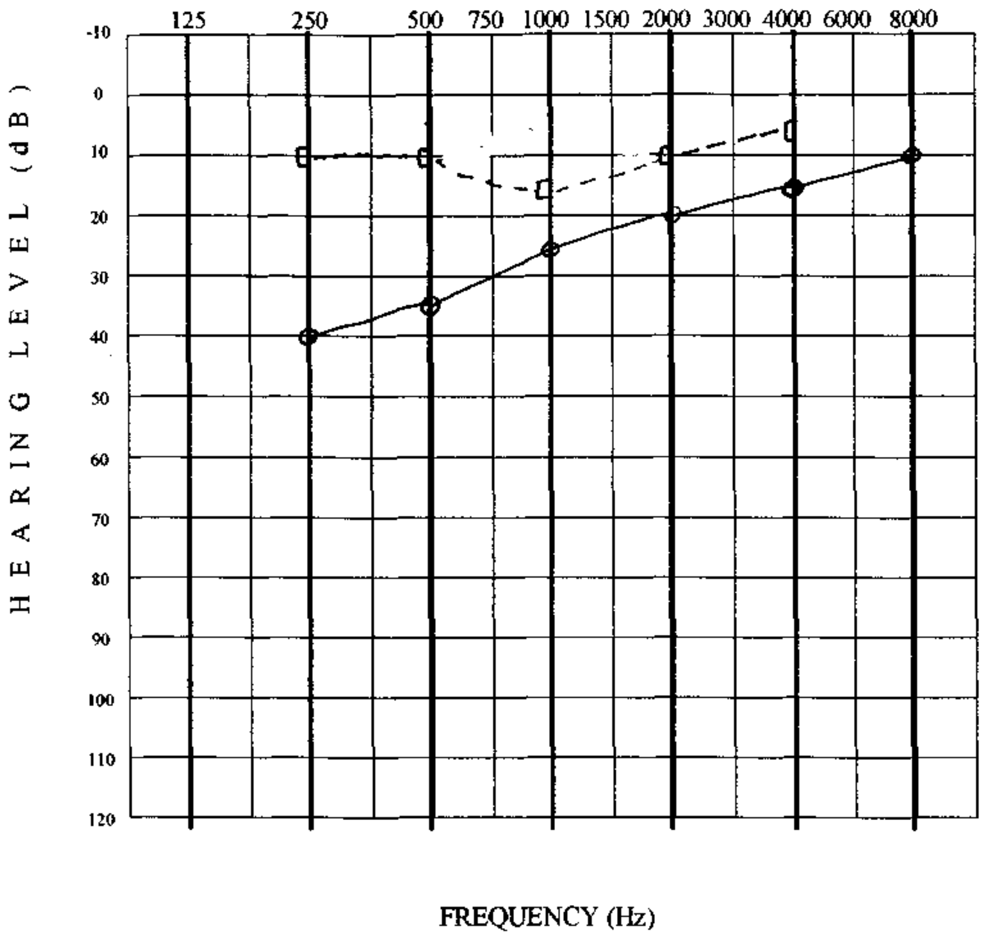
It was given by the American Academy Of Opthalmology and Otolaryngology. In this method only the speech frequencies are assigned any percentage values. Percentage impairment is computed for each ear separately by averaging the air conduction hearing levels at 500,1000 and 2000 Hz. Subtracting 26 dB from this average and multiplying the remainder by 1.5%. The binaural percentage impairment is computed by multiplying percentage impairment of the better ear by 5, adding this product to the percentage impairment of the poorer ear, and dividing this sum by 6.

Importance of the audiogram

The audiogram may be useful in the following ways:

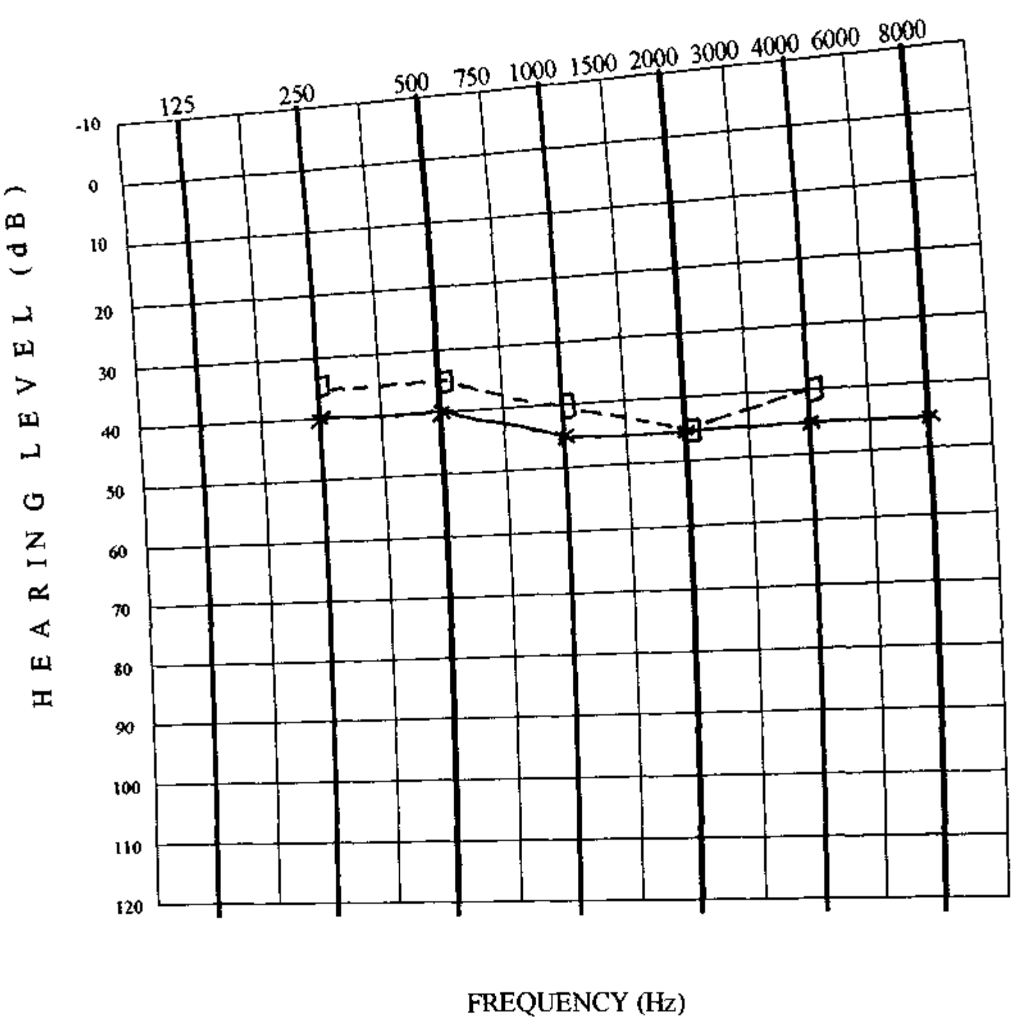
1. To illustrate patterns of hearing sensitivity for tones as a function of frequency.
2. To decide if an individual has hearing loss or not.
3. To determine if the loss is of conductive, mixed or sensorineural type.
4. In identifying the nature of the problem.
5. In Quantifying the amount of hearing loss in determining the amplification needs of an individual.
6. To compare air and bone conduction sensitivity.
7. To present the results of other related pure tone tests.

Typical Audiograms



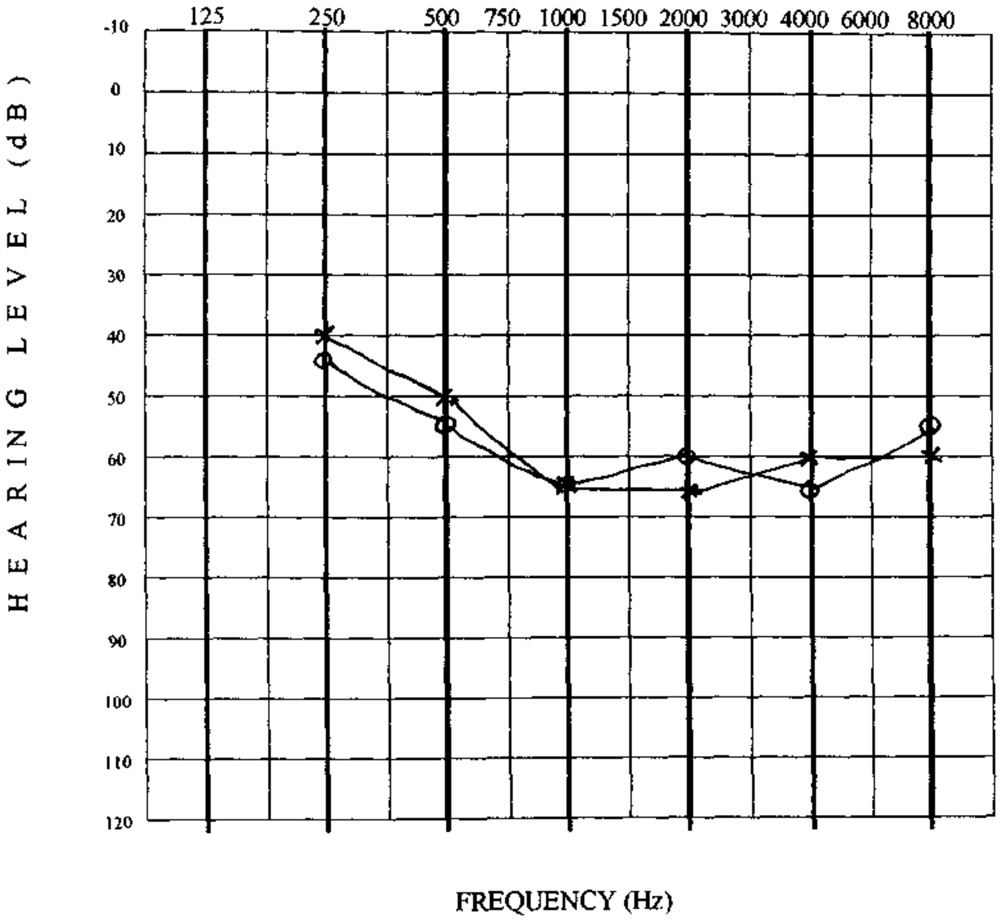
- Early stages of Meniere's disease.
- Low frequency hearing loss.
- History of vertigo and Tinnitus.
- (Goodhill and Guggerheim, 1971)

Graph 16: Early stage of Meniere's disease



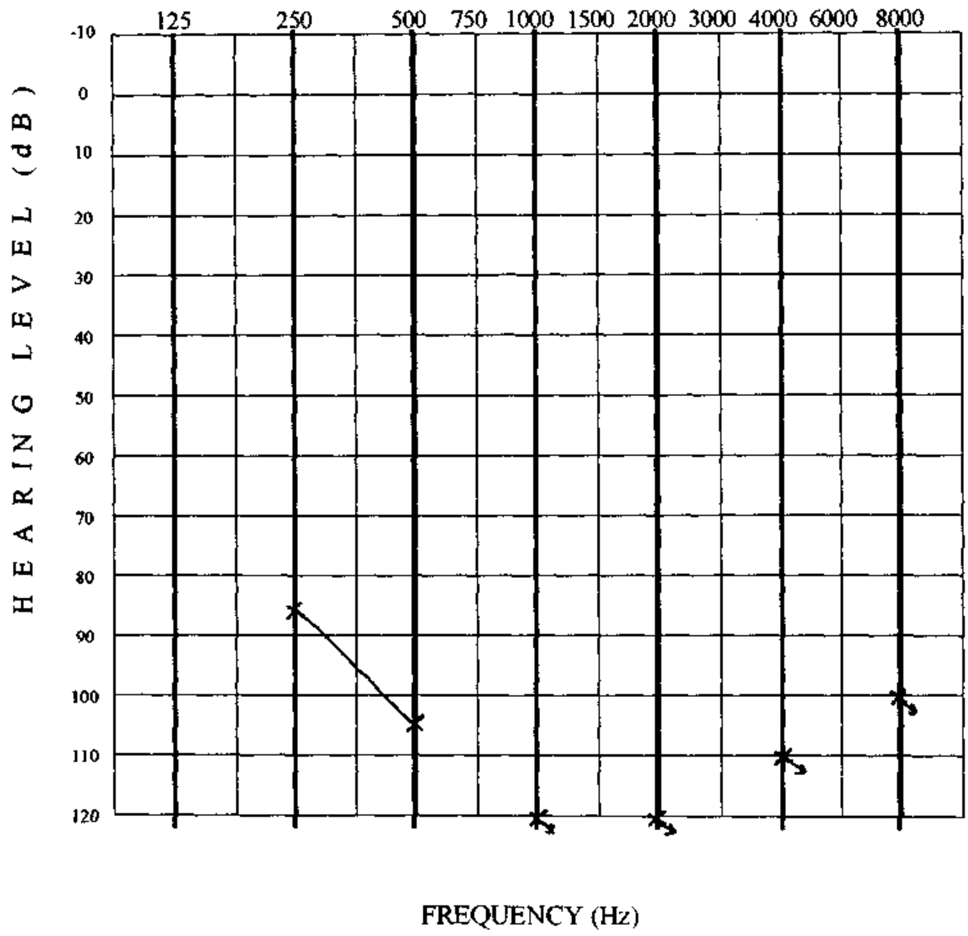
- Moderately advanced stage of Meniere's disease
- Flat frequency hearing loss of sensory type
- (Goodhill and Guggerheim, 1971)

Graph 17: Moderately advanced stage of Meniere's disease



- Maternal rubella and Malingerers
- Saucer shaped audiogram
- (Prescord,1978)

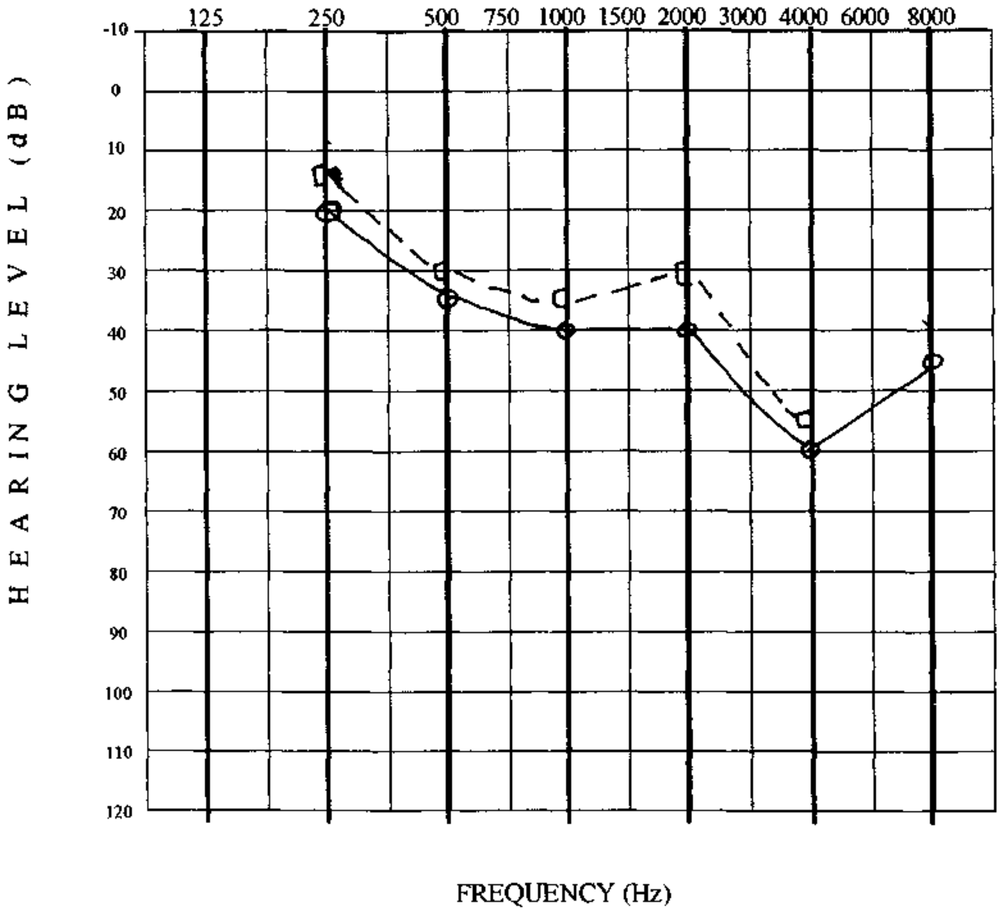
Graph *19:* Maternal rubella



- Congenital hearing loss and viral disease
- Corner audiogram

(Davis J, 1978)

Graph 20: Congenital hearing loss

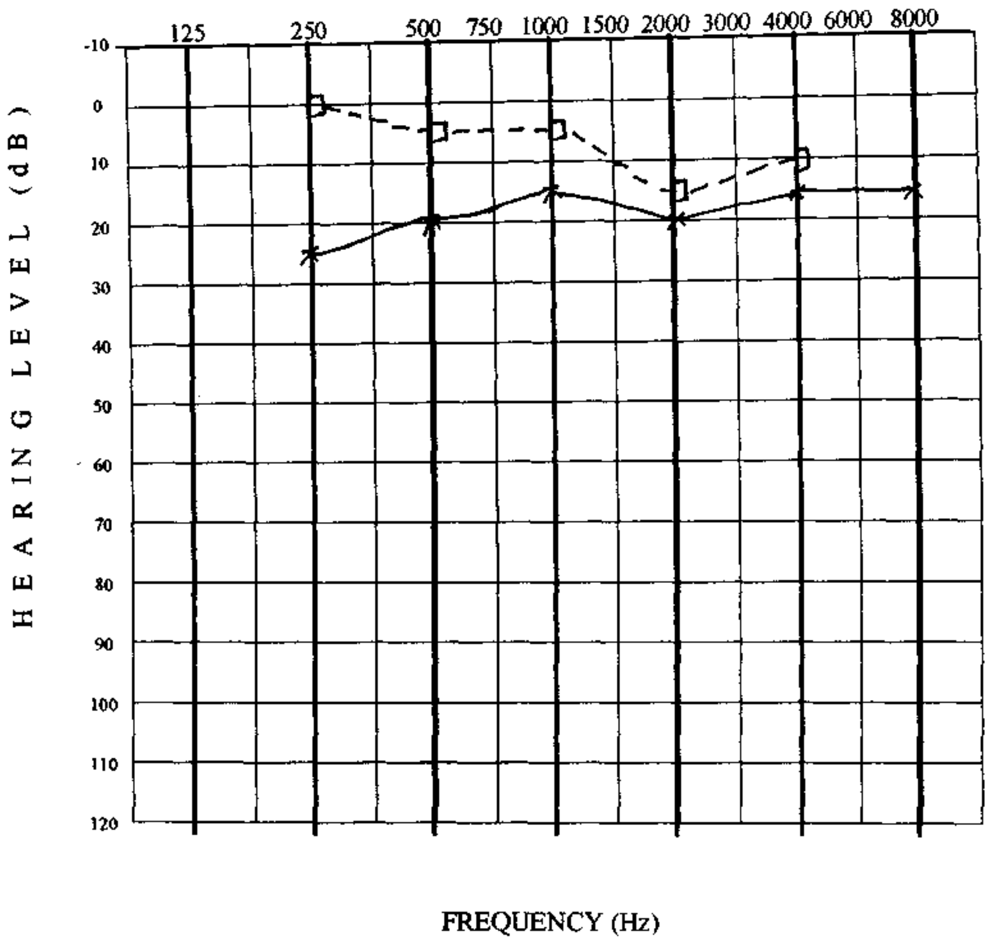


* Noise induced hearing loss

* Dip in 4 kit for both AC ^ 8c

* History of tinnitus and exposure to high intensity

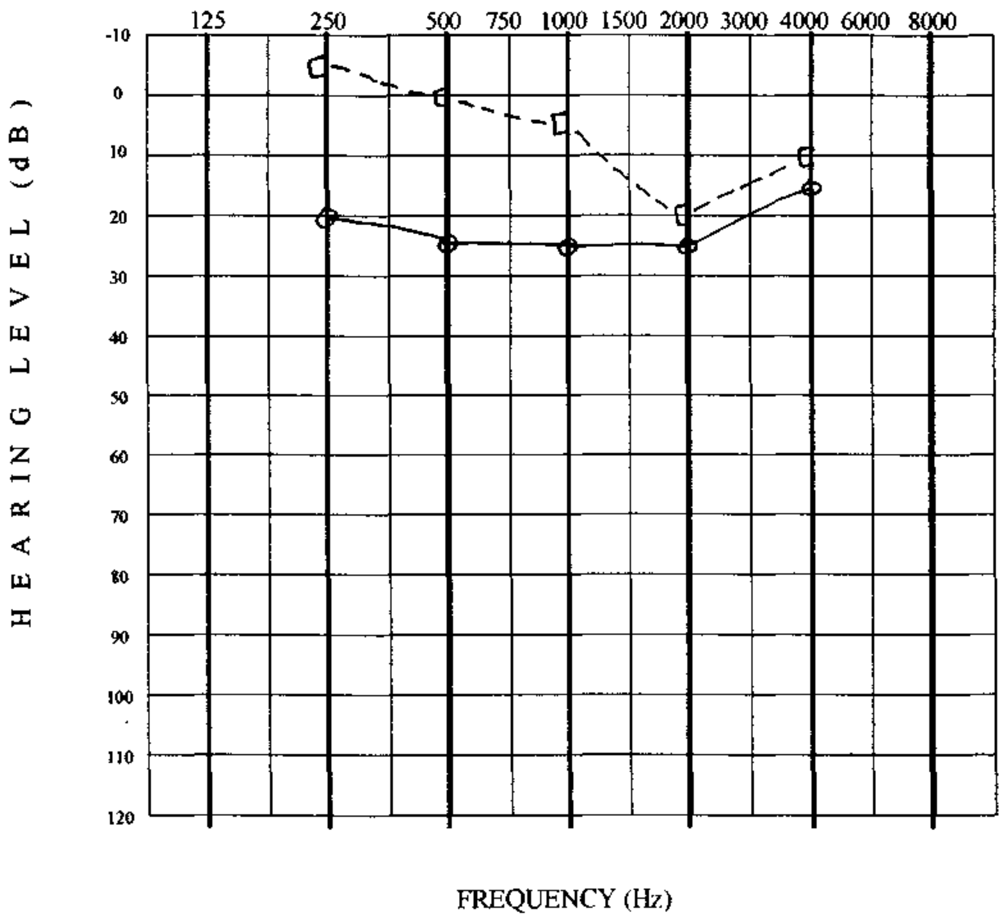
Graph 20: Noise induced hearing loss



- Early otoscleorsis
- Early stapes fixation
- Induces slight stiffness slit in AC audiogram without affecting BC threshold.

(Carhart,1971)

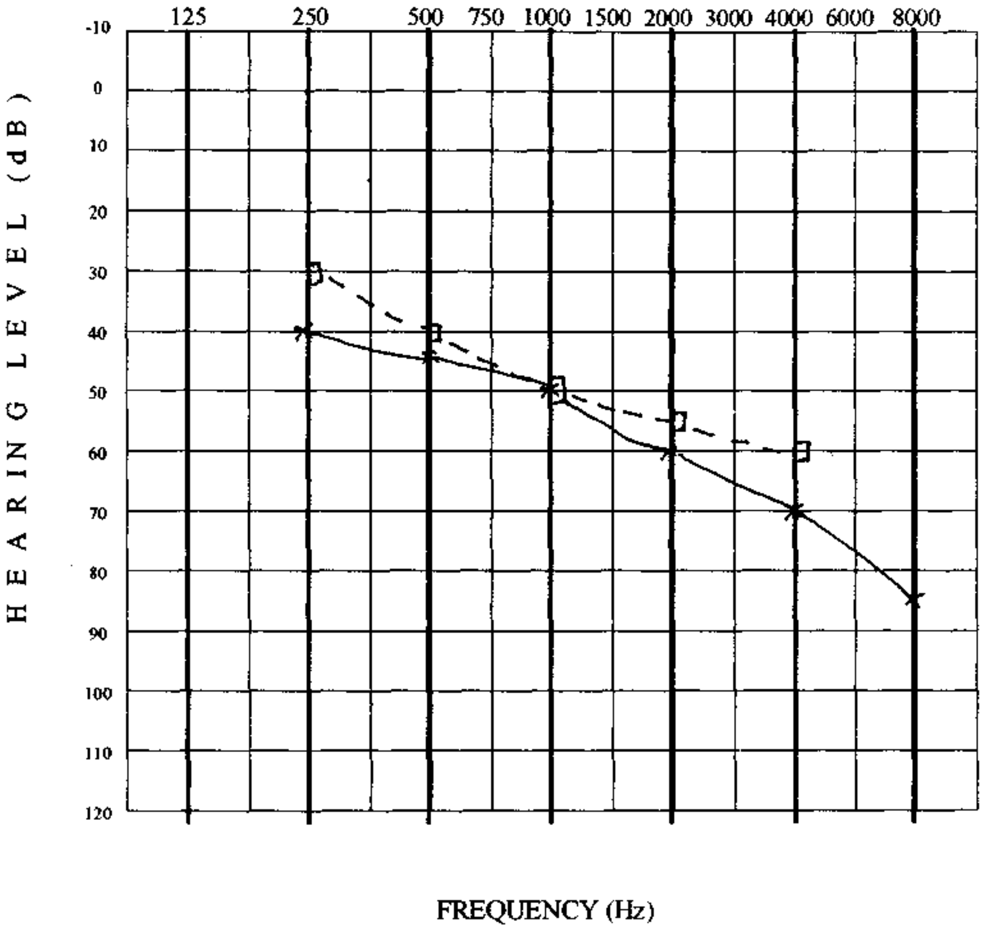
Graph 21: Early otoscleorsis



- Otosclerosis
- Incomplete stapes fixation free from SN Hearing loss
- Mild AC loses and distortion of BC audiogram

(Carhart,1971).

Graph 23: Otosderosis



- Sensory presbycusis
- High frequency hearing loss
- Usually bilateral

(Katz 1978).

Graph 23: Sensory presbycusis

Questions :

I. Match the Following

1	Right head phone	(a)	Red color
2	Frequency	(b)	Type of hearing loss
3	Intensity	(c)	Degree of hearing loss
4	Left headphone	(d)	Modified Goodman
5	Gradually sloping	(e)	Abscissa
6	Severe loss	(f)	Pattern
7	Normal bone conduction	(g)	Initial stages of Meniere's
8	ANSI Specification for degree of hearing loss	(h)	Ordinate
9	Through pattern	(i)	Blue color
10	Rising	(j)	Maternal rubella
11		(k)	Conductive hearing loss

II. Fill in the blanks

1. The darker lines on the graph represent————————interval of frequency while the lighter lines represent————————
2. The————————symbols which mark the points of hearing threshold across the audiogram are connected by solid lines.
3. In case of 'No response' the arrow should point right for——————ear and left for——————ear.
4. A person with pure tone average 55 dB is said to have——————degree of hearing loss
5. A greater loss at mid frequencies than at extreme frequencies is seen in————————pattern of hearing loss.

III. State true or false

1. If a person has a pure tone average of 15 dB he is said to have normal hearing loss.
2. A loss of more than 90 dB is called a moderately severe loss and that above 105 dB a moderate to severe hearing loss.
3. A hearing loss caused not due to the peripheral mechanism but due to the central nervous system is called central hearing loss.
4. The classification of degree of hearing impairment in terms of percentage of loss was given by ANSI.
5. In the flat pattern of hearing loss there is approximately equal degree of hearing loss in all test frequencies.

IV. Questions on plotting of Audiograms

1. Given the diagnosis, plot a probable Audiogram for the same
   a. R - Moderate conductive HL L - Severe mixed hearing loss
   b. R - Profound mixed loss L - Moderately severe SN hearing loss
   c. R - Minimal conductive HL L - Mild SN HL
   d. R - Normal hearing L - High frequency hearing loss

2. Given the case history what are the probable Audiograms that might be obtained in these cases.
   a. A 35 year old woman who complains of hearing loss, after child birth and also has a familial history of conductive hearing loss
   b. A factory worker after 12 years of work experience in a noisy environment complains of hearing loss.
   c. A child with maternal rubella syndrome
   d. A man of age 85 years who complains of gradual hearing loss over the years.

V. Audiogram construction

Instruction:

1. Given the audiometric data, draw a diagram that illustrates the condition use the symbol indicating masking when an asterisks (*) is shown for the following

(a).

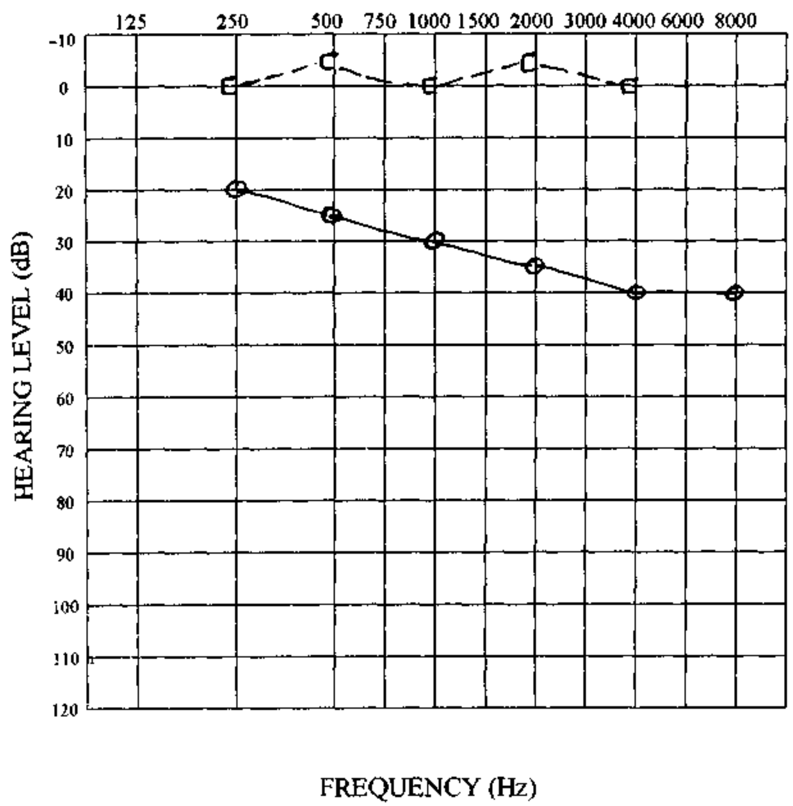
	Right Ear						Left Ear					
	250	500	1k	2k	4k	8k	250	500	1k	2k	4k	8k
AC	40	40	35	40	45	40	35	45	40	40	50	45
BC	-5	0	5	10	0	-	0	0	5	5	0	-

(b).

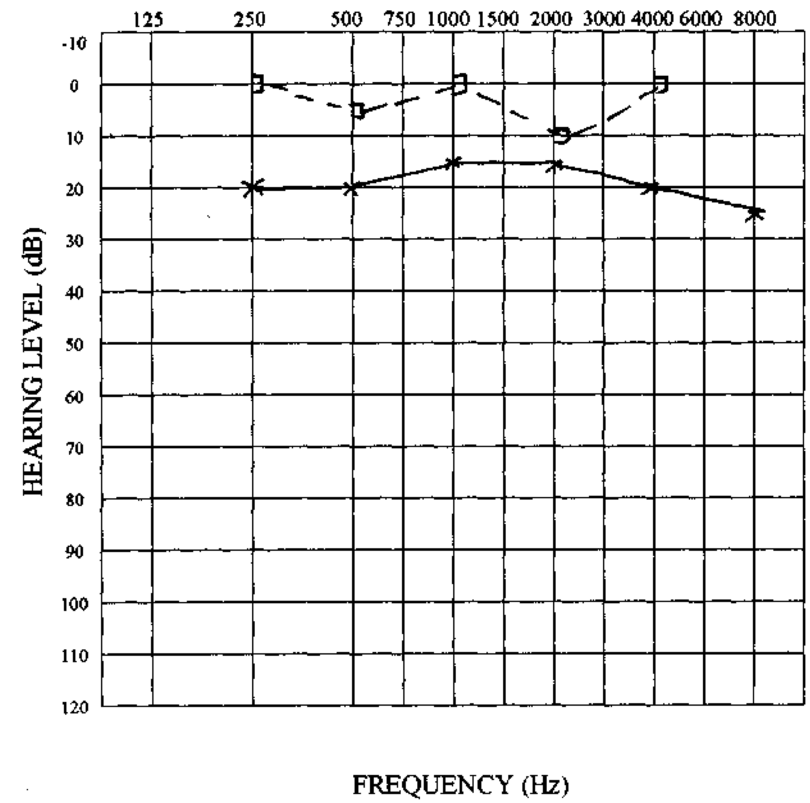
	Right Ear						Left Ear					
	250	500	1k	2k	4k	8k	250	500	1k	2k	4k	8k
AC	0	5	0	0	5	10	5	5	0	-5	0	5
BC	0	0	0	0	5	-	0	5	0	-10	0	-

V. 2. Answer the following with the help of the given information.

Right



Left

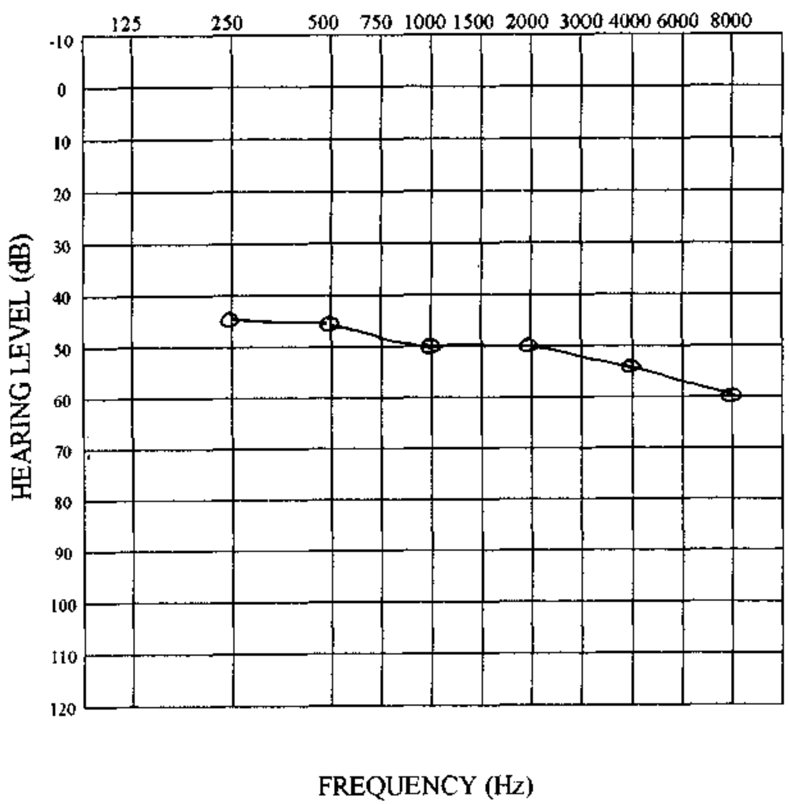


A.

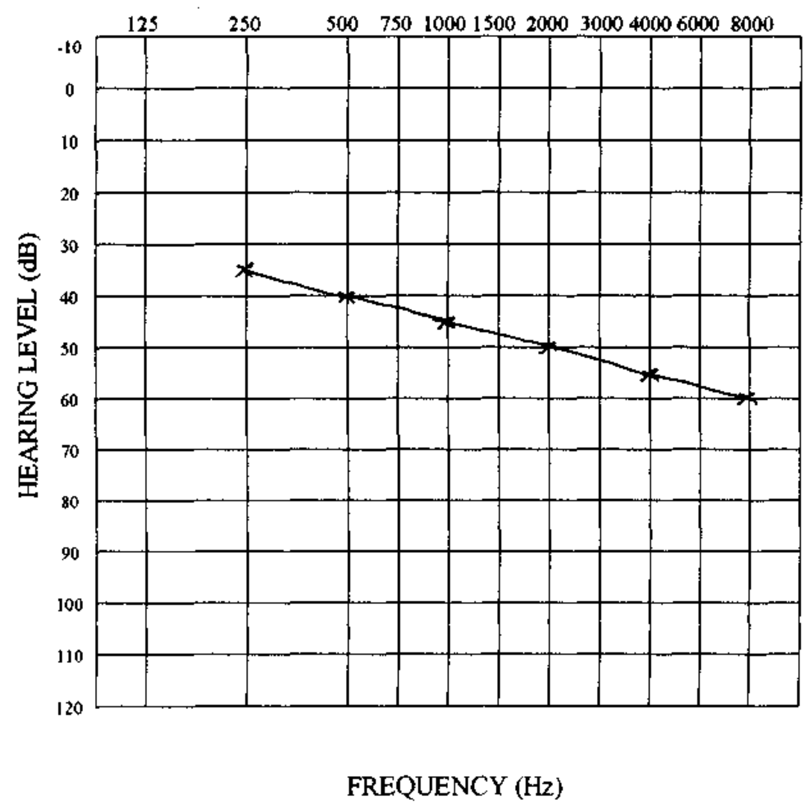
1. What type of hearing impairment does she have?
2. What Audiometric and case history information support your answer

V. 2.

Right



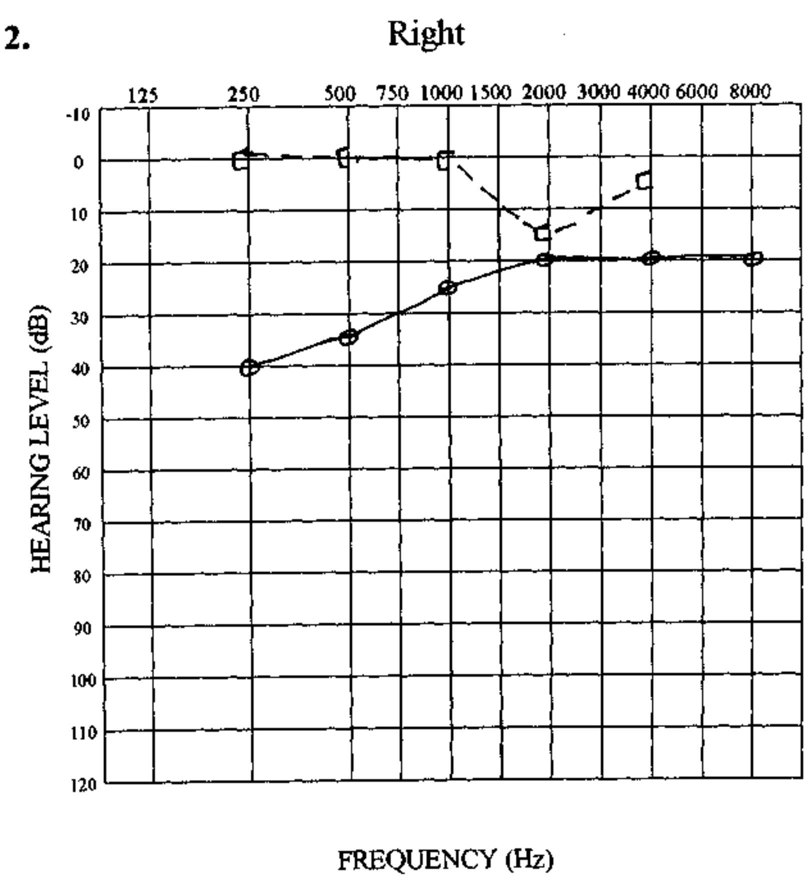
Left

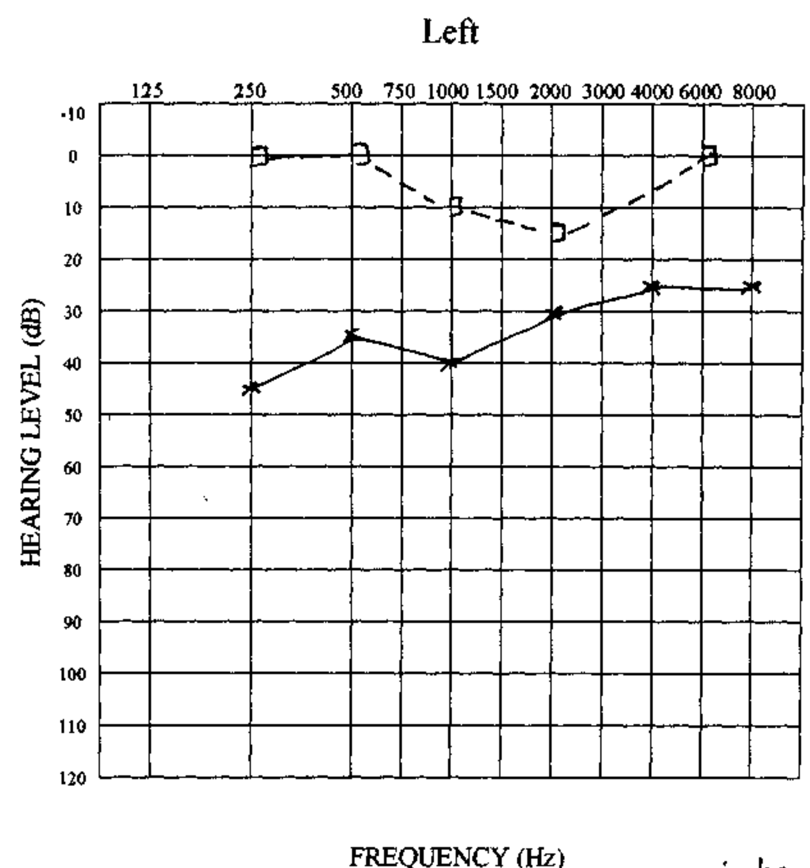


B.

1. Does this client have a hearing impairment
2. What type of hearing impairment is it?

V. 2.



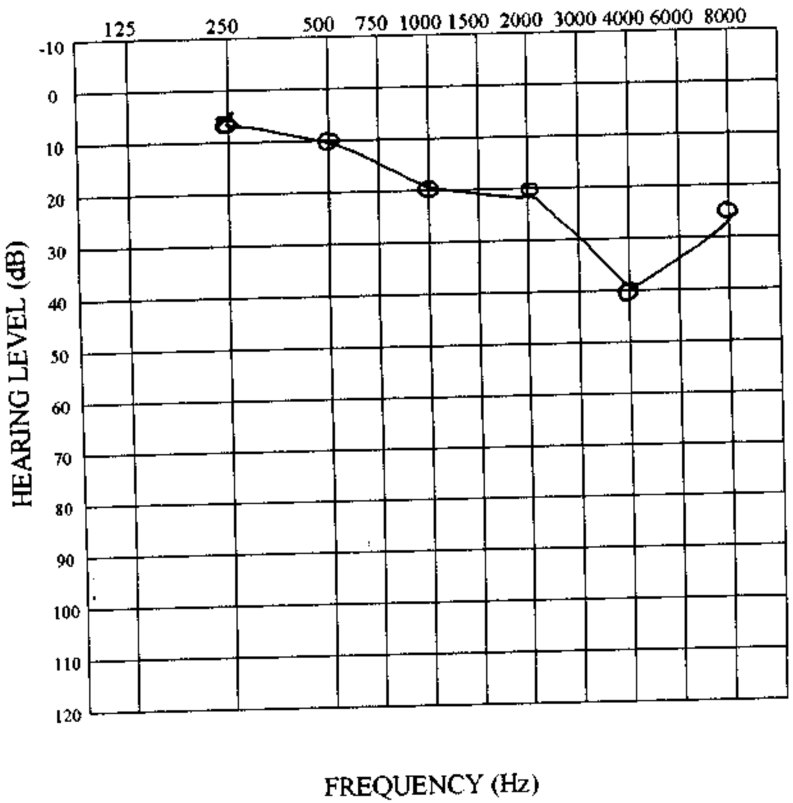


C. Case history information: This woman first became aware of hearing problem, acompanied by constant tinnitus, in her early twenties grandmother, mother, sister & a male cousin developed similar hearing problems.

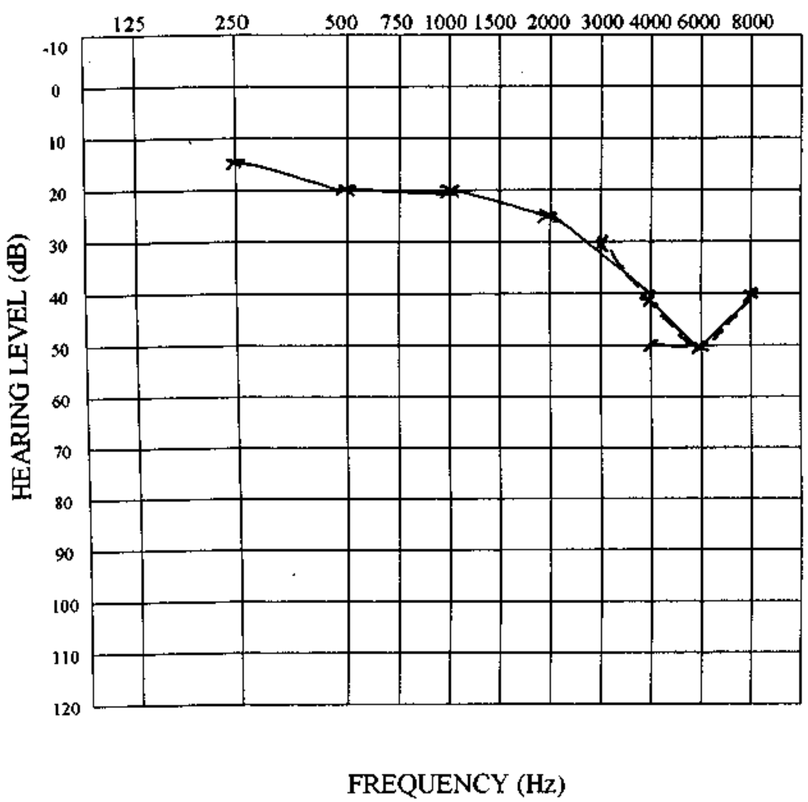
1. What type of hearing impairment does this woman have?
2. What audiometric & case history information support your answer?
3. Calculate pure tone average for both ears.

V. 2.

Right



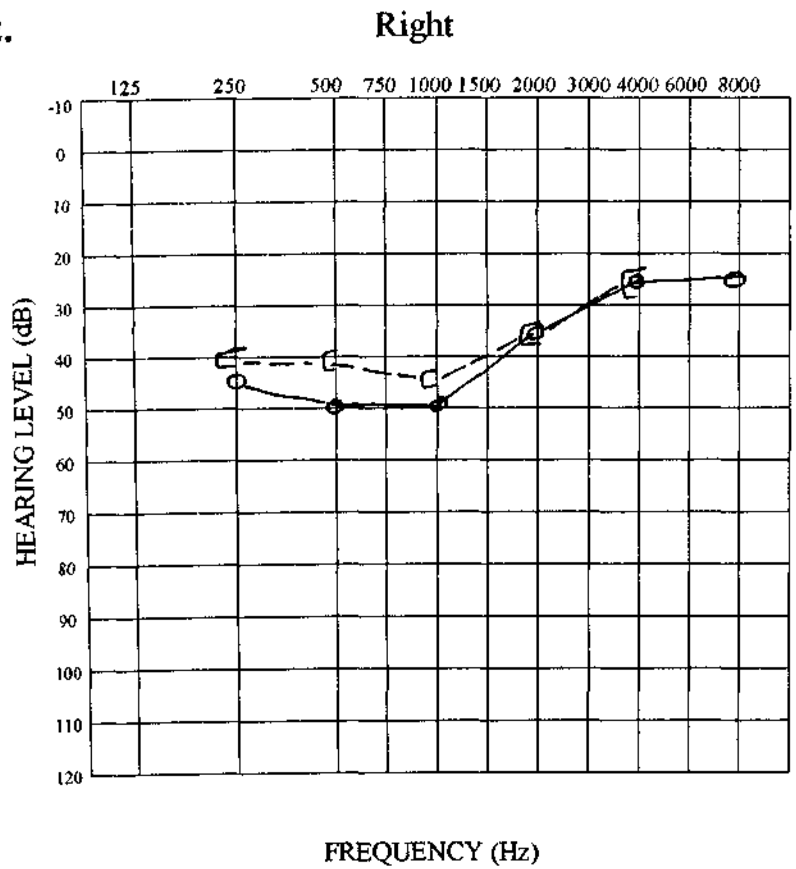
Left

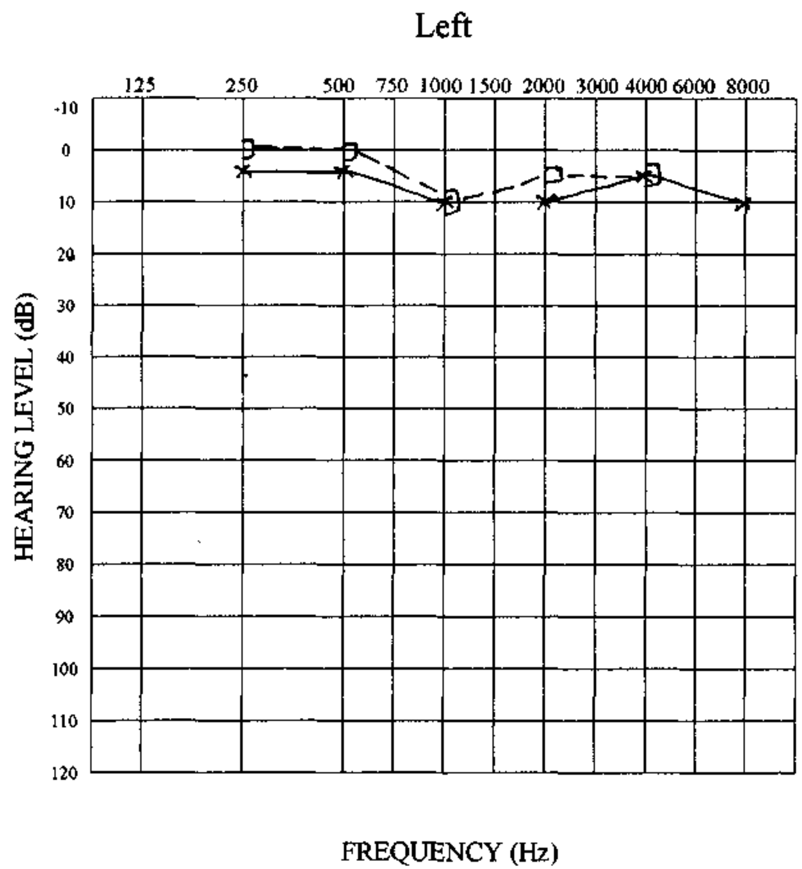


D. Case history information: This man is a victim of the Kargil war, during which he saw active duty. He reports no communicative difficulties but does experience constant high frequency tinnitus in both ears.

1. Describe this man's hearing. What type of impairment does he have ?
2. What type of etiology is suggested by the audiometric configuration and case history information ?
   Congenital Atresia , Serous otitis media, Otosclerosis, Noise induced loss, Meniere's disease

V. 2.



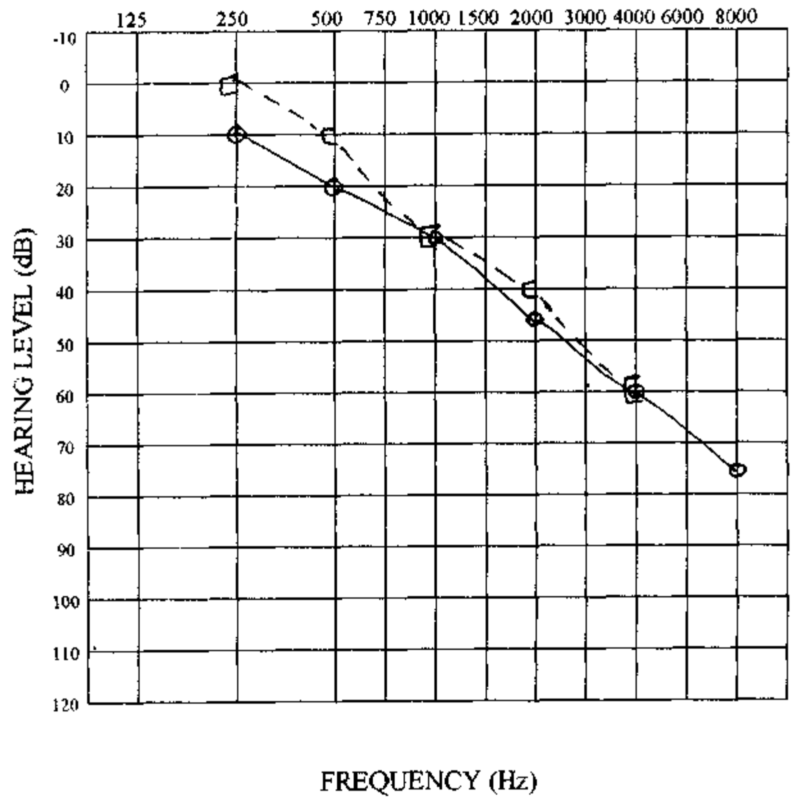


E. Case history information : This woman reports of a history of fluctuating hearing loss in right ear accompanied by an increase in tinnitus that is always present. Severe vertigo and extreme sensitivity to loud sound after the vertigo subsides, the hearing in the right ear improves some what but does not return to normal

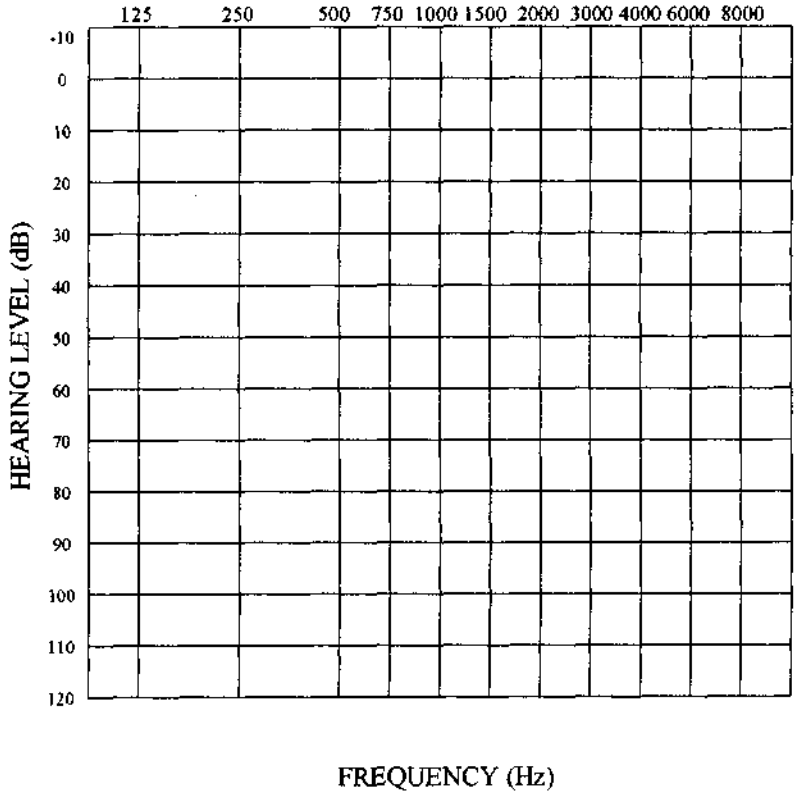
1. What type of impairment does this woman have?
2. What audiometric case history information support your answer to the above question?

V. 2.

Right



Left

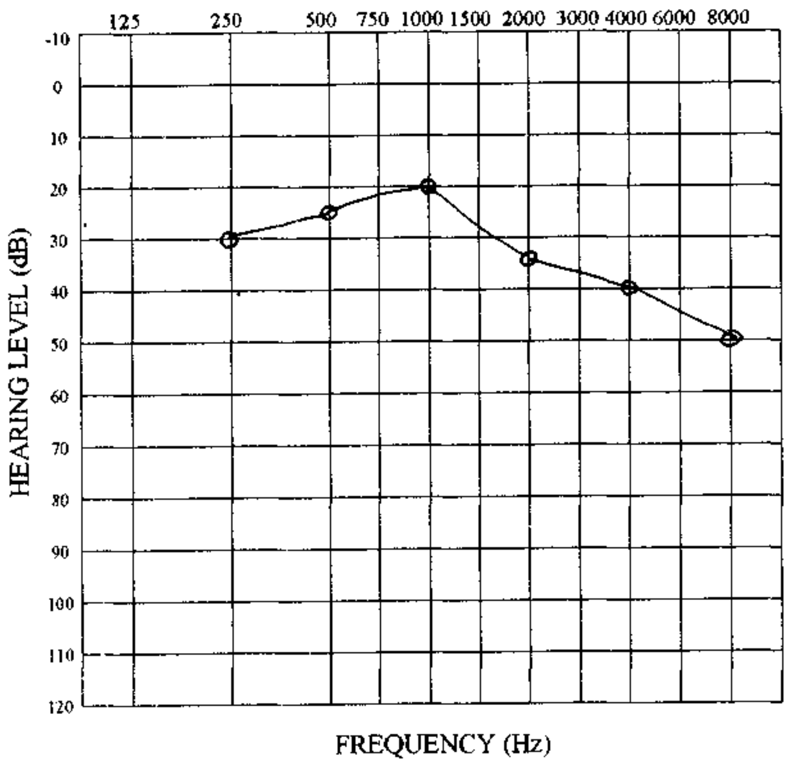


F. Case history information: This man has been aware of a hearing problem for the past 8 years and reports that his hearing has been gradually getting worse. There is no history of earpathology, famalial hearing problems, noise and pressure or oto toxic drugs.

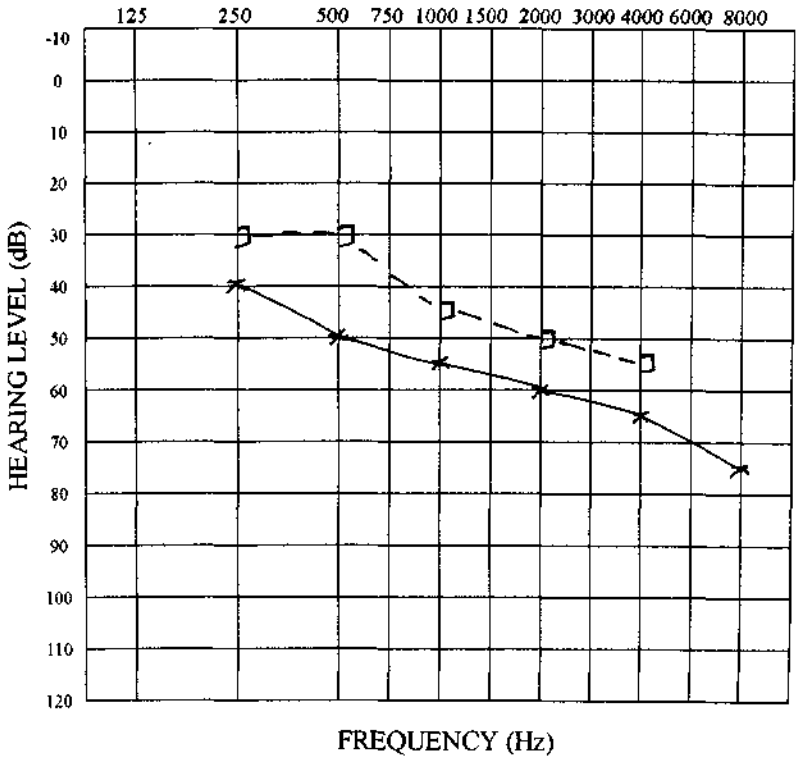
1. What type of hearing impairment does he have?
2. What type of etiology does this audiometric pattern and case history information suggest?

VI. (a). Is the following Audiogram possible ? if not, then why ?

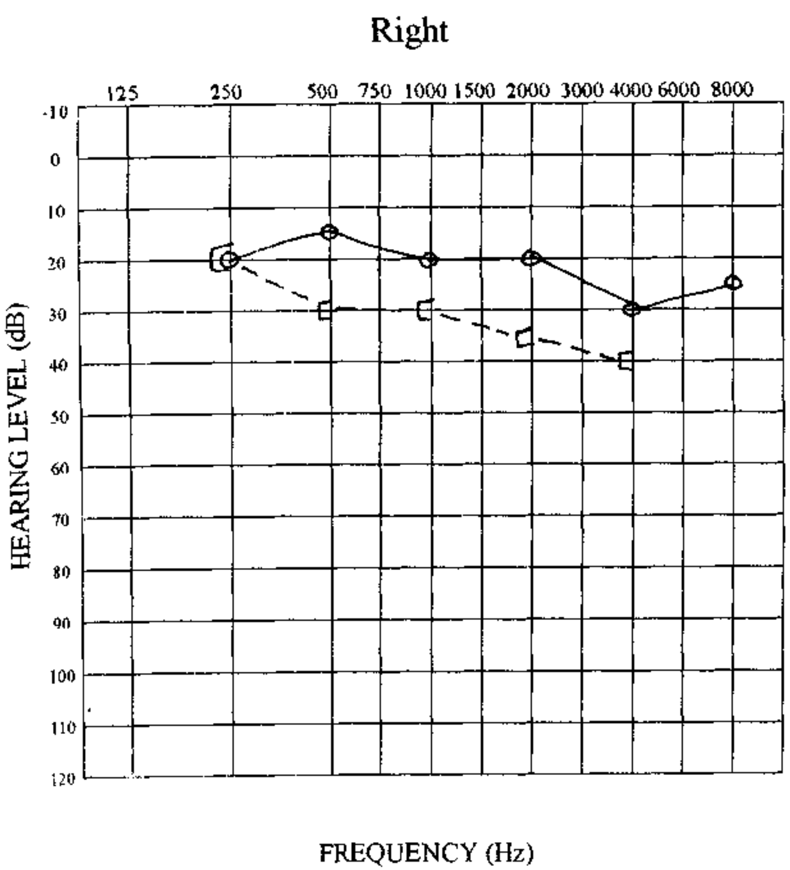
Right

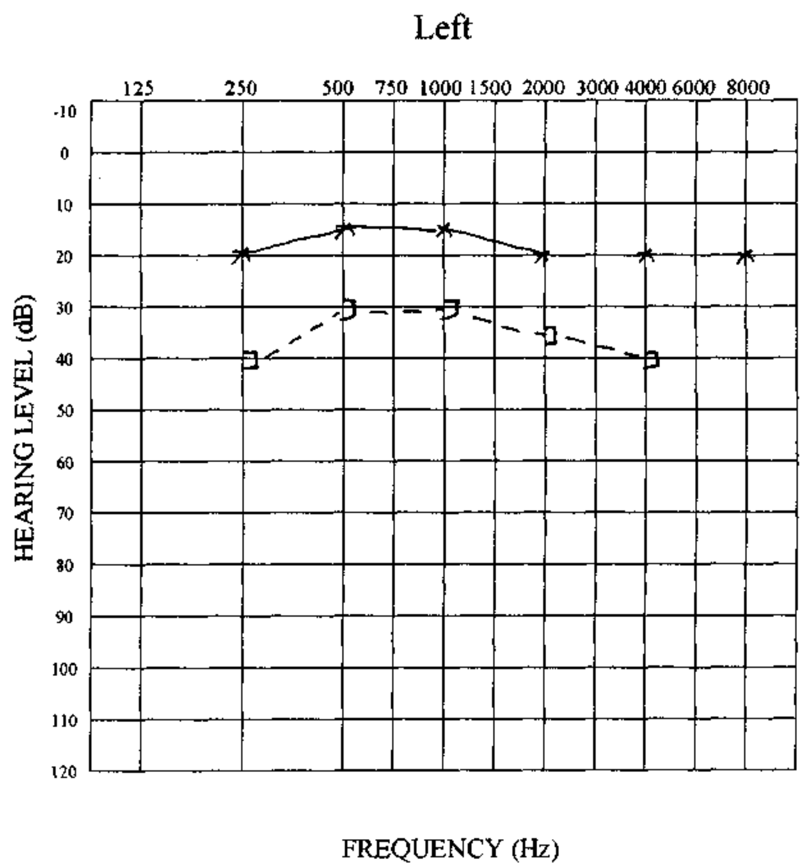


Left

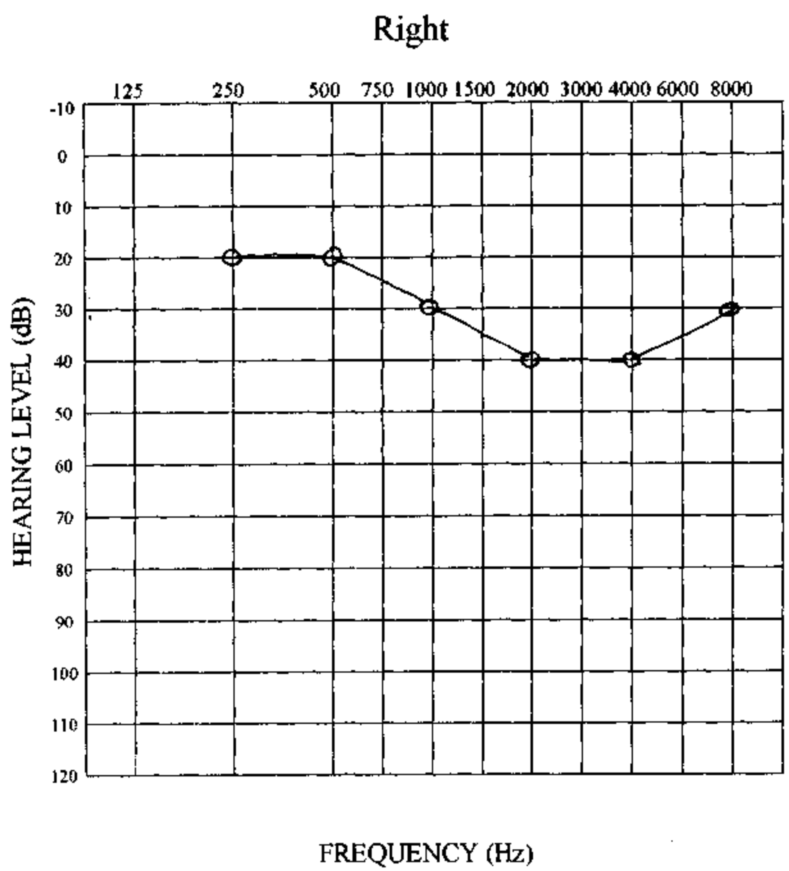


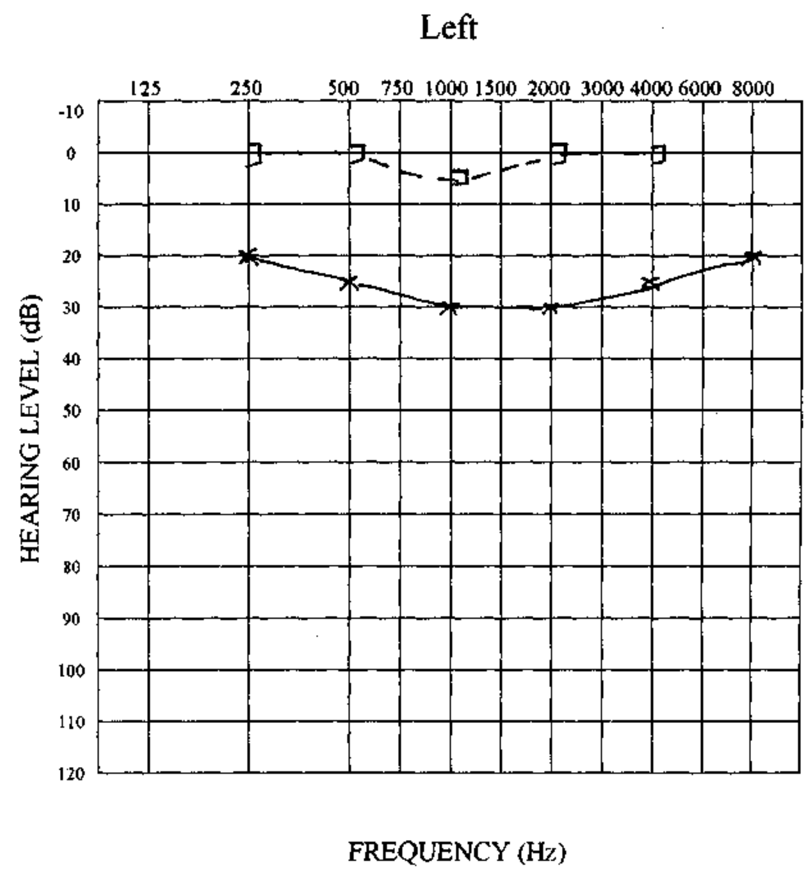
VI (b). Is the following Audiogram possible ? if not, then why ?



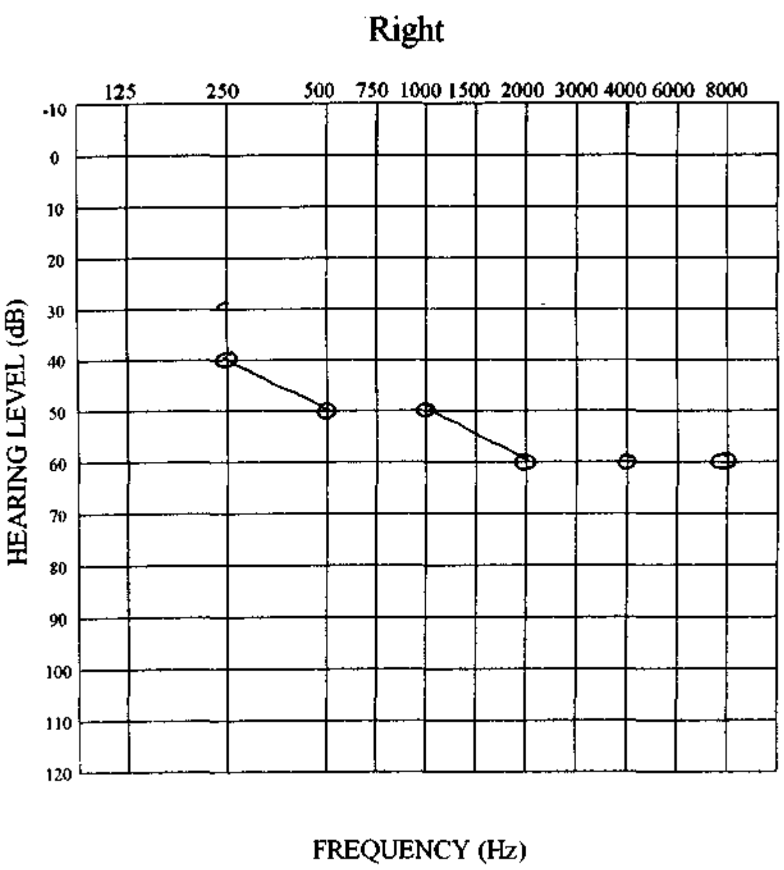


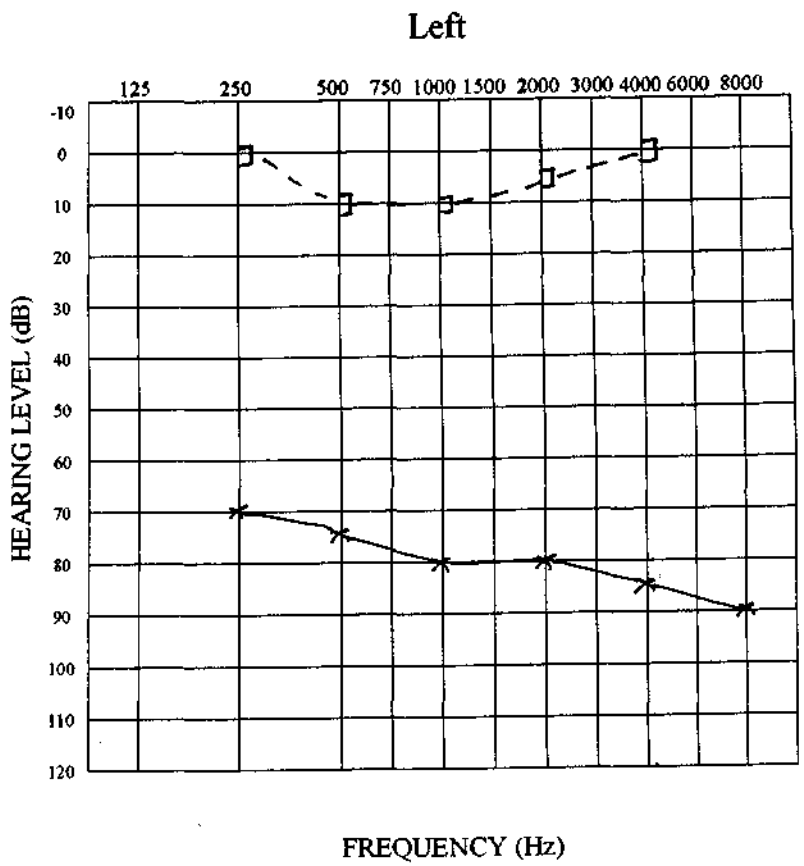
VI. (c). Is the following Audiogram possible ? if not, then why ?





VI. (d). Is the following Audiogram possible ? if not, then why ?





FACTORS AFFECTING AIR CONDUCTION TESTING

There are a number of factors that can influence measures of pure tone threshold. A clinician should be aware of these and take the necessary steps to lessen them or compensate for their effects. A general overview of the various possible sources of error in audiometry may be structured as follows:

A. PATIENT VARIABLES
B. INSTRUMENTATION AND ENVIRONMENTAL VARIABLES
C. CLINICIAN VARIABLES

They may be further classified as

A. PATIENT VARIABLES

1. Physiological factors
2. Psychological factors
3. Pathological factors
4. Physical factors

B. INSTRUMENTATION AND ENVIRONMENTAL VARIABLES

1. Equipment Operation
2. Temperature and Ventilation
3. Calibration
4. Ambient Noise Environment

C. CLINICIAN VARIABLES

1. Placement of headphones
2. Placement of bone vibrator
3. Method of testing
4. Visual Cueing
5. Linguistic factors

6. Rapport
7. Frequency Sequencing
8. Ear selection
9. Listener / Tester position

A. PATIENT VARIABLES

1. Physiological Factors

There are 4 major physiological factors that may affect the testing procedure;

a. Physiological noise
b. Adaptation effect
c. Temporal integration
d. Central masking

a. Physiological noise

Internal noise or physiologic activity linked with vascular, digestive and respiratory functions can establish a "masking floor" below which signal detection is absent even though the organism may be capable of sensation. Random acoustic or neural energy generated within the system including tinnitus can contribute to this result.

b. Adaptation

This is another physiologic phenomenon, which may influence the test result. It is the gradual reduction of the activity in the sense organ when exposed to a constant stimulus of long duration. Using stimulus, which has a duration that is short, can eliminate this.

c. Temporal Integration

This occurs when the duration of a tone pulse influences its audibility and loudness. Nearing thresholds the tone pulse duration must be at least 0.5 sec for maximum audibility

d. Central Masking

This is a phenomenon when the masker presented to one ear causes a threshold shift of signal at the other ear even when the masker signal is too low for it to cross over to the signal ear. This contralateral effect of the masker is most likely due to an interaction of the masker and the test signal within the central nervous system probably at the level of the superior olivary complex. There is an effect or shift of around lOdB due to central masking.

2. Psychological factors

a. The result of the test is greatly influenced by the ability and willingness of the testee to co-operate. This ability may be influenced by factors such as fatigue, worry, anxiety, insecurity or an uncomfortable test room.
b. Distracting events in the test room may also disturb the listener's ability
c. The motivation of the testee during the test
d. False responses may occur which are of two types, false positive and false negative. To reduce or eliminate these effects, the clinician should reinstruct the case, change the method used to obtain thresholds, vary interstimulus intervals, use warble tones etc. Learning effect and psychoacoustic testing learning effects are also present to some degree. In simple detection task learning period is usually quite short, which allows the listener sufficient training before actual testing is started.

3. Pathological Factors

a. Adaptation:

Some patients with marked adaptation associated with retrocochlear pathology will display large intrasubject variability in thresholds, appropriate modification should be employed. To reduce this, such as

a. Use of short stimulus duration
b. Use of lengthened interstimulus intervals
c. Use of ascending approach to obtain the threshold

Collapsed Ear Canal

In some elderly patients, the mastoid process may be ossified, possibly leading to bone conduction thresholds that are more than 15 dB poorer than the air-conduction thresholds at low frequencies. Also, in some there may be ear canal collapse because of decreased skin elasticity in the cartilagenous part of the external Auditory meatus. A quick way to confine whether a potential problem exists is to retest with the earphone elevated slightly from the pinna. If threshold improves, canal wall collapse must be considered.

The various management techniques have been suggested in case of collapsed ear canal

(i) Place pads of gauze or tissue behind the pinna so that the pinna and the posterior canal wall are forced backward when the earphones are replaced.

(ii) Others have recommended inserting into the canal a thick-walled plastic tube, ear stopple, stock earmold or probe tip like those used in immittance audiometry

(iii) Other suggestions include open ear retest in calibrated sound field and substitution of circumaural for conventional supraaural cushions

(iv) Use of insert earphones to test.

4. Physical Factors

a. Standing Waves

The average length of the ear canal is approximately 1.5 inches. The wavelength of an 8000 Hz tone is also approximately 1,5 inches. When an 8000 Hz tone is delivered via the ear phone into the ear canal, and the distance between the tympanic membrane and the earphone diaphragm is approximately 1.5 inches, the reflected wave from the tympanic membrane will be 180 degrees out of phase with the incident wave and cancellation of the wave will take place. This may also occur at around 6000 Hz. Therefore, whenever there is a disparity between the 4000 and 6000 or 8000 Hz thresholds, the presence of standing waves should be suspected and the clinician should readjust the earphones.

B. INSTRUMENTATION AND ENVIRONMENTAL VARIABLES

1. Equipment Operation

a. Inaccurate thresholds may be obtained if the earphone plugs are not plugged into or are incompletely plugged into the correct jack.

b. If there is excessive winding of the phone leads

c. If the earphones are placed on the wrong ear

d. If the transducer and stimulus buttons on the audiometer are incorrect and if the amplifiers have not been activated properly for sound field-testing.

e. Clinicians should be especially suspicious of equipment problems in cases of asymmetrical or unilateral hearing loss or when normal hearing thresholds are obtained despite the patients reporting hearing loss.

f. Make sure that the audiometer is receiving power and that the electric supply is proper for the instrument being operated.

g. Earphone contamination is another common problem Talbot (1969) concluded that the potential for infection was present although there was no evidence of patients incurring infections from the cushions.

The most common way to disinfect earphone cushions is to wipe them off with an ethanol sponge.

2. Temperature and Ventilation

a. High temperature exceeding 85° F and lack of ventilation in the bofrth can affect accuracy of the pure tone thresholds, especially in children. Wilber, (1979).

3. Calibration

a. Lack of accuracy in pure tone thresholds can also stem from inadequate calibration.

4. Ambient Noise

Ambient noise is another source of inaccuracy in audiometric measurement. The noise levels at each octave band should meet specified standards. (Refer to the chapter titled "Standards relevant to puretone audiometry). The table shows the maximum permissible noise levels at each octave band in the audiometric booth used for testing done at 0 dBHL in sound field or by bone conduction.

C. **CLINICIAN VARIABLES**

1. Placement of Headphones

The clinician should ensure that the earphone diaphragm is against the entrance of the ear canal. Variations by a few millimeters up and down or forward and backward can give rise to measurable variation in sound levels reaching the eardrum. The earphones must also fit snugly to reduce the problem of leakage of stimulus around the earphone.

In sound field audiometry, large variations in test sound level may arise in the test room if it is not anechoic. Also, the speakers should be placed at a distance of 1 meter and an angle of 45° from the patient.

2. Visual Cues

Visual cues, such as looking down or making certain body gestures every time the tone is presented or relating to tonal presentation should not be given.

3. Rapport with the patient

A friendly and understanding attitude increases the motivation of the patient.

5. Linguistic Factors

a. Instructions

Instructions should be clear and the clinician should check if they are understood.

The patient may need to listen to some tones or words before the test begins.

The exact phrasing of the instructions is not as important as making sure some concepts are understood.

In order to make sure that the patient understands what he is to do, the audiologist should ask him to repeat the instruction.

b. Language used

The clinician should explain instructions in a language familiar to the testee and tester.

c. Contact:

The clinician should make use of appropriate content words and his length of sentence chosen should not be too long.

5. Ear selection

Normally the test should begin with the ear that appears more sensitive. The presumption is that the better ear will not need retesting in the event masking must be used after the poorer ear is evaluated. Also individuals use better ear advantage for the better ear usually perceives day to day sounds.

6. Frequency Sequencing

The testing should usually begun at 1000 Hz for three primary reasons

a. 1000 Hz is identified perceptually as a pitch familiar to most listeners
b. Thresholds obtained at this frequency tend to be more reliable.
c. All individuals usually have some amount of residual hearing at this frequency.

7. Listener Position

If threshold tests are conducted in a single room, the listener must be seated so that movements of the examiner can not be directly observed but those of the listener are visible to the examiner. It is also important that acoustic radiation does not emanate from the chassis of the audiometer.

8. The personality motivation and experience of the clinician are factors, which may also affect the testing.

Factors Affecting Bone Conduction Testing

Some specific factors which affect bone conduction testing alone are:

A. **Bone vibrator placement**

The bone vibrator must be placed on the mastoid process no closer than a thumbs width to prevent acoustic radiation. Mastoid placement is also recommended over frontal bone forehead placement because the reference level in ANSI S3.26 (1981) are based on mastoid placement and the dynamic range is larger for mastoid than forehead placement. The frontal site is advantageous in that it has smaller inter and intra subject variability and it excludes the contribution of the middle-ear inertial-ossicular component of bone conduction.

1. **Headband tension**

Hearing sensitivity changes sufficiently with change in headband tension, which is less when the tension is around 750 gms. The recommended value, as per the ANSI (1969) Standards, for the headband tension of the bone vibrator is 550 gms or 5.4 N.

2. **Surface area**

More the surface area, more the acoustic radiation. Also, there are more chances of getting tactile sensation at higher levels. Hence the ideal surface area or the contact area of the bone vibrator is 1.75 cm ±'25 mm2 ANSI (1969).

3. Type of Bone vibrator

The type of bone vibrator may also influence the bone conduction testing. For example, the old radio ear B-70 series has a contact area larger than the recommended value. Also, acoustic radiations or aerial radiation at high frequencies is a common problem associated with the B-71 and B-72 bone vibrator.

B. Occlusion effect

The occlusion effect is the improvement in the bone conduction threshold when the external ear is covered by an ear phone or when the ear canal is occluded by a finger, ear insert, earmold, ear protector over the unoccluded bone conduction threshold (Studebaker (1979). The occlusion effect occurs primarily at low frequencies and is an average of 20 dB at 250 Hz, 15 dB at 500 Hz, 10 dB at 1000 Hz and 0 dB at 2000 Hz and above (Goldstein and Hayes, 1965 ; Martin, Buttler and Burns, 1974).

C. Effect of Middle Ear Pathology on Bone Conduction Thresholds

1. Ossicular Fixation

The bone conduction threshold is often elevated at frequencies around 2000 Hz in patients with ossicular fixation, referred to as the carharts notch (Carhart, 1950). The elevation occurs because of the loss of the middle-ear inertial-ossicular component of bone conduction. The carhart notch occurs approximately at 2000 Hz since, in humans, the ossicular chain resonates at 2000 Hz. The classical carhart notch usually shows a bone conduction thresholds of approximately 15 dBHL.

2. Otitis Media

In otitis media, the bone conduction thresholds are decreased at the low frequencies and increased at high frequencies (Huizing, 1964; Hulka, 1941; Naunton and Fernandez, 1961; Liden and Kim, 1984). According to Huizing (1964), Hulka, (1941), Naunton and Fernandez, (1961) the attenuation in bone conduction threshold is related to resonance changes because of mass loading of the middle ear system.

D. Physiological Factors

1. In geriatric, ossification of mastoid area leads to a decrease in the bone conduction sensitivity due to which the BC thresholds may be poorer than AC thresholds by more than 15dB .
2. In some patients with mastoid abnormalities, good bone vibrator placement may be difficult. In such cases, the clinician should place the vibrator on the better mastoid or move the bone vibrator around the mastoid process or on the forehead with the tone continuously on until a site is reached where the tone is loudest.

QUESTIONS

I. Match the Following

1. Physiologic noise	(a) Clean and precise instruction
2. Psychological factor	(b) insert earphones
3. Retrochochlear pathology	(c) 8000 Hz
4.Ear canal collapse	(d)power supply
5. Standing waves	(e) 1000 Hz.
6.Equipment operation	(f) Better ear advantage
7. Inadequate calibration	(g)Lack of accuracy
8. Linguistic factor	(h) Adaptation
9. Ear selection	(i) Neural activity
10. Residual hearing.	(j)Motivation
	(k)B-71 bone vibration

II. Fill In The blanks

1. Placement of the bone vibrator on the___________position is preferred over _____________position.
2. The effect of central masking is approximately___________dB.
3. False responses can be of two types______________and________________.
4. Speakers should be placed at a distance of_____________and an angle of

5. The standard vaives for headband tension & contact area of the bone vibrator are___________and_____________.

III. State whether true or false.

1. The occlusion effect is seen more for higher frequencies.
2. In psychoacoustic testing learning effect is always present to some degree.
3. High temperature exceeding 86°F can affect accuracy of measurement.
4. As per standards the ideal headband tension for the bone vibrator is 5.9 N and the approximate surface area is 50cm
5. The elevated bone conduction threshold at around 2000 Hz is after referred to as Carharts notch.

IV. Find the 10 factors, which are known to affect air and bone conduction thresholds.

L	A	N	A	C	R	A	E	D	E	S	P	A	L	L	o	C	C	M	E	E	O	C
A	A	R	F	I	L	O	S	T	I	o	N	L	T	C	I	M	O	I	F	E	C	E
P	R	A	U	G	Y	I	T	I	E	c	M	A	O	M	A	E	T	T	I	L	c	U
I	I	S	T	L	U	N	O	I	T	I	S	0	P	R	E	N	E	T	S	I	L	Q
C	T	T	S	A	R	T	T	I	N	M	E	L	o	O	G	I	T	U	L	E	U	c
K	A	I	I	M	A	A	A	M	E	s	T	I	c	I	M	I	E	T	O	S	s	o
T	T	C	L	I	T	P	R	M	E	T	I	C	o	C	P	Q	U	R	I	E	I	T
U	U	Q	U	T	U	R	E	G	F	H	I	J	K	L	L	M	N	O	R	S	o	F
M	R	B	o	N	E	V	I	B	R	A	T	0	R	P	L	A	C	E	M	E	N	T
I	I	Q	u	O	M	R	I	M	E	O	L	K	O	S	I	T	I	F	E	R	E	I
T	C	O	p	I	I	A	R	O	Q	P	T	U	R	P	M	I	N	I	L	A	F	L
A	Q	U	E	T	T	M	I	s	u	U	Q	M	S	I	T	T	J	A	O	L	F	N
L	A	T	C	A	A	K	A	T	E	o	O	I	N	A	O	0	U	N	T	0	E	A
0	S	P	I	R	R	N	I	M	N	M	E	S	O	L	L	Y	K	C	I	P	C	E
P	s	0	R	B	U	T	R	W	C	A	R	E	T	T	L	U	F	C	O	s	T	T
R	E	T	A	I	P	E	A	T	Y	R	A	K	M	I	T	L	A	M	I	N	R	O
S	T	I	S	L	E	M	U	Q	S	E	V	A	W	G	N	I	D	N	A	T	S	T
S	A	N	o	A	T	P	E	p	E	A	T	E	I	T	R	T	E	S	M	I	A	M
p	I	T	I	C	M	E	L	u	Q	J	P	O	K	S	E	F	I	G	U	S	T	I
E	L	A	M	E	I	R	I	T	u	K	L	E	M	E	T	R	U	R	T	E	E	L
S	E	F	E	G	E	A	R	S	E	L	E	r[1]	T	1	O	N	o	M	I	L	M	K
s	R	O	G	U	E	T	I	N	N	E	S	s	F	A	T	E	E	T	I	S	I	A
T	W	I	G	M	A	U	U	L	C	Z	O	T	X	T	S	M	N	O	P	Q	C	T
I	I	N	E	T	I	R	A	S	I	A	L	I	V	U	R	E	M	A	C	I	A	I
C	F	R	O	G	I	E	I	M	N	O	I	T	A	V	I	T	O	M	A	N	D	R
M	R	O	T	I	C	A	T	I	G	T	E	M	I	c	A	L	I	O	N	E	E	O

CLINICAL MASKING IN PURE TONE AUDIOMETRY

In its simplest term masking may be referred to, as, the noise which is presented to the non test ear (i.e., NTE) to elevate threshold in that ear. It may be defined as " Masking is the term given to the psychoacoustic phenomenon where the threshold of audibility is raised by the presence of another auditory stimulus".

WHY IS MASKING NECESSARY

Masking is used in order to make certain that the test tones are perceived only in the ear that is being tested, i.e., to prevent the responses of the non test ear from contaminating the responses of the test ear.

Therefore masking should be done in order to prevent the occurrence of

(i) Cross hearing or

(ii) Shadow curve

(i) Cross hearing

In unilateral hearing loss cases or asymmetrical bilateral hearing loss cases, when we present a tone to the poorer ear, it may be transferred and heard in the better ear well before reaching the threshold of the poorer ear. This is called cross hearing.

According to O'Niell & Oyer (1970) this transfer may be due to

(a) Aerial radiation or radiation through air transmission

(b) Through the headband or earphone.

(c) Bone conduction or transmission through bones of the skull which is well accepted & used in clinical masking

(ii) Shadow curve

From the above paragraph we come to know that the possibility exists that, the patient is hearing the tone in the NTE or his "good" ear even though we are presenting tone to the poorer ear. The response curve, thus obtained, by participation of the NTE with out masking is false & gives rise to a shadow curve.

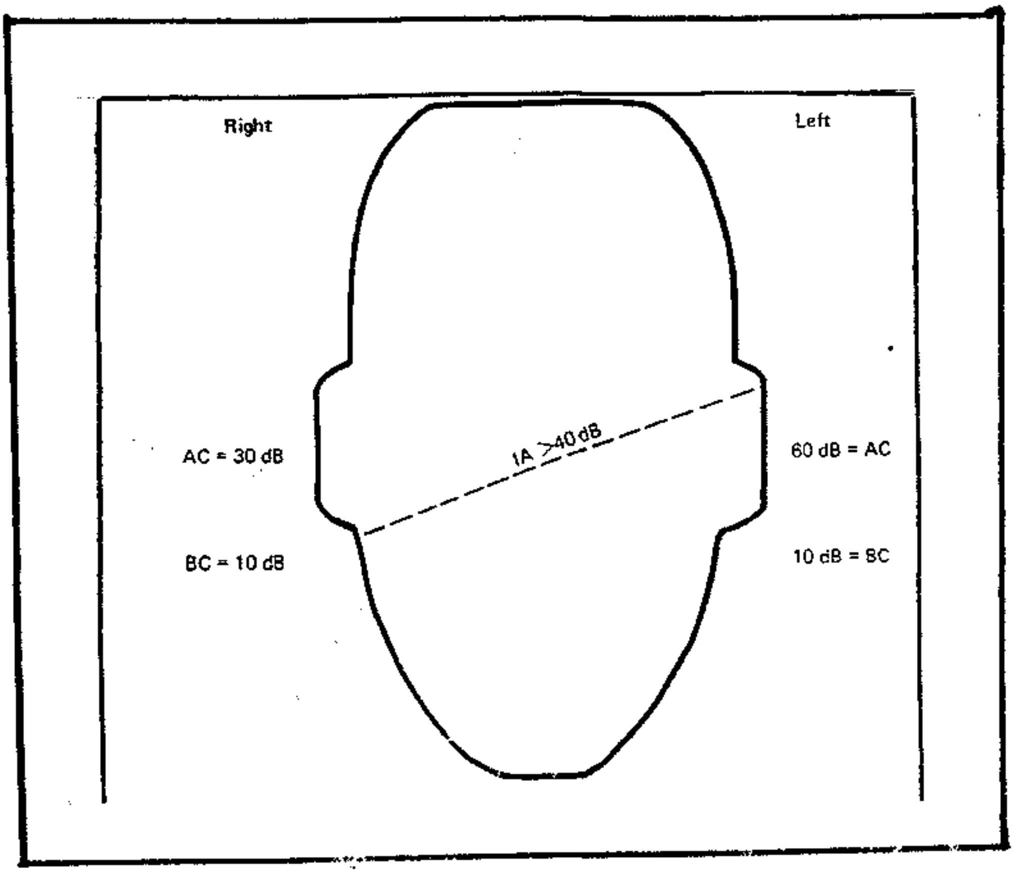


Figure 9: An example of cross hearing

This phenomenon of cross hearing & of the shadow curve depends on the following factors:

(i) Presentation level of the test signal (PL)

(ii) Inter-Aural Attenuation (LA)

(iii) Threshold sensitivity of the non test ear (BCNTE)

$$\text{i.e., PL-IA} \geq BC_{NTE}$$

- cross hearing will take place.

The IA varies depending on the mode of sound transmission & transducer used.

Accordingly the minimum IA that has been calculated is as follows

Headphones: 40 dB

Ear insert: 70 dB

Bone vibrator: 0 dB i.e., because the test signal stimulates both cochleae with approximately equal intensity regardless of the placement of the bone vibrator.

WHEN TO MASK?

The decision about 'when to mask' will vary depending on whether, we are masking the air conduction or the bone conduction.

For Air Conduction

It is necessary to mask AC whenever the air conduction presentation level at the test ear exceeds the bone conduction threshold of the opposite ear by more than the smallest inter aural attenuation value (Studebaker, 1967).

Symbolically it is represented as

$$PL - IA \geq BC_{NTE}$$

The minimum IA for headphones is 40dB therefore

$PL-40 \geq BCNTE$ or $PL-BC_{NTE} \geq 40$ dB

For example: Consider a left ear with threshold 45dB & a right ear with threshold OdB. If the headphones are being used, the IA is 40 dB. Therefore the presentation level i.e., 45 dB is greater than the BC of the non test ear i.e., 45 dB is greater than the BC of the non test ear i.e., -5dB. Therefore by applying the formula we get

= PL- BCNTE

= 45-(-5)

= 45+5

=50 i.e., > 40 dB therefore masking is required.

For Bone Conduction

Studebaker (1964) recommends masking should be used any time the bone conduction thresholds are better than air conduction thresholds in the ear being tested by more than 10 dB . Symbolically that is,

$$PL - BC_{NTE} \geq 10.$$

Since, bone conduction involves the stimulation of both cochleae the question of which ear to mask becomes difficult to answer. For this reason it has been suggested that the Audiometric Weber test be used to determine which ear to mask during bone conduction testing, which is, the ear to which the individual lateralises.

It is expected that tones will be referred to the poorer hearing ear in a conductive loss to the better ear in a sensorineural loss & to the midline in a symmetrical loss.

METHOD FOR MASKING

There are several methods used for masking, however, the "plateau seeking method" given by Hood is the most preferred method.

Hood (1960) first reported this technique. It is called threshold shift procedure, shadowing method. It consists of the following steps.

1. Whenever the danger of cross hearing is indicated calculate minimum effective masking level & introduce noise in the better ear.

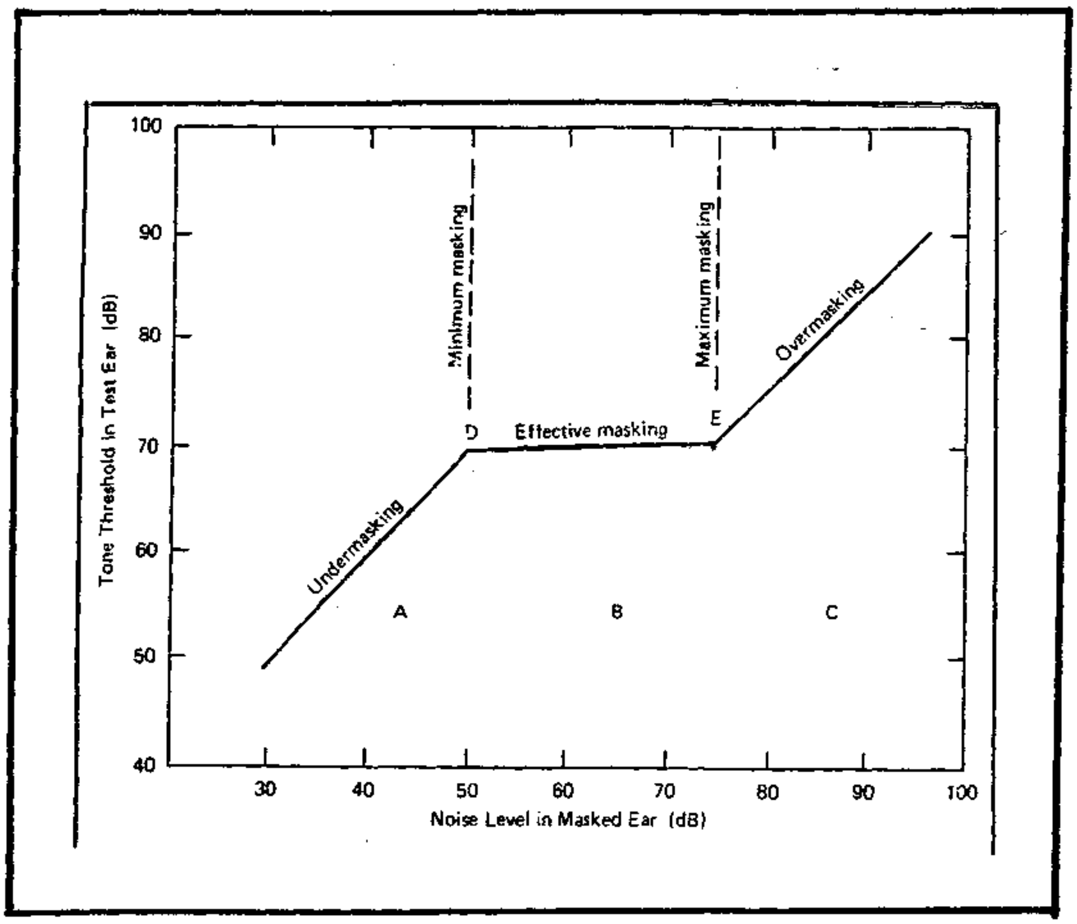
2. Reestablish threshold in the test ear, if there is no threshold shift non-test ear is not participating. If there is a threshold shift, note down the level at which the subject responds & the level of the noise and proceed to the next step

3. Increase the level in the non-test ear by 5- 10 dB & again note the level at which he responds & the level of the noise.

4. The process should be repeated until the subject shows no further shifts of the threshold with increase in noise in the better ear. When the level of the noise can be increased several times (20-30 dB) with out

shifting the threshold in the test ear, the plateau' has been reached. The level at which plateau was reached is the threshold.

5. Further increases in noise will shift the threshold again. This is due to over masking.



Graph 24: Indicating Hood's piateau seeking method

HOW MUCH TO MASK?

The effectiveness of the amount of masking is determined by 2 factors

(A) The Minimum Effective Masking Level

(B) The Maximum Effective Masking Level.

(A) The Minimum Effective Masking Level. (Min.E.M.L.)

It is the minimum amount of noise in the NTE, which is just sufficient to mask a pure tone that might appear in the NTE because of cross hearing. In short, the noise level just sufficient to mask the test signal in the ear to which noise is presented. This is mainly done to avoid under masking.

The minimum effective masking level for air conduction /bone conduction is determined by the following factors:

(i) The level of the test tone reaching the cochlea of the non-test ear i.e., PL -IA.

(ii) Effective level of masking (usually 0 dB as all diagnostic audiometers are calibrated in effective masking level)

(iii) Air bone gap in the NTE. For air conduction & air bone gap in the non test ear/occlusion effect for bone conduction. This occlusion effect is added when the air bone gap is 10 dB in the NTE. This alters the S/N ratio in the NTE as noise is perceived though the air conduction mode & tone is perceived through the bone conduction mode. Hence, this much more noise needs to be added even in the case of bone conduction. Bone conduction sensitivity increases due to occulsion effect resulting in a change in the S/N ratio. Hence occlusion effect needs to be added to the minimum effective masking level when air bone gap in the NTE is absent

(B) The Maximum Effective Masking Level. (Max.E.M.L.)

It is the highest level of noise that can be presented to one ear via a transducer before the noise crosses the skull & shifts the threshold of the opposite ear (Martin, 1975). In order to calculate the Max.E.M.L. we must try to avoid over masking which can be defined as,

When ever the level of effective masking presented to the masked ear minus the patients' inter-aural attenuation is above the bone conduction threshold of the test ear, a sufficient amount of noise is delivered to the inner ear of the test ear to elevate it's threshold. This is called over masking & is given by the formula

$$EM_{NTE} \geq BC_{TE} + IA$$

Maximum effective masking level is equal to the threshold of the test ear by bone conduction i.e., BC_{TE} plus the IA minus 5 dB (Martin 1975).

$$Max.EML = BC_{TE} + IA - 5$$

QUESTIONS

1. Choose the right one

1.To measure inter-aural attenuation when masking for bone conduction one may use

(a) Sound field

(b) Insert receivers

(c) Hearing aid

(d) Standard receivers

2. Cross hearing is a possibility during pure tone air conduction tests when,

(a) SRT_{TE} - 35 dB = BC_{NTE}

(b) $ABG \geq 10$ dB

(C) $AC_{TE} - IA > BC_{NTE}$

(d) AC_{TE} - BC_{NTE} = ABG

3. The energy lost as sound travels from one ear to the other is called

(a) Inter-aural attenuation

(b) Cross hearing

(c) Contralateralisation

(d) Lateralisation

4. Minimum effective masking for bone conduction at 250 Hz is

(a) $EM = AC_{TE} + OE$

(b) $EM = ACNTE + OE$

(c) $EM = ACTE - IA$

(d) $EM = AC_{N}TE - IA$

5. The formula for maximum effective masking level is given by the formula

(a) $Max\ EML = BCNTE + 5 + IA$

(b) $Max\ EML = BCTE - 5 + IA$

(c) $Max\ EML = BC_{TE} + 5 + IA$

(d) $Max\ EML = BC_{NTE} - 5 + IA$

II. Fill in the Blanks

1. When a tone presented to the poorer ear is heard in the better ear well . before reaching threshold of poorer ear then__________takes place

2. The response curve obtained by the participation of the NTE, without masking is called__________

3. The minimum IA for head phones, Insert receiver and Bone vibrator is --__________? and__________dB respectively.

4. The method given by Hood for masking is also called the __________ method.

5. In the__________test the ear to which the persons lateralises is to be masked.

III. Unscramble the letters to find terms relevent to masking.

1. gorcshanies
2. niaratoelariade
3. vsudcwroae
4. anretnoiantett alranui
5. dgkenieohutamlaepet
6. wadtrerieiopcnb
7. lponitserevelnat
8. gbpanrieoa

IV. In the following cases would masking be necessary? If yes what masking is required?

1.

	AC	BC
R	40	
L	20	10

2

	AC	BC
R	60	25
L	70	

3.

	AC	BC
R	15	0
L	60	0

4.

	AC	BC
R	55	
L	50	50

TRANSDUCERS

Bone Conduction Vibrators

The requirements for the physical characteristics of an idealized bone receiver were generally well described by Lierle & Reger (1946). The characteristics being,

(i) A mechanical design that will stand up under continued & rough usage without change in calibration

(ii) Extension of the frequency range to values near or coincident with the normal upper limits of audibility

(iii) Freedom from overtones

(iv) Freedom from the effects of differences in pressure when the vibrator is held against the head. & a wide ac.-b.c. differential.

Sanders & Olsen (1964) have reported undesirable harmonic distortion at low frequencies for a hearing aid-type vibrator.

Both national & international standards recommend that bone vibrators used in audiometry have a plane circular contact tip area of 1.75 $cm^2 \pm 5\ mm^2$. The old radioear B-70 series vibrators have contact tip larger than recommended by current standards. The newer radio ear B-71& B-72 vibrators contain contact tips corresponding to the current standards for bone conduction audiometry.

The physical output of the B-72 is significantly greater at 250 Hz than other bone conduction traducers. The figure on the next page shows examples of the frequency responses of two bone-conduction vibrators.

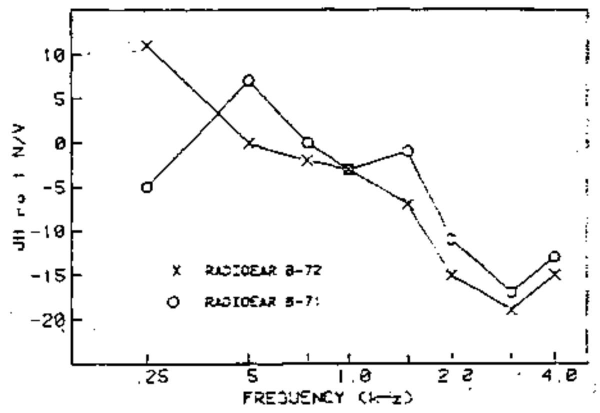
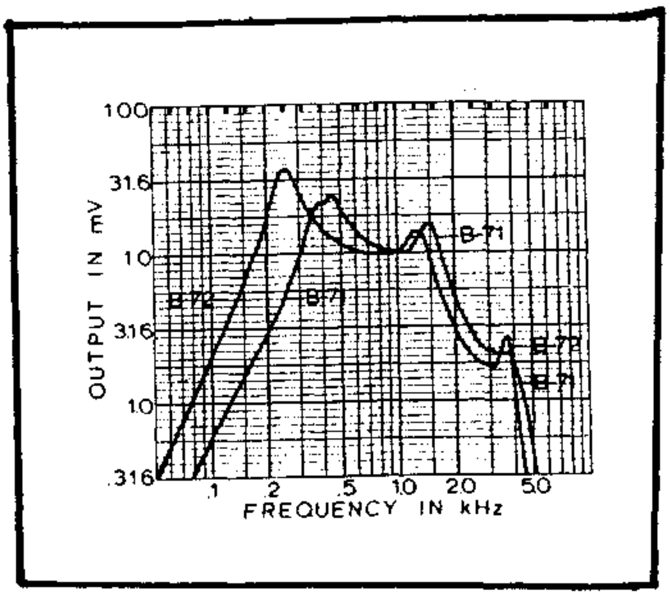


Figure 9.5. Frequency response of Radioear B-71 and B-72 bone vibrators in dB *re* 1 N/V as measured on a Bruel and Kjaer 4930 artificial mastoid.

Graph 25: Frequency Response of B-71 and B-72 bone vibrators in dB re: 1N/V as measured on a Bruel and Kjaer 4930 artificial mastoid.

The resonance of the B-72 vibrator is found at a lower frequency (250 Hz) than for the B-71 vibrator. Thus the output is greater for the B-72 at 250 Hz; increasing the potential dynamic range for testing & reducing the harmonic distortion.

Frequency response curves were obtained for a radioear B-71 bone vibrator with a revised Bruel & Kjaer model 4930 artificial mastoid. 3 resonant peaks which decreased in amplitude as frequency increased characterized the curves for each vibrator. The maximal output volatage variations of the artificial mastoid were ≤ 2 dB for each vibrator at all audiometric frequencies (± 3 %), except for the B-72 at 4000 Hz where the variation was 6.9 dB



Graph 26: Comparison of the frequency response curves of the B-71 and B-72 bone vibrators

According to Shipton et al., (1980) and Haughton (1982), the mechanical behavior of the B-71 Vibrator may also lead to unsatisfactory acoustic radiations at the high frequencies of 3000 and 4000 Hz. Frank and Holmes (1981) investigated the influence of acoustic radiation produced by bone vibrator at 4000 Hz on bone conduction testing, using a radioear B-70A, B-71 and B72 vibrator. Results indicated that the B-70A and B-71 produced minimal acoustic radiation. However, the B-72 was found to have excessive acoustic radiation which would be sufficient to influence BC thresholds and produce an invalid high frequency air bone gap. These authors suggest that the test ear of the patient be occluded by a small ear plug when bone conduction testing is conducted at these frequencies. Thus the air conducted signal will be attenuated in the ear canal and eliminate the influence of air radiation of the bone conduction thresholds.

This suggestion is reasonable because the occlusion effect bone conduction is minimal or absent at these high frequencies. Haughton, (1982) observed that acoustic radiation for the B-71 vibrator could be reduced by enclosing the vibrator in a more rigid case.

Ear Phones

Ear phones are electroacoustic transducers, which convert electrical signal into acoustic signal. There are two types of earphones namely external type and internal type.

External Type

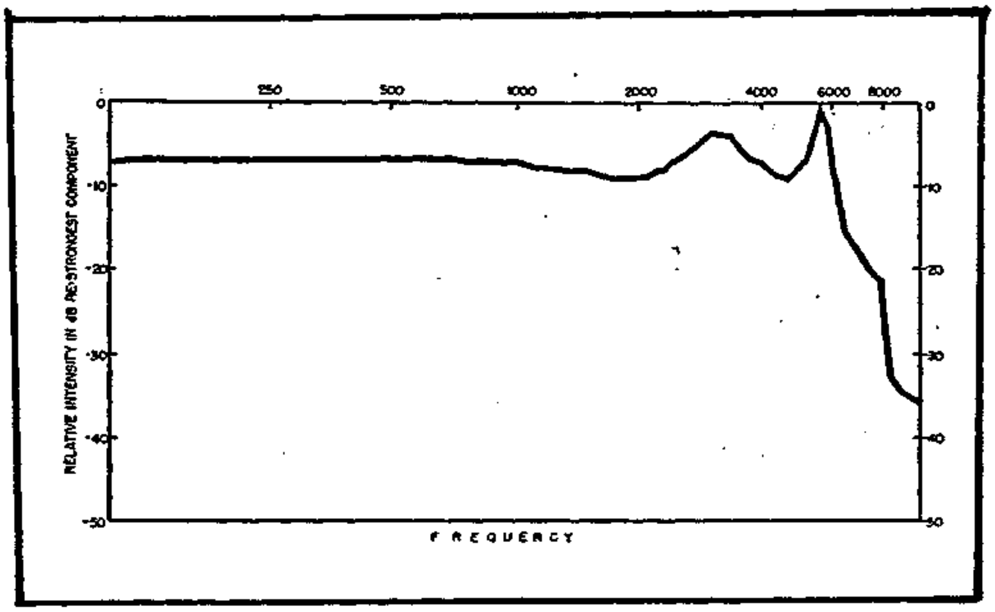
These types are mounted in rubber cushions and placed facing the external canal. External type earphones are generally used to deliver audiometric air conduction signals. Each ear may be tested separately. They are selected on the basis of good long-term stability, flat frequency response and ability to deliver high intensity signals. There are a variety of earphones that differ in terms of impedance characteristics, frequency response, sound pressure level etc. Some of the more, commonly used ones are the telephonic series: TDH-39, TDH-49, TDH-50, TDH-140, Permoflux series PDR-1, PDR-10.

Comparison of the spesifications of the TDH-39, TDH-49, TDH-50 and Telex 1470 A.

Types of ear phones-parameters.	Telephonies TDH-39	Telephonies TDH-49	Telephonies TDH-50	Telex-1470-A
Impedance	10 (standard)	10	60	10 50 ±10% 300
Continous power rating	300 milliwatts at any single frequency from 100 to 8000 Hz	300 MW. at any single frequency from 100 to 8000 Hz	300 MW. at any single frequency from 100 to 8000 Hz	
Sensitivity	100 + 4 dB SPL output with 1MW input at KHz	106 ± 2dBSPL output with 1MW input at KHz	106 ± 2 dB SPL output with 1MW input at KHz	106 ± 2 dBSPL output with 1MW.
Distortion	Less than 1 %	Less than 1 %	Less than 1 %	Less than 1 %
Linearity	Linear for power input from 0 to 400 MW.	Linear for power input from 0 to 400 MW.	Linear for power input from 0 to 400 MW.	Linear for power input from 0 to 400 MW.
Earphone Type	Dynamic	Dynamic, moving coil	Dynamic, moving coil	Dynamic
Reference	f0 dBSPL	0 dBSPL	OdBSPL	0.0002 dynes/cm^
Frequency response	20-20000 Hz	20-20000 Hz	20-20000 Hz	20-10000 Hz
Maximum output	r			136 dBSPL to 1KHz

Among them TDH-39 and TDH-49 both mounted on MX-41/AR & P/N 510C017-1 cushions are commonly employed in hearing testing. Selection of a particular earphone is specific to the audiometer and will affect the calibration of the audiometer.

ANSI S3.6-1989 specifies the dB SPL values equivalent to audiometric zero at the audiometric frequencies for various supra-aural earphones as measured in an NBS-9A 6cc artificial ear. These reference levels were based on large survey of hearing levels. The TDH-39, TDH-49 and TDH-50 earphones, mounted in an MX/41AR & P/N 510C017-1 cushion are mostly supplied with the audiometer.



Graph 27: Frequency response of an external type ear phone (TDH50) in response to a broad band spectrum

Internal type

They are also called the insert type. They extend into the external auditory meatus with or without the help of ain earpiece. These type have limited frequency response and in most of them output drops sharply in the frequecy range above 2000 to 3000 Hz (Lybarger, 1972). They also present calibration problems they may also be used for delivering masking noise. Also it increases IA by 15 to 20 dB, thus reducing chances of over masking.

They are often substituted for traditional supra aural earphones, particularly in cases of masking dilemma, incases of collapsed ear canals and when testing in noisy environment.

Etymotic research developed the ER-3A insert ear phones which is commercially available. Wilber et al., (1988) obtained mean output levels across five studies of the ER-3 A at threshold in dB SPL, using a 2cc coupler. The technical specification and limits for the E-A-R TONE 3 A are as follows

Impedance 10Ω, 50Ω, 300Ω

1KHz sensitivity 102.5dB SPL in DB-0138 (HA-2) coupler

@0.1Vrms(10Ω)
@0.2Vrms(50Ω)

103.5 dB SPL in DB-0138 (HA-2) coupler

@ 0.49 V rms (300Ω)

Limits : ± 3dB

Distortion : < 3 % measured @ 500 Hz, 118.5 dB SPL

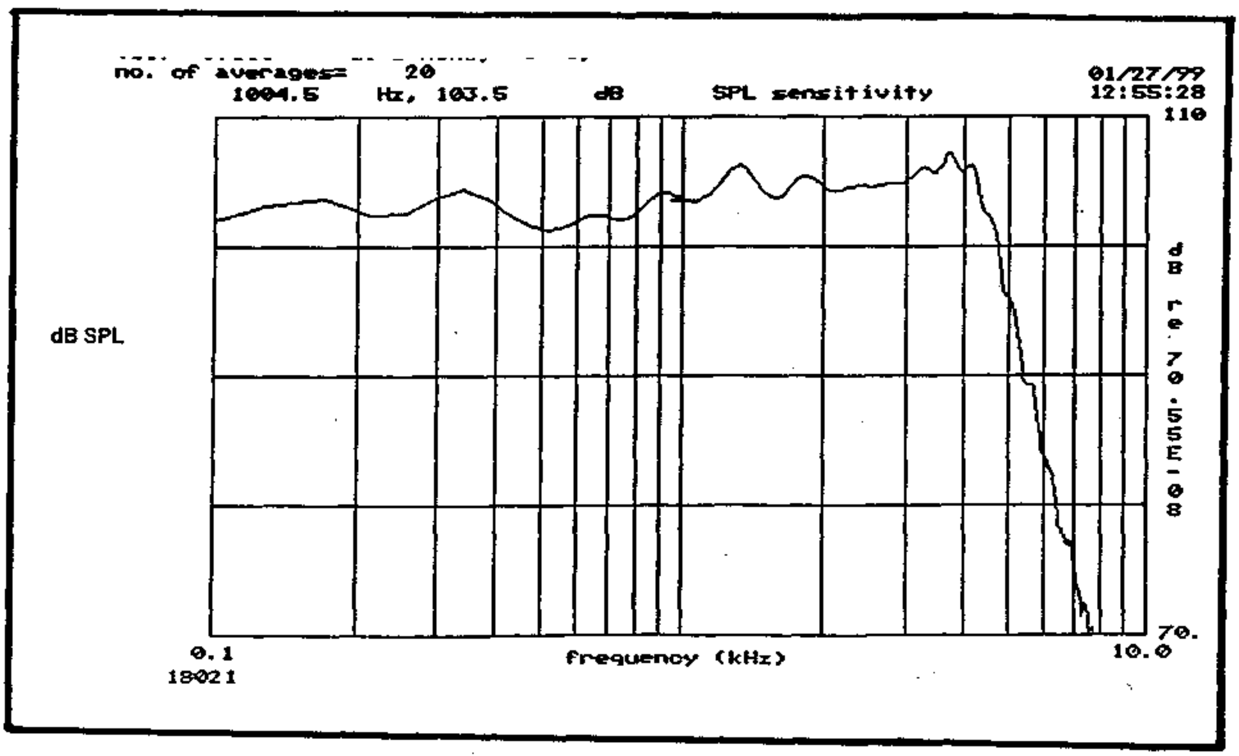
Maximum output: meets or exceeds 110 dBHL at standard audiometric frequencies between 500 to 4000 Hz.

Safe Operating limits: maximum continues sine wave drive:

2.5Vrms(10Ω)

5.0Vrms(5OΩ)

13.75 Vrms (300Ω)



Graph 28: Frequency response of an internal type earphone (ER-3A)

Ear cushions

The enclosures surrounding the external ear type earphones are called ear cushions. They are made of rubber and have specific size and shape. They are

1. Supra aural type
2. Circum aural type

Supra aural cushion

It covers only the outer part of the pinna and seals against the skull for example: MX 41/AR Telephonics Corp. P/N 510C017-1

Circum aural cushion

It occupies a larger volume than supra aural cushion. It is approximately 6 cc which is similar to the volume of the NBS-9A standard coupler. The specific volume of the circum aural are not known as there is no standard coupler to measure the same. Example : Aural research AR 100, Aural domes.

The supra aural cushion MX-41/AR (as specified by ANSI-1969) are most commonly used for hearing testing. It is a two piece foam. The cushion is made out of Buna rubber and sponge Neoprene (cap). Another model of the supra aural cushion is the model 51. Comparisons between the MX-41/AR and the model 51 revealed more significant difference in their performance. However, there was a strong indication of model 51 giving more consistent results with much improvement of comfort also. (Micheal and Bienvenue, 1980) similar to this model 51 is the telephonics corp. P/N 510C017-1 which is most often being used presently with TDH series.

It is recommended that $^{3}A''$ be the diameter of the opening of the hole of the ear cushion (ANSI 1962). If the dimension is less than $^{3}/_{4}$" it may lead to alteration in the output at certain frequency. Specific combinations of either supra aural or Circum aural have their own advantages and disadvantages. Some of them are :

Ear Phone - Supra Aural Cushion Combination

Advantages

1. It can be easily calibrated using the NBS 9A coupler, thus approved by various standards such as ANSI, ISO, etc.

Disadvantages

1. They become uncomfortable after wearing for long time which may effect the performance.
2. They do not attenuate ambient noise as effectively as that of circum aural ear phone.
3. It might deform the flesh around the canal entrance and constrict the opening which results in lowering of the resonant frequency of the system (Villchur, 1969)

Ear Phone Circum Aural Cushion Combination

Advantages

1. It provides greater attenuation of ambient noise, so it is more advantageous in noisy situations.
2. It is more comfortable for the wearer
3. There is less likely hood of energy leakage
4. It has low impedance in the low frequency region

Disadvantages

1. It can not be calibrated using the NBS 9A, standard coupler. No standard coupler has been developed to calibrate the circum aural ear phone as yet. Its use is limited to laboratory investigations where careful calibrations can be performed
2. At frequencies above 2000 Hz, circum aural ear phone response varies depending upon type of head phone and cushion, applied force and placement of earphone on coupler (Shaw and Thiesson, 1962)

Artificial Ear

It is a coupler used to calibrate air conduction ear phones. A standard convenient way of indicating the sound generated by an ear phone is to measure, using a precision microphone, sound pressure produced in a precisely machined cavity of specified dimensions. This is accomplished by "coupling" the ear phone to the measuring microphone by an enclosed volume of air.

In ear phone calibration for audiometry a 6cc coupler is used because it approximates the volume of air enclosed between the earphone diaphragm and the tympanic membrane of the ear when the ear phone is placed on the ear.

The artificial ear is made of heavy steel body with the cavity at the center. The cavity volume can be changed from 6cc to 4cc or 2cc by placing a steel cylinder.

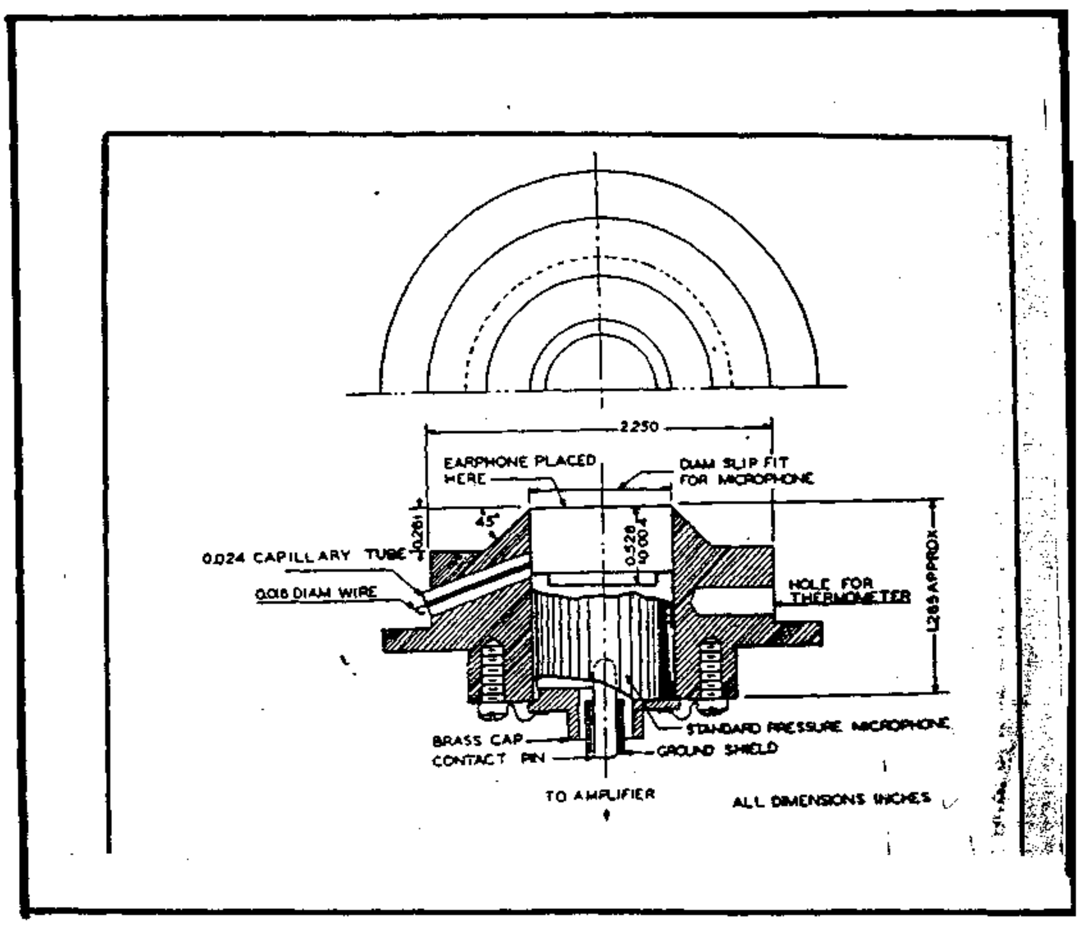


Figure 10: NBS - 9A coupler

The whole steel body is mounted on a wooden base isolated from the table with a mechanical suspension. The lower part has a provision to fix a 1" condenser microphone and preamplifier. Head band tension is provided by a ebonite cup and spring loaded tension with the scale from 0 to 1000 gms.

ANSI S3.6-1969 standard specification for audiometers designates the national bureau of standards (NBS) 9A coupler as a standard for this purpose. The NBS 9A coupler used in conjunction with a sound analyzer for measuring ear phone response is called an "Artificial Ear". It provides for making measurement of an ear phone mounted in supra aural cushions.

However Burkhard and Corliss (1954) pointed out that the impedance characteristic of a 6cc coupler probably simulates the impedance of human ear over a small part of the frequency range. Because the 6cc coupler does not replicate the impedance of the human ear, it can not be considered a true artificial ear.

There are further disadvantages as well such as the present 6cc NBS 9A is known to have a natural resonance at 6000 Hz (Rudmose, 1964) This interferes with the measurement of output of an audiometer and ear phone around that frequency.

Also the size of the coupler, its shape and the hard walls permit the possibilities of standing waves at the frequencies above 6000 Hz.

Insert ear phone are being used increasingly with audiometric equipment. The 9A coupler is not appropriate for assessing performance of this type of ear phone. The coupler usually specified for this purpose is the 2cc coupler described as HA-1 in ANSI 3.7-1979. It should be noted that output measured with a 2cc coupler can not be compared directly with that measured on a 6cc coupler Wilber, 1985.

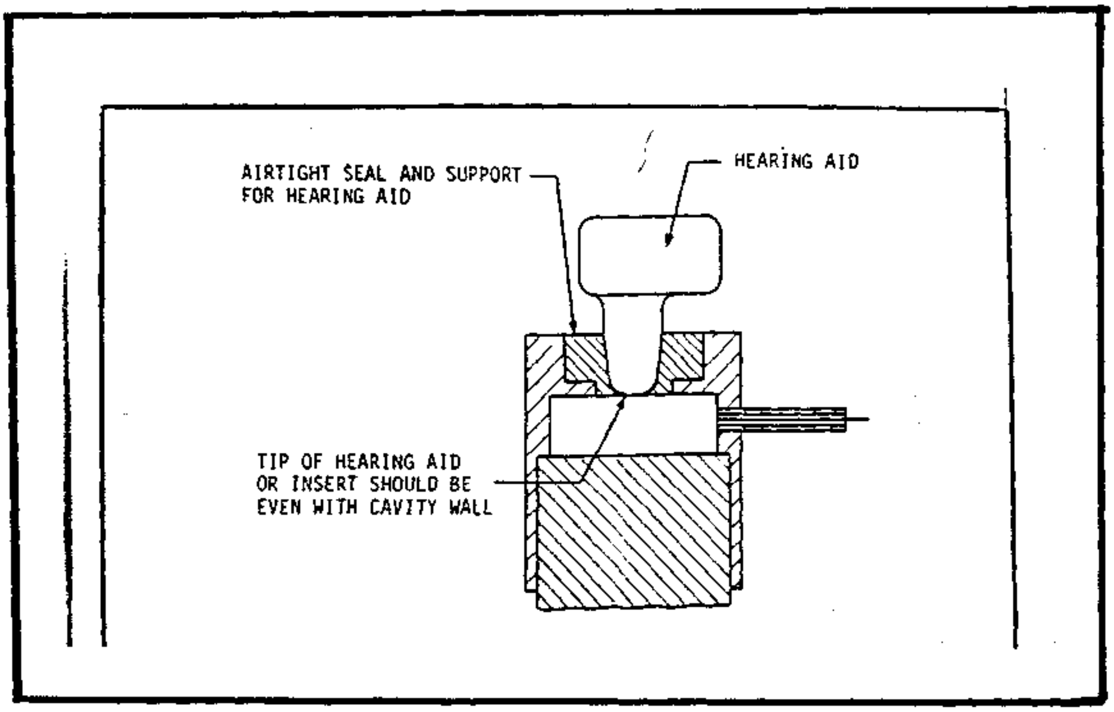


Figure 11: The HA - 1 , 2cc coupler.

Artificial Mastoid

It is a mechanical coupler used to calibrate bone conduction vibrators. The output of the bone vibrator should be measured in a device resembling the average human head with respect to its mechanical impedance characteristics. Under such conditions it is assumed that the force developed at the output of such a mechanical device is equal to the force at the output of the skull to the cochlea. The specifications according to IEC/ANSI is based on the characteristic of the mechanical impedance of the human mastoid (Dadson, Robinson and Grieg, 1954 ; Coliss and Koidan, 1955)

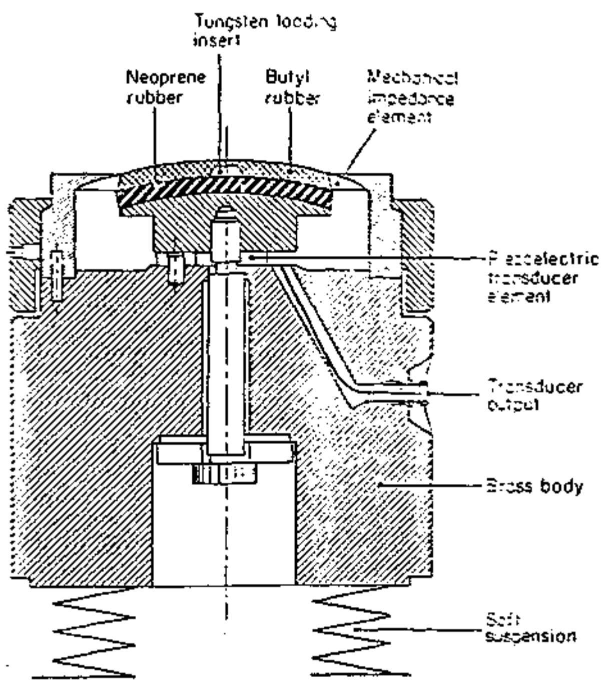


Figure 12:Artificial mastoid

It mainly consist of a cylindrical mass of 6.5 kg by weight which corresponds to the weight of the human head. The central part of the steel mass is provided with a layer of silicon butyl rubber. A crystal bymorph is fixed to convert the vibration received from the bone vibrator in to electrical signal. To provide the headband tension arrangement is made with a spring load on arm. The tension on the arm can be adjusted using a spring balance. The complete system is mounted on a steel base separated from the base with a suitable suspension.

Two artificial mastoids have been available in the united states, the Beltone 5A model and the Bruel & Kjaer 4930. In Europe and consulting the IEC the standard 4009 was commercially available. Currently only the B&K 4930 artificial mastoid is commercially available. However, according to Dirks, Lybarger, Olsen and Billings (1979), no available artificial mastoids meet the ANSI S3.13-1972 and the IEC 373 (1971) standards.

QUESTIONS

I. Fill In The Blanks

1. Clinically,__________is the most commonly used bone vibrator.
2. The_____________vibrator has acoustic radiations at around 3000-4000 Hz.
3. The resonance of the____________vibrator is found at lower frequencies of around< 250 Hz.
4. A good earphone should have______________,_________________and ability to deliver_______________signals.
5. Earphones convert_______________signal into______________signal.

II. Match the Following

1. Hearing aid type	(a) greater output at 250 Hz.
2. TDH 50	(b) Bone vibrator
3. B-72	(c) 2CG coupler
4. KH70	(d) 6cc coupler
5. HA-2	(e) Harmonic distortions at low frequencies
6..B-71	(f) Supra aural cushion
7. ER- 3A	(g) 125 Hz-16000 Hz
8. NBS 9A	(h) Earphone
9. MX-41/AR	(i) Insert receiver
10. AR-100	(j) circum aural cushion

Bekesy Audiometry (automatic audiometry)

Bekesy audiometry, first described by Bekesy (1947) is a technique which works on the principle of automatic audiometry, thereby causing the signal intensity to decrease at the rate of 2.5 dB /s. The subject releases the button as soon as the signal disappears, causing the signal intensity to increase. A broad-band noise or narrow-band noise is presented to the ear contralateral to the test ear whenever the possibility of cross hearing exists. Because a graphic level recorder is connected to the audiometer, a graphic representation of the subject's tracking behavior can be obtained. The signal is either continuous or pulsed and fixed in a frequency or changing in frequency (sweep frequency). When sweep frequency bekesy audiogram is obtained, the direction of frequency change can be forward (low to high) or backward (high to low) usually over the range of about 100 to 10000 Hz (the backward sweep is also called the reverse sweep). The graphic representation of the tracking behavior is referred to as the bekesy tracing or the bekesy audiogram.

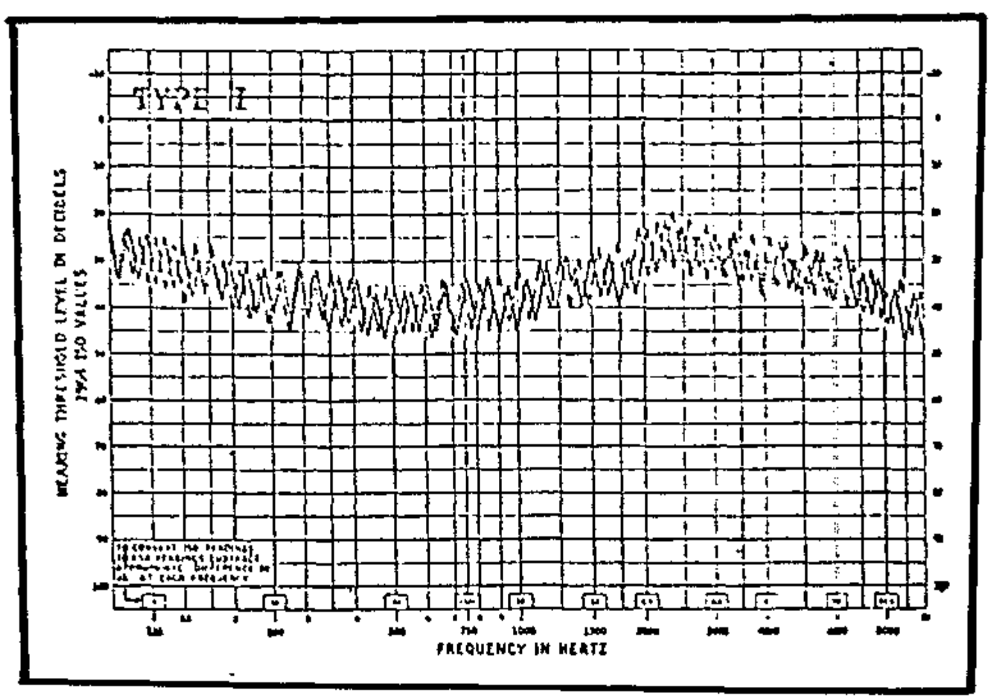
Studies have been done on the relation between bekesy audiogram and pure-tone thresholds obtained by conventional audiometry (Burns and Hinch cliffe, 1957 ; Corso, 1956; Harris, 1979 ; Reger, 1952 ; Rodda, 1956) to specify whether the midpoints, peaks or troughs of the excursion correspond to pure-tone thresholds. Differences between the bekesy tracing and conventional pure-tone thresholds result, at least in part from differences in psychophysical procedures; conventional pure-tone audiometry is based on method of limits whereas bekesy audiometry is based on method of limits and adjustment and the adaptive procedures (Gelfand 1981)

On the basis of the relation between the continuous and interrupted tracings, Jerger (1960) classified bekesy audiograms as Type I, Type II, Type III, Type IV, Type V.

Presently the standard classifications are described and illustrated as follows

Type I:

An interweaving of interrupted & continuous thresholds through out the audiogram. Tracking amplitude averages 10 dB. Type I audiograms are typical of normal patients & of lesions of the middle ear, although patients with sensorineural loss of unknown etiology frequently shows this pattern. In general the midpoint of the excursion is considered the best estimate of the pure tone threshold



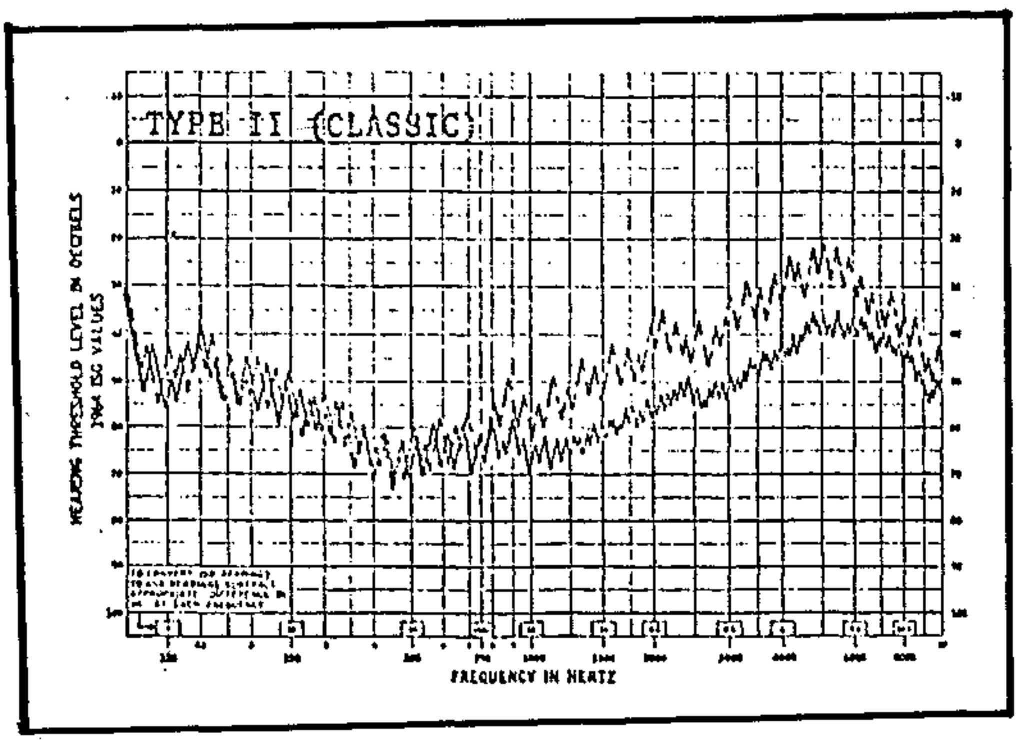
Graph 29: Type I Bekesy tracing.

Type II

The Type II audiogram is characteristic of cochlear pathology and is rarely associated with normal hearing or retrocochlear lesions. There are two distinct configurations.

Classic

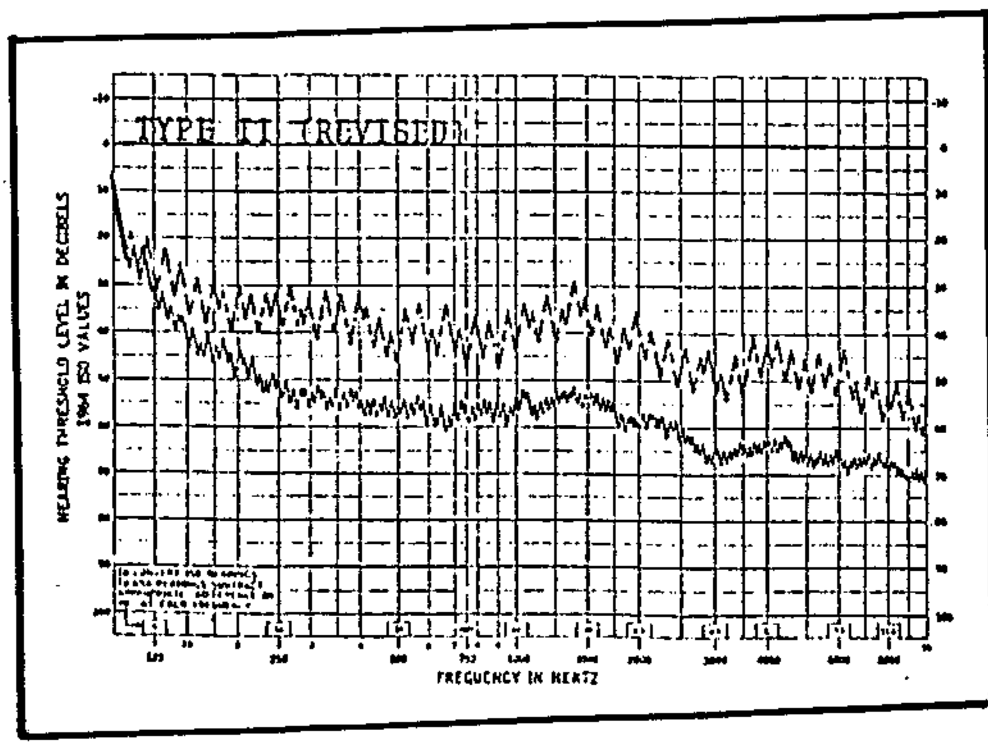
The continuous threshold separates from the interrupted around 1000 Hz and travels roughly parallel to high frequency end of the audiogram. The separation does not exceed 20 dB. In addition, the amplitude of the continuous tracing usually narrows considerably to 3-5 dB.



Graph 30: Type II Bekesy tracing(Classk).

Revised

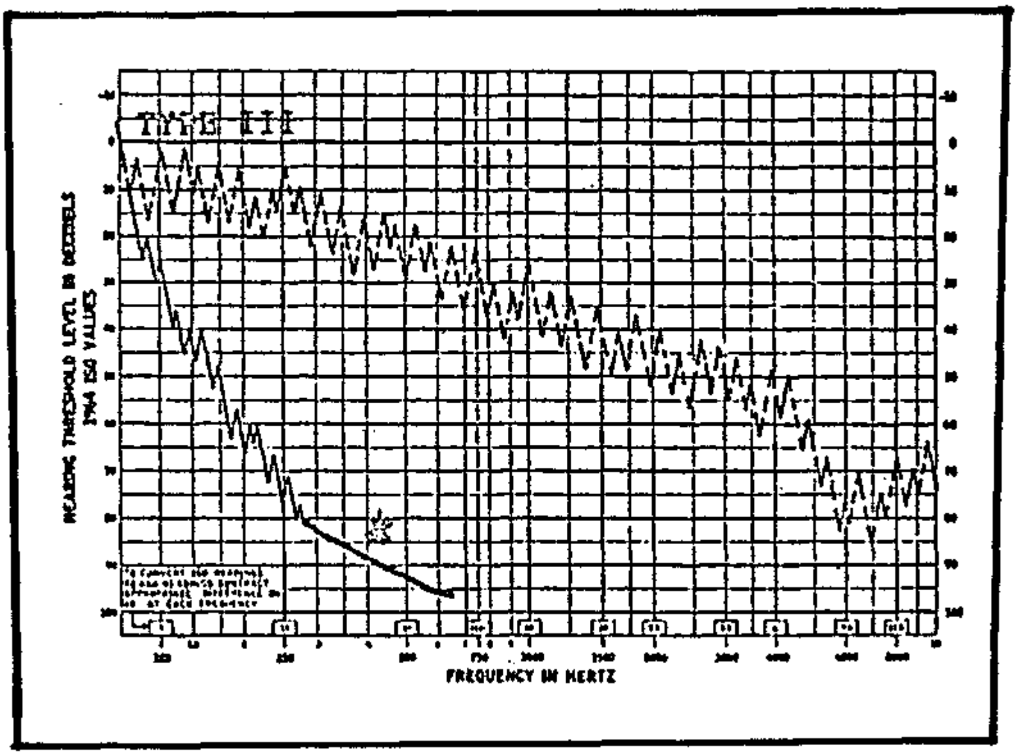
It is very similar to type IV , except that the separation (which can occur at any point in the audiogram) is less than 25 dB and the tracking amplitude is considerably narrowed as in the classic Type II (Jerger,1962; Hughes, Winegar and Crabtree, 1967).



Graph 31: Type II Bekesy tracing(Revised).

Type III

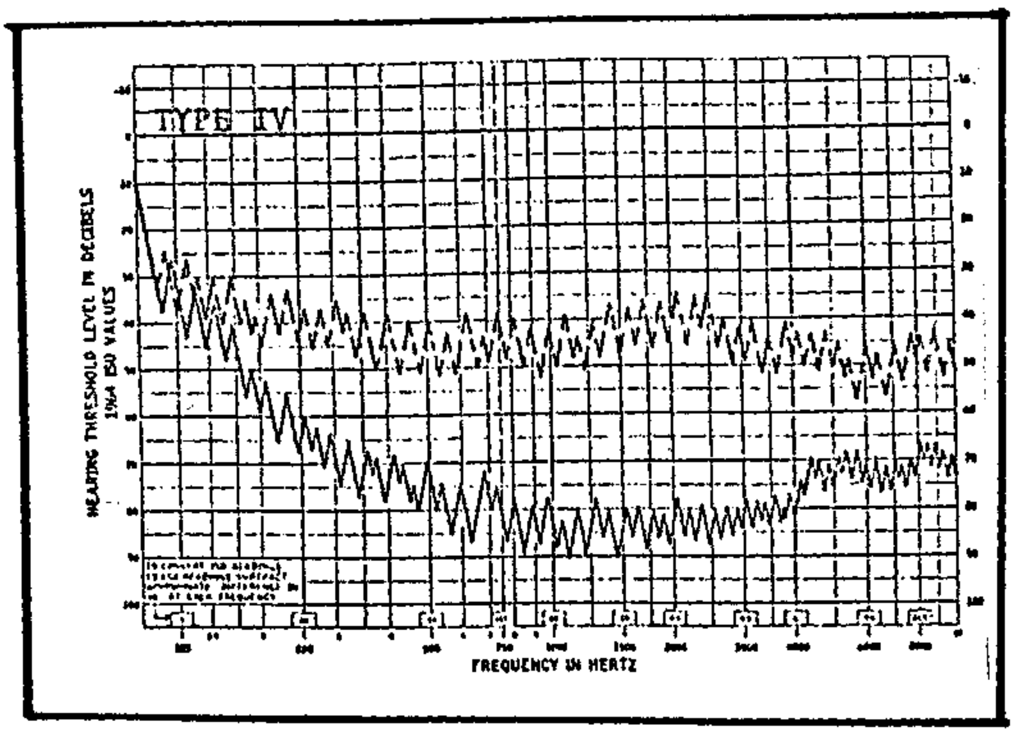
The Type III trace is prevalent in retocochlear pathology, although it is occasionally seen in sensorineurai losses of sudden onset with undetermined etiology (Presumably vascular). In both the sweep & fixed frequency audiograms the continuous trace demonstrates a marked and rapid decline in threshold sensitivity. Deterioration occurs early in the audiogram and continues to the output limits of the audiometer. The amplitude of exclusion is usually undiminished.



Graph 32: Type III Bekesy tracing.

Type IV

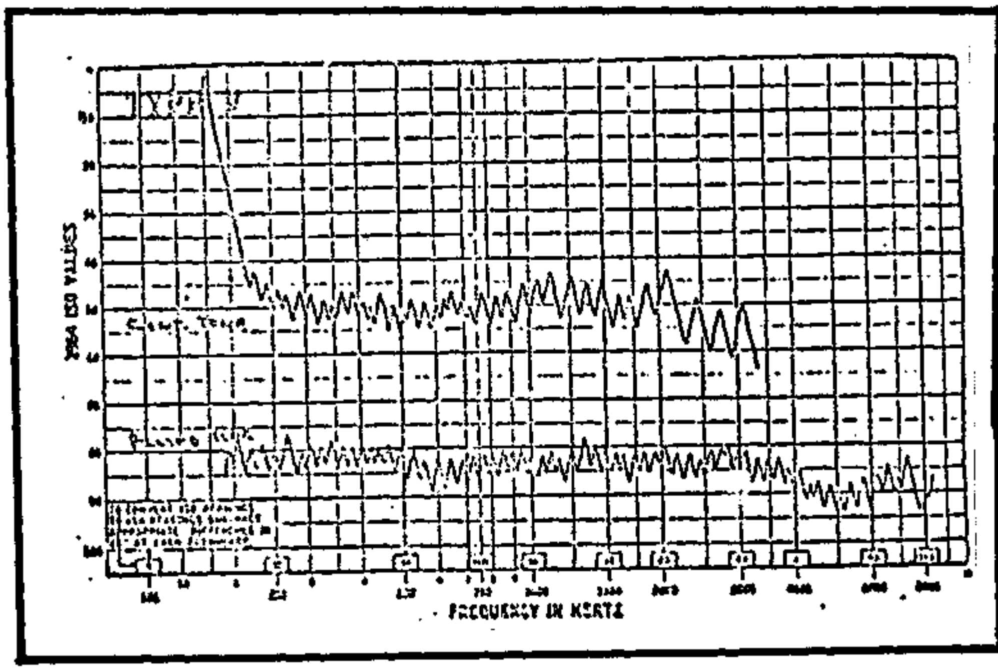
The prominent feature of type IV audiogram is an early separation of continuous and interrupted thresholds that occurs below 500 Hz. The separation usually extends into the high frequency range and there is 25 dB or greater difference between the two tracings. Tracking amplitude may or may not be narrowed in the continuous trace. This type is associated with retrocochlear lesion.



Graph 33: Type IV Bekesy tracing.

Type V

This audiogram is considered suggestive of functional hearing loss. The configuration differs distinctively from the other four Types, in that the threshold for continuous tones is tracked at significantly less intense levels than threshold for pulsed signals.



Graph 34: Type V Bekesy tracing.

QUESTIONS

1. Answer with one word

1. A Type III tracing is obtained, in this pathology .
2. In the Bekesy Audiometer this parameter changes at the rate of 2.5 dB/s
3. In the Bekesy Audiometer this parameter may be discrete or sweep type.
4. A Type I tracing is obtained in these persons during Bekesy Audiometr
5. This part of the excursion width is considered the best estimate of the pure tone threshold
6. This parameter can be continuous or interrupted.
7. It is also called 'backward' sweep.
8. Another name for Bekesy Audiometry.
9. This case shows a type V tracing..

HIGH-FREQUENCY AUDIOMETRY

High frequency audiometry is threshold estimation at frequencies above 8 kHz (to 20 kHz) either through AC or BC. Specialized equipment and unique calibration procedures are required for high frequency audiometry. It may have both diagnostic and rehabilitative ability (Fausti et al., 1979; Berlin, 1982). There are commercially available audiometers for testing this frequency range. The transducers for these audiometers are the Senheisser HDA 200 earphones which permits testing till 20,000 Hz and the KH-70, Oticon A20 bone vibrators permit which testing till 16 kHz.

Clinical Applications of High Frequency Audiometry

(i) Differentiation between noise induced hearing impairment and other high frequency sensorineural hearing impairment such as Presbycusis (Laukli and Nani, 1985)

(ii) Early detection of ototoxicity (Dreschler, Van der Hulst, and Tange, 1984 ; Tange, Dreschler and Van der Hulst, 1985 ; Tonndorf and Kurman, 1984)

(iii) Measurement of speech recognition ability in persons with significant hearing impairment at the routine audiometric frequencies with good speech intelligibility and articulation (Berlin, 1982).

(iv) It is important in the prediction of sensorineural component, before it affects the speech frequencies.

(v) It has also been used to predict the prognosis of the treatment or surgery in different conductive hearing losses (Laitila, et. al., 1997, Mair and Laukli, 1985, Mair and Helhno, 1994).

Disadvantages of HFA

The calibration of these audiometers is problematic. They overcame the problem by using a special electric transduction mode in which a 60 Hz carrier frequency is modulated by the desired audiofrequency.

QUESTIONS

I. Match the Following

1. Frequency	(a) KH 70
2. Headphones	(b) Prognosis of treatment & surgery
3. Differentiation	(c)Ototoxicity
4. Detection	(d) 8 kHz-20 kHz
5. Bone vibrator	(e) Senheisser HDA 200
6. Prediction	(f) NIHL & other SN losses.

Special Considerations in the Difficult-to-test Population

In the 1940's it was considered a major accomplishment to obtain pure tone data from 5-6 and 7 Year old children now, audiologists using play audiometry are usually successful in attaining reliable and valid pure tone data from children as young as 20 months (Frisina, 1973; Lloyd and Cox, 1975).

In conventional or standard pure tone Audiometry, the person raises a hand or presses a signal button when he hears a sound. The person is usually given verbal instructions and a brief demonstration of the task. An appropriate response may be followed by social reinforcement such as a smile, nod of the head, or pat on the back to communicate the appropriateness of the response.

Hand raising the most common response used with school age children and adults. It has also been used successfully with many retarded individuals, (eg. Atkinson, 1960; Fulton, 1967 ; Lloyd & Reid 1967a ; Lloyd, Reid and MacManis, 1968a). Although success with some difficult-to-test has been reported, many are untestable with the conventional or standard hand raising technique. In such cases the audiologist may be able to use either response modes.

Ear Choice Methods

In the original Curry and Kurtzrock (1951) ear choice technique and modified ear choice technique (Lloyd, 1965 a) the individual points to the ear in which he hears a sound. The application of reinforcement is similar to the conventional or standard method. The appropriate response is pointing to the ear in which the signal is presented. The technique is successful with difficult to test because pointing to the ear is less abstract than hand raising.

Play Methods

Play audiometry is an efficient and frequent method used to test young children (O' Neill, Oyer and Hillis, 1961 ; Webb et al., 1964 ; Ewertson, 1966 ; Lloyd and Reid, 1967b ; Lloyd and Cox, 1975). Play audiometry involves responses such as putting rings on a peg, putting pegs in holes, hitting a pegboard, hitting a drum, Coloring or drawing lines on a piece of paper, stacking blocks, putting marble in a box and putting blocks in a box. It is assumed that play is interesting to the child and that making the response is rewarding. Although the play activity itself may be reinforcing, the audiologist pairs the inherent reinforcement of the play response with social reinforcement. However, with the difficult to test the selection of an appropriate reinforcer is one of the most critical factors (Lloyd, 1966). Also, what may be reinforcing for a person at the beginning of the test session may become a relatively weak reinforcer by the end of the session. Changes in response latency, force and consistency are frequent early signs of satiation. Changing the play activity seems to be the best solution to this problem.

Visual Reinforcer methods

Audiologist use several pure tone techniques with visual stimuli as reinforces to increase a child's button pressing response to a pure tone. Visual reinforcement methods may be classified into 5 areas : Pictures, including slides (Dix and Hallpike, 1977 ; Weaver, 1965 ; Lloyd, 1965a), miniature scenes (Lesak, 1970 ; Statten and Wishart, 1956) animated toys or puppets (Knox, 1960 ; Miller, 1962), and either mechanical toys (Schwartz, 1952 ; Wolfe and MacPherson, 1959). The task is demonstrated and the child's response to puretones are increased by reinforcing responses when the pure tone is presented and not reinforcing his response in the absence of a pure tone signal. Regardless of the response method and the kind of reinforcer, verbal and non-verbal social reinforcers are important. Research also indicates that the visual reinforcement of auditory localization responses has developed as an effective clinical tool for infants as young as 5 months of age (Lloyd and Nelson, 1974 ; Moore, Wilson and Thompson, 1975).

Tangible Reinforcement Methods

During behavior audiometry, intangible reinforces such as good, a smile etc are reinforcing for many individuals and relatively ineffective for others. More tangible reinforcement have been used with operant conditioning procedures to attain audiometric data on retardates (Bricker and Bricker, 1969a, 1969b ; Bricker, Bricker and Larson, 1968 ; Fulton, 1974 ; Spradlin and Lloyd, 1965) Edible items such as candy, popcorn, sugar coated cereal, crackers, dietry suppliments, and various fluids, as well as nonedible objects such as miniature toys or trinkets, have been used as material or tangible reinforcement in operant conditioning audiometry (TROCA).

Some times a single tangible item is given to each subject In other cases each subject is given a variety of tangible items selected by the examiner since TROCA is used when more conventional forms of reinforcement are not effective. The audiologist should determine effective tangible reinforcers for each individual instead of using arbitrarily selected reinforcers.

Finally behavioral audiometry procedures should emphasise the application of operant or instrumental conditioning principles and should not be viewed as special gimmicks for use with children.

Behavior Observation Audiometry

Some difficult-to-test individuals appear untestable because of time limitations, or a limited skill in applying behavior modification procedures. In such cases the audiologist may get some index of sensitivity by using sound field behavior observation audiometry. It refers to the audiologists attempt to elicit observable responses to sound. These responses may be respondents (or reflexive) and / or operants (voluntary), but they must be temporally and reliably related to the auditory stimulus. Warble tones, speech and complex sounds produced by noise makers are the auditory stimulus in BOA.

In the Elderly

The primary data base for a believable diagnosis is found within the audiological assessment itself. Although the actual measures employed with the elderly may not differ greatly from those used with younger persons, certain modifications may be necessary. Aging persons present special problems in testing. These difficulties can be circumvented, by providing the elderly client with clear brief, carefully worded instruction to minimize confusion and apprehension.

During the evaluation the older person may be distractable and may evidence a slower reaction time. Berkowitz (1975) cautions that the entire timing sequence of the test battery may have to be prolonged including greater durations for pure tone signals and lengthened intervals between stimuli. In order to enhance attending behavior and offset possible confusion of tinnitus with the test tones, the audiologist may find it necessary to employ pulsed or warble tones. Fatigue can contaminate test results but the probability of retesting on another scheduled date may prevent this occurrence

For such and other reasons certain shortcuts may be necessary for some aspects of testing. Such changes in conventional operating procedure must be calculated once, reflecting a minimal loss in either the reliability or validity of the assessment battery, which is highly important since the audiological test both qualifies and quantifies the handicap. It is an essential precursor to intervention. (Maurer and Rupp, 1976)

Simonton (1965) proposes, further, a set of specific guides to the audiologist when assessing older clients:

1. Tonal presentations may need to be lengthened to as long as 5s.
2. Patients head noises may necessitate use of frequency - warbled tones so that the listener can separate the signal from the noise.
3. Time between tonal presentations (i.e., interstimulus interval duration) may need to be increased.
4. Live voice presentation of speech material is preferred
5. Familiarisation of spondee words prior to determining the spondee thresholds is essential.
6. If the patient cannot handle standard phonetically balanced word lists, alternative lists should be available, such as the Pb-K or WIPI lists.
7. Half list presentations of phonetically balanced lists may be acceptable.
8. Possible collapse of external ear canal under headphone pressure should be considered with each elderly client.

QUESTIONS

I. Which method would you use to obtain thresholds for these children

1. A seven year old boy who is slightly restless & is not responding well to conventional pure tone audiometry.
2. A six month old baby who is blind and is also suspected of having hearing loss
3. A two year old child who loves playing with toys
4. A mentally challenged child who loves sweets and is not responding approximately to conditioning audiometry.

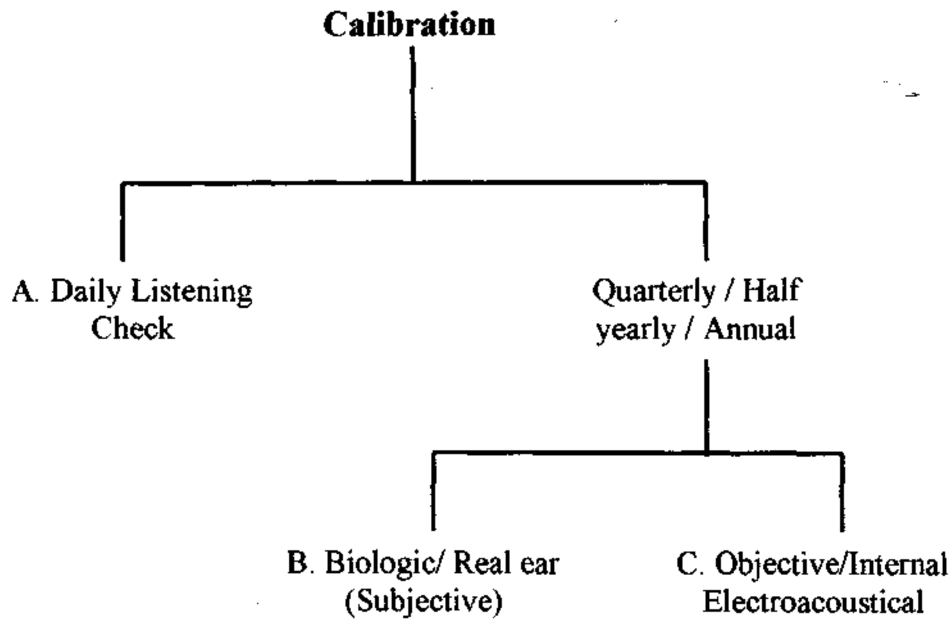
II. True or False

1. Administration of the entire spondee list is compulsory, in the elderly!
2. The elderly should be tested in most detail, since their problems are long standing & progressive.
3. Live voice Presentation of speech material should be administered for the elderly, due to head phone pressure.
4. Older people may evidence a slower reaction time.

CALIBRATION OF PURE TONE AUDIOMETERS

The American National Standards Institute has set up minimum requirements for pure-tone audiometers. These requirements provide guidelines for audiometer manufacturers regarding frequencies to include, intensity ranges, test tone purity, attenuator accuracy etc. The audiologist should always ensure that his equipment is in good working condition before testing a patient.

These Calibration procedures can be of two major types:



A. DAILY LISTENING CHECK / ROUTINE CHECK

Routine checks are subjective procedures employing simple tests throughout without the help of measuring instruments. These procedures are performed to ensure,

(i) That the audiometer is performing in a proper manner.

(ii) That the audiometer calibration has not noticeably altered,

(iii) That the audiometer's attachments, leads and accessories are free from any defect that may adversely affect safety.

These routine checks should be done everyday/every week on all audiometers in service, before commencing the clinical examination. Care should be taken that;

(a) The operator with normal hearing, at least in one ear, should perform the checks.

(b) Checks should be performed in sound treated room or in satisfactory ambient noise conditions.

Procedure

1. The earphone cushions should be checked. They should not be hard or marked with crevices due to shrinkage and they should be free of cracks.
2. Check that the tension in the bone vibrator and earphone headband is adequate.
3. Check the earphone cords (wires) for signs of worn or cracked insulation and straighten the twisted cords.
4. Check for static or other noises on the earphone by flexing the earphone cords while a continuous tone is on at 1000 Hz at 40 dBHL. Do this first for one earphone and then the other. Then do this for the bone vibrator cord.
5. Check for loose dials on the audiometer. Inspect the front panel, if there are such faults present, the dial readings will not be meaningful. Defective dials should be repaired immediately and the audiometer should be recalibrated to determine the outputs at new dial settings.

6. Check for hum or other noises in the earphones by listening to the tone through one of the earphones at 1000 Hz at 90 dB. Also listen to the tone to check for distortion in tonal quality. Interrupt the signal and listen again for hum, click on other noises. Do the same thing at 50 and 0 dB H1. Repeat for the other earphone and then the bone vibrator using 70 dBHL as the highest intensity for the check.
7. Place the earphone over your ears and listen to the just audible tones by sweeping through at 10-15dBHL. This should be done at all appropriate frequencies and for both earphones and bone vibrator. Also check for gross linearity at 1000 Hz, for example, by setting the attenuator at 10 dBHL and then increasing in 10 dB steps upto 90 dBHL. The listener should determine whether the increases in loudness are roughly equivalent from one 10 dB increment to the next. This should be done for both earphones and bone vibrator.
8. Noise in the attenuator should be checked at 1000 Hz, for example, by setting the attenuator, at the lowest level and then increasing slowly from minimum to maximum with the tone continuously on. The listener should check for noise or interruptions in the signal or decreases in loudness.
9. Check for cross-talk by disconnecting the earphone plug for the right earphone applying a signal at 1000 Hz at 60 dBHL to the right earphone and listening through the left earphone. The procedure should be repeated for the other earphone by disconnecting the plug for the left earphone.
10. The similar protocol should be followed for noise stimulus through the earphone.

B. Biological Calibration of Audiometers

Biological calibrations otherwise called subjective calibration, makes use of human subjects. Generally these procedures are employed when the calibration measuring equipment are not available and therefore not used.

In this method, the audiologist empirically calibrates

(i) Air conduction output level and

(ii) Bone conduction output level

He/she finds out whether there is agreement between the intensity dial reading and the actual output of the earphone or bone vibrator. This procedure should be performed on a monthly basis.

Some of the methods are as follows

(i) Air Conduction Output Calibration

The methods given here are called Real ear methods because they make use of human ears to calibrate the earphone outputs.

Method I

1. First of all, have a record of your thresholds obtained from a calibrated audiometer. This record serves as reference thresholds.
2. Then check your responses with the audiometer to be calibrated. The threshold at a particular frequency obtained may be better or poorer than your reference threshold level. Thus, you can spot gross deviations in audiometer output for different frequencies.

Correction Rule:

Take the reference value (R)(Person's threshold) and the obtained value on the uncalibrated audiometer (O). The correction factor (C.F.) is given by the formula C.F. = R- O . For example if a person's reference value is OdB and the value obtained on the audiometer is 10 dB then C.F.=0-i0 = -10dB.

Limitations

1. Since threshold is not a fixed point it may vary within the range of 10 dB from day to day (Carhart and Jerger 1959)
2. Variations in the placement of earphones will have effect on the thresholds to vary within 10 dB particularly at low frequencies.

Method II

1. Select about 10 normal hearing adults without any history of familiar hearing loss, otological problems or noise exposure.
2. Test one ear of each subject at all frequencies with the audiometer to be calibrated
3. Then find out the average threshold at each frequency

Correction Rule

Average threshold at each frequency is used as correction factor in clinical diagrams for example, at 1 kHz average threshold is + 10 dBHL, the correction factor is - 10 dB. If a patients thresholds at 1 kHz is 35 dBHL, his correct threshold is 25 dBHL i.e. 35-10 dBHL.

Limitations

1. Adult healthy group of normal ears will present an average threshold at -lOdBHL at most of the frequencies with the calibrated audiometer. But, they also produce a -lOdB average threshold (-lOdBHL is the minimum intensity level in most of the audiometers) with the audiometer producing more output (strong signals)
2. It is time consuming and laborious.

Method III.

Loudness Balance method:

In this method, the output from a calibrated audiometer is matched against the output of an audiometer to be calibrated. The method is more practical with no serious limitations. The steps are as follows:

1. Requirements
   (i) A calibrated audiometer known to be accurate
   (ii) At least three young subjects with normal hearing and negligible difference in hearing sensitivity between ears.
2. Detach one earphone of the known audiometer (Calibrated audiometer) and fix it to the headband of the unknown audiometer (audiometer to be calibrated), after removing one of its earphones.
3. Instruct the subject to match the loudness of the tones.
4. Place this headset on the ears of the subject.
5. Set the frequency selector of each audiometer to 1 kHz and intensity dial of known audiometer to 40 dBHL and present the interrupted tones. When the signal is 'off in the 'known earphone', then signal should be presented in the 'unknown' earphone.
6. While this presentation of signals continues; without looking at the intensity dial, adjust the hearing level of the unknown audiometer until the subject tells you that loudness of the tones are equal, or approximately equal.
7. Stop presentations and then note down the intensity dial reading of the unknown audiometer.
8. Similarly, get loudness balance at the other hearing levels. Repeat the procedure at other frequencies. Also perform for other subjects.

Note:

1. Avoid simultaneous presentation of the signals from both audiometers
2. The sensitivity of this procedure can be increased by training the subjects to listen carefully and match the tones.

Suppose the dial is set 40 dBHL (AHL) at 1 kHz and the subject matches the tone of the unknown audiometer when the intensity dial reads at 45 dB (BHL). Then the difference is (A_{HL} - B_{HL}) i.e., 40 dB - 45 dB = - 5 dB. Thus, ther is difference in out put at this frequency. Then the correction is - 5 dB at 1 kHz, which should be written on the calibration chart.

Correction Rule

The correction values are positive, if the hearing level of the tone matched is lesser than the hearing level of the known audiometer. The correction is negative if the hearing level of the tone matched is greater than the hearing level of the unknown audiometer.

This can be easily determined by the formula:

$$A_{HL} - B_{HL} = \text{correction value}$$

LIMITATIONS:

1. It does not permit to find out the attenuator linearity of the intensity dial of the audiometer.
2. It requires two audiometers, one of which is calibrated.
3. It requires the task of loudness balance which is not easy.

Method IV

Objective - biological calibration

Objective calibration of ear phone outputs is made possible by the following method (Vyasmurthy, M.N.,1977) even in the absence of the calibration instruments in a centre. This procedure is both objective and biological in its approach. It makes use of an electronic instrument to elicit the response with out the co-operation of the subject; hence it is called objective method and employs human subjects for calibration, hence called biological calibration.

Requirements

1. An impedance bridge
2. A few subjects with normal hearing
3. Audiometer to be calibrated

Procedure: The steps are as follows:

1. Determine the subject's acoustic reflex thresholds (ARTf), at different frequencies using impedance bridge. Note down the ART1
2. Detach the ear phone of the impedance bridge and replace it by a ear phone of the audiometer, to be calibrated.
3. Now, determine the acoustic reflex thresholds (ART_2) for the same ear, same subject for different frequencies.
4. Find out the correction factor by subtracting ART_2 from ART1 for each frequency.
5. Determine the reflex threshold (ART_3) for the same ear, same subject, placing the other ear phone of the audiometer to the head set of the

impedance bridge. Then find out the correction factor by subtracting ART_3 from ART1 for each frequency.

Note : The impedance bridges balance meter needle should be nearly same while determining the ART1 and ART_2 for the same frequency an d for the same subject. Same conditions should prevail while ART_3 is found.

Correction Rule:

Similar to the procedure used in method I that is R-O.

Limitations:

1. Does not permit to find out the attenuator linearity of the intensity dial of the audiometer.
2. Calibration of output levels at 4kHz and 8 kHz may not be possible as reflex is usually absent at these frequencies.

(ii) Bone conduction output calibration

In the absence of artificial mastoid for BC calibration, audiologist can keep check on the calibration by employing the method recommended by Roach and Carhart, (1971). This happens to be the most accurate approach available today.

Procedure

1. Select ten subjects with typical bilateral moderate sensorineural loss (Hearing loss need not be equal in all ears).
2. Determine the air conduction thresholds of both ears of each subject at 250, 500, 1000, 2000, & 4000 Hz using well calibrated air conduction system.
3. Then determine the bone conduction thresholds for some ear using the bone vibrator to be calibrated.

4. Find out the average AC thresholds and average BC thresholds at each frequency.

Correction rule- Use the formula

$$\text{Ac Th}_{avg.} - \text{Bc Th}_{avg.} = \text{correction}$$

Assumption of this method

A typical sensorineural hearing loss subject, the AC and BC thresholds are equal. The difference is considered as error in the bone vibrator output.

Limitation

A slight conductive component might add to the air - bone differences in thresholds. Hence to that extent, accuracy of this method is limited.

C. Objective Internal or Electroacoustic Calibration

A quarterly, half yearly or annual electroacoustic evaluation includes the following:

1. Measurement of output sound pressure levels for puretones
   (i) Through headphones
   (ii) Through bone vibrator
2. Frequency calibration for pure tones
3. Determination of attenuator linearity

Calibration procedure

Preliminary check-up

Before calibrating the audiometer, one should check for the following

(i) The working voltage is within permissible limits

(ii) All the jacks, cords and plugs are in place and there are no loose connections

(iii) There is no visible damage on the audiometer, its controls and its accessories. Damage, if any, should be rectified before checking the calibration

(iv) The earphones and the vibrator are of the type that match the audiometer

(v) The headbands have adequate tension

(vi) The instrument is not delivering any electric shocks

1. Calibration of Audiometric output intensity

(i) Via Headphones

Purpose

1. To measure the output sound pressure level of an audiometer at various frequencies and to check the attenuator linearity via the earphone.

Equipment Necessary

1. Audiometer to be calibrated
2. Artificial ear (NBS 9A Coupler)
3. Condensor microphone
4. Sound level meter (SLM)
5. Microphone adaptor
6. Octave filter set (OFS)

Procedure

It can be divided into 4 phases.

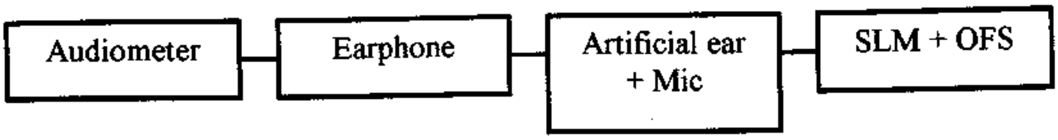
Phase I : Mounting of microphone and the ear phone or artificial ear

Phase II : Measurement of output sound pressure level.

Phase III : Adjustment of the output

Phase IV : Linearity check

Phase I



(a) Unscrew the coupler from the artificial ear
(b) Unscrew the protection grid from the microphone. Without touching the diaphragm fit the microphone into the socket inside the artificial ear.
(c) Replace the coupler on the artificial ear
(d) Remove the earphone to be calibrated from its headband clamp. Place it on the coupler so that the earphone perforations face the coupler cavity
(e) Unscrew the adjustable clamp on the artificial ear slightly and adjust the weight on the earphone to 0.5 Kg or as per specification provided by the manufacturer.
(f) Connect the artificial ear and the octave filter set to the SLM

Phase II

(a) Switch on the Audiometer
(b) Set the attenuator to 60 dB / 70 dB (depending upon the manufacturers specifications) frequency dial to 125 Hz or 250 Hz as required.
(c) Set the output selector to right / left depending on the earphone placed on the artificial ear
(d) The octave filter set is connected to the SLM. Set it to the required frequency i.e., the same frequency as that selected on the Audiometer.
(e) Switch on the SLM and set it to "slow response" and to "external filter"
(f) Adjust the tone switch on the audiometer so that the signal is continuously on
(g) Set the attenuator on the SLM to 60 dB / 70 dB, depending on the intensity selected in the audiometer. If the needle deflects to either extreme, vary the

attenuator setting suitably so that the needle deflects to the centre of the meter

(h) Note down the combined reading from the attenuator and the meter

(i) Repeat the procedure for each of the test frequencies. Remember to vary the frequency setting on the octave filter set

(j) Repeat the entire procedure with the other earphone.

Phase HI

a. If the autocal switch is available on the audiometer, If measured output is not as per expected level then turning the attenuator dial either clockwise or anticlockwise adjust the output and press the mentioned switch to store the changes in the memory.

b. The difference should not exceed ± 3 dB at frequencies from 250 Hz to 4000 Hz, ± 5 dB at 6000 and 8000 Hz (IS9098 - 1979).

Phase IV

The procedure is similar to that in phase III. However, linearity need be checked at only one frequency

(a) Follow the steps (a) to (i) in phase II except in step (b), where the intensity dial should be set at maximum level, frequency dial should be set at 1000 Hz

(b) Set the attenuator to the SLM at a level that corresponds to the maximum level on the audiometer.

(c) Decrease the attenuator setting on the audiometer in 5 dB step and note down the corresponding reading on the SLM.

(d) Repeat (step c) till the audiometer reads 30 or 40 dBHL. Record the level on the SLM. If with every decrease in the dial reading the SLM indicates a corresponding reduction then the intensity variation is linear

(ii) Via Bone Vibrator

Purpose

To measure the output sound level of an audiometer at various frequencies via bone conduction vibrator.

Instruments Necessary

1. Audiometer to be calibrated
2. Artificial Mastoid
3. Sound Level Meter
4. Adaptor
5. Octave Filter set
6. Other accessories: a. Spring balance b. Level indicator

Procedure

Phase I: Mounting of bone conduction vibrator on the artificial mastoid to the SLM

Phase II: Measurement of sound pressure levels

Phase III: Adjustment of the output

Phase I

(a) Ensure that the artificial mastoid is placed on a horizontal plane

(b) Detach the BC vibrator from the headband and place it on the artificial mastoid

(c) Note the level, with the help of the level indicator and remove the BC Vibrator

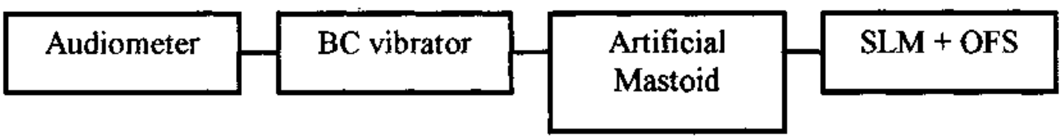
(d) With the help of the spring balance, check the weight (500 gms) on the clamp / arm of the artificial mastoid and readjust the level of the clamp with reference to the level indicator

(e) Remove the spring balance and level indicator

(f) Connect the adaptor to SLM

(g) Plug in the output jack of the artificial mastoid to the adaptor and thus the artificial mastoid is connected to the SLM

(h) Connect the OFS to the SLM



Phase II

(a) Switch on the audiometer

(b) Set the intensity dial at 20 / 40 dB (depending upon the instructions in the manual) and the frequency dial 250 Hz

(c) Set the output selector to bone

(d) Set the OFS to the required frequency

(e) Switch on the SLM and set it to slow response and to external filter

(f) Set the tone switch on the audiometer so that the signal is continuously on.

(g) Set the attenuator on the SLM depending on the expected output reading. If the needle deflects to either extremes, change the attenuator setting suitably so that the needle deflects to the central area of the meter

(h) Note down the combined reading from the attenuator and meter

(i) Repeat the procedure for each of the test frequencies. Also adjust the frequency setting on the OFS to correspond with the test frequency

Phase III

Same as for Air conduction

2. Frequency Calibration of Pure Tone

Purpose: To determine the deviation of the output frequency from that of the dial reading.

Equipment

1. Audiometer to be calibrated
2. Digital Frequency Counter

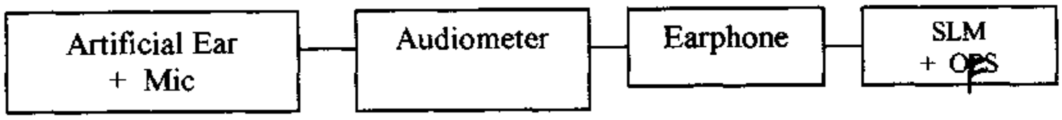
Procedure

(a) Remove one of the earphone jacks from the output socket
(b) Insert a spare ear phone jack in to the socket
(c) Connect the spare jack to the input terminals of the frequency counter with a wire
(d) Switch on the Audiometer and the Frequency counter
(e) Set the Audiometer frequency dial to 125 Hz, as the case may be
(f) Set the output intensity to maximum
(g) Adjust the tone switch to continuously 'on' position
(h) Turn the function selector on the frequency counter to frequency
(i) Note down the reading on the frequency counter. Adjust the sensitivity of the counter to obtain a stable value
(j) Compute the deviation of the frequency generated by the audiometer from the expected frequency
(k) Repeat the procedure for other test frequencies
(1) Whenever the deviations exceed ± 3 % (IS9098-1979) internal calibration is required

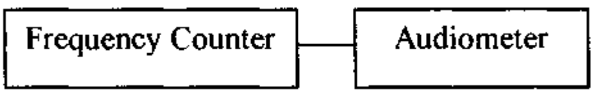
QUESTIONS

I. Rearrange the block diagrams to make the arrangement right.

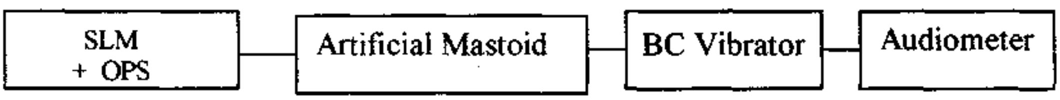
1. For air conduction output sound pressure level



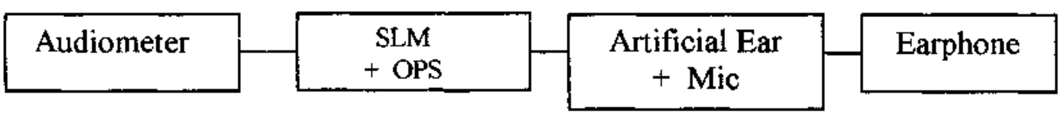
2. For frequency calibration



3. For bone conduction output sound pressure level



4. For linearity check



II. State whether true or false.

1. The person performing daily calibration may have a minimal hearing loss, yet it won't affect calibration.
2. The importance of daily calibration is that it need not be performed in a sound treated room.
3. In the loudness balance method, for biological calibration, the output from a calibrated audiometer is matched against the output of an audiometer to be calibrated by an individual.
4. The biological method for bone conduction output calibration using comparison of normal hearing versus sensorineural loss was given by Roach & Carhart.
5. During routine/ daily calibration linearity check is done beginning with intensity level of 60-70 dB.

III. Fill In The Blanks.

1. The objective biological calibration method was given by_____________.
2. The Accessories of the artificial mastoid are____________and_________.
3. The artificial ear is coupled with a______________microphone during calibration.
4. The headphones and audiometer should have_____________matched during calibration.
5. For frequency output calibration the deviation should not exceed_________ for frequencies from 500-4000 Hz and_________for 250, 6000. 8000 Hz (ANSI 1969).

STANDARDS RELEVANT TO PURE TONE AUDIOMETRY

The standards relevant to pure tone audiometry have been arranged in order of their appearance in the text.

Standards Relevant To The Specification For Audiometers.

CLASSIFICATION OF AUDIOMETERS

International Electrotechnical Commission (IEC: 1976) classified audiometers as: Typel, Type2, Type3, Type4, Type5. Typel, 2 & 3 are the diagnostic type & have the facility of both AC &BC, where as Type 4 & 5 are screening type having only AC facility.

(IS.9098-1979) classified audiometers as pure tone audiometer & digonostic audiometer. The pure tone audiometer has the facility to test using pure tones whereas the diagnostic audiometer has both, speech and pure tone testing facility.

According to ANSI (1969), the specifications for audiometers covers two major types of instruments-Pure tone audiometers & speech audiometers. Audiometric instruments are further categorized into wide, limited, &narrow range devices.

According to the Bureau Of Indian Standards:

Table 10. The diagnostic or pure tone audiometer shall be capable of generation or producing at least the following test frequencies for which HL values are indicated.

Sl. No.	Frequency in Hz	Minimum upper limit for Air conduction		Minimum upper limit for bone conduction	
		Diagnostic	Pure tone	Diagnostic	Pure tone
i)	125	70	70	-	-
ii)	250	90	90	45	30
iii)	500	120	100	60	50
iv)	750	120	100	60	-
v)	1000	120	100	70	50
vi)	1500	120	100	70	-
vii)	2000	120	100	70	50
viii)	3000	120	100	70	50
ix)	4000	120	90	70	50
x)	6000	110	-	-	-
xi)	8000	100	80	-	-
	Minimum value of output	-10		-10	

Tablell. The table gives the values for the maximum permissible deviations in the actual sound pressure level and the standard reference equivalent sound pressure level

Nominal Frequency Of Test Tone	Maximum Permissible Deviation	
Hz	Diagnostic dB	Pure tone dB
125	±3	±3
250	±3	±3
500	±3	+3
750	±3	±3
1000	±3	±3
1500	±3	±3
2000	±3	±3
3000	±3	±3
4000	±3	±3
6000	±5	±5
8000	±5	±5

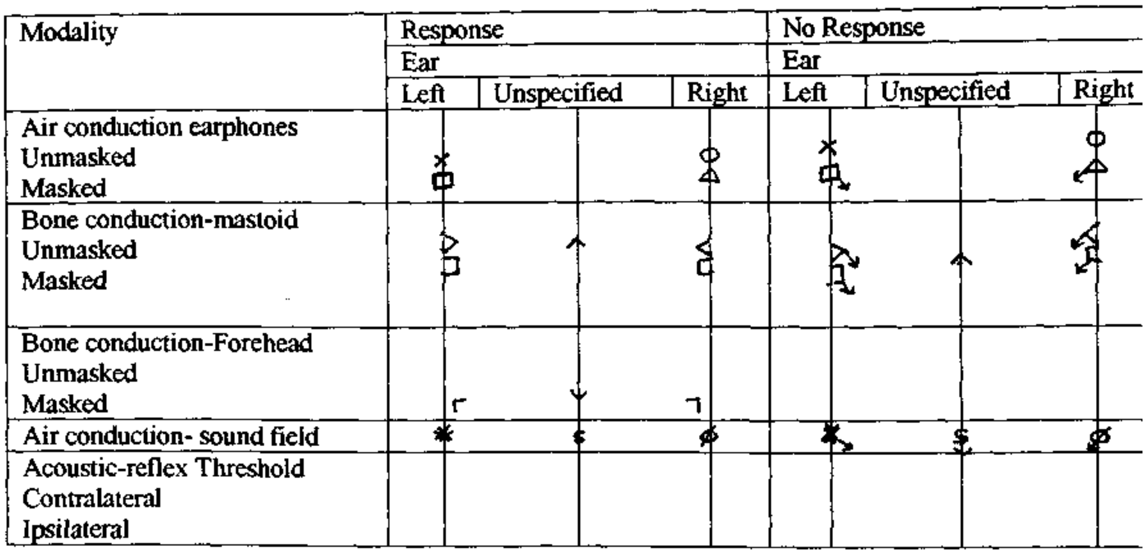
Tablel2. A table indicating the difference between the free field sensitivity level using G_F and the coupler sensitivity level G_c for four types of earphones using an ear simulator according to IEC 318 and 1/3 octave bands of noise as test signals.

Sl. No.	Centre Frequency	Gp-Gc (dB)			
		Byer DT 48 with flat cushion	Telephonic TDH49 withMx 41/ARor PN51 cushion	Telephonic TDH49 withMx 41/ARor PN51 cushion	Pracitronic DH80 with flat cushion
(1)	(2)	(3)	(4)	(5)	(6)
i)	125	-14	-16	-19	-17
ii)	160[1)]	-13	-14	-17	-16
iii)	200[1)]	-12	-12	-14.5	-15
iv)	250	-11	-10	-12	-14
v)	315[1)]	-9.5	-7	-9	-11.5
vi)	400°	-7.7	-4	-5.5	-8.5
vii)	500	-5.5	-1.5	-2.5	-5.5
viii)	630	-4	-0.5	-1	-3.5
ix)	800	-2.5	-1	-2	-3
x)	1000	-3	-1.5	-3	-3
xi)	1250	-2	-1.5	-2	-3.5
xii)	1600	-6.5	-5	-6.5	-8.5
xiii)	2000	-10	-7	-9	-11
xiv)	2500	-12	-7.5	-10.5	-12.5
xv)	3150	-12	-10.5	-12.5	-13
xvi)	4000	-10.5	-11.5	-13	-12
xvii)	5000	-5.5	-7.5	-8.5	-7.5
xviii)	6300	-6.5	-17	-12	-11.5
xix)	8000	-2.5	-6.5	-7.5	-6

[1)] Values for these frequencies are derived by interpolation.

Standards Relevant To The Audiogram.

Table 13: Audiometric symbols recommended by ASHA (1990).



Note : For standards regarding the construction, plotting and specifications of audiograms please refer to the chapter titled " The Audiogram".

Tablel4: The classification for the degree of hearing of hearing impairment as given by ANSI S 3.6 (1989).

Average Threshold level (dB)	Suggested Description
-10 to 15c	Normal hearing
16 to 25c	Slight Hearing loss
26 to 40	Mild hearing loss
56 to 70	Moderately severe hearing loss
71 to 90	Severe hearing loss
91 plus	Profound hearing loss

Modified from Goodman, A. 1965. Reference zero levels for pure tone audiometer, Asha 7, 262-263. Average threshold level re Ansi-1989 for 0.5, 1 and 2 kHz. Modified by Clark (1981); Goodman recommended normal hearing from-10 to 25 dB.

Standards Relevant To The Factors Affecting Pure tone Audiometry.

Table 15: Comparison of acceptable noise levels (in dB SPL for one-third octave bands) for ANSI and ISO standards in Audiometric test rooms when testing is expected to reach "0" dB HL for uncovered ears (e.g. Bone condution or sound field).

Frequency (Hz)	ANSIS 3.1-1991	ISO 8253- part1, 1989 (Assumes testing starts at 125 Hz)
125	23.0	20.0
250	13.5	13.0
500	9.5	8.0
1000	9.0	7.0
2000	3.5	8.0
4000	4.0	2.0
8000	15.5	15.0

Table 16: Maximum permissible sound levels for ambient noise during Audiometric testing.

Frequency (Hz)	Ears uncovered		Ears covered	
	Octave band	1/3- octave band	Octave band	1/3- octave band
125	28.0	23.0	34.5	29.5
250	18.5	13.5	23.0	18.0
500	14.5	9.5	21.5	16.5
750	12.5	7.5	22.5	17.5
1000	14.0	9.0	29.5	24.5
1500	10.5	5.5	29.0	24.0
2000	8.5	3.5	34.5	29.5
3000	8.5	3.5	39.0	34.0
4000	9.0	4.0	42.0	37.0
6000	14.0	9.0	41.0	36.0
8000	20.5	15.5	45.0	40.0
Values for ears not covered apply to bone-conduction and soundfield testing. Values for ears covered apply to air-conduction testing. Adapted rrom ANSI (1977).				

Standards Relevant To Masking For Pure Tone Audiometry.

Table 17: Recommended Band width for narrow band noise.

Test tone frequency	Band widths (Hz)
125 Hz	100
250 Hz	100
500 Hz	115
750 Hz	145
1kHz	160
1.5 kHz	225
2 kHz	300
3 kHz	470
4 kHz	700
6 kHz	1130
8 kHz	1500

Adapted from Scharf (1970).

Table 18: Maximum allowable Octave band SPL for no more than 1 dB Masking re Reference Hearing Threshold levels as specified in ANSI- S3.6-1969.

Test Frequency (Hz)											
Test condition	125	250	500	750	1000	1500	2000	3000	4000	6000	8000
Sound field or Bone conduction (in dB SPL)	28.0	18.5	14.5	12.5	14.0	10.5	8.5	8.5	9.0	14.0	20.5
Earphones with MX 41/ AR cushion	34.5	23.0	21.5	22.5	29.5	29.0	34.5	39.0	42.0	41.0	45.0

Adapted from ANSI 3.1-1977.

Standards Used With Reference To Transducers In Pure Tone Audio metry.

For Ear Phones.

Table 19: Reference Threshold levels For Audiometric Earphones[a].

Frequency (Hz)	Reference Threshold levels For all Earphones[b] |jPa
125	45.0
250	27.0
500	13.5
750	-
1000	7.5
1500	7.5
2000	9.0
3000	11.5
4000	12.0
6000	16.0
8000	15.5
[a] ISO R389 (1964, R [b]IEC 318 coupler.	1975).

Table 20: Reference Threshold levels for various earphones.

Reference Threshold levels re 20 mPa (0.0002 dynes/cm^2)[a]				
Frequency (Hz)	Western Eletric 705A	Telephonies TDH-39	Telephonies[b] TDH-49&50	Telex 1470[c]
125	45.5	45.0	47.5	47.0
250	24.5	25.5	26.5	27.5
500	11.0	11.5	13.5	13.0
1000	6.5	7.0	7.5	6.5
1500	6.5	6.5	7.5	5.0
2000	8.5	9.0	11.0	8.0
3000	7.5	10.0	9.5	7.5
4000	9.0	9.5	10.5	8.5
6000	8.0	15.5	13.5	17.5
8000	9.5	13.0	13.0	17.5

[a] Adapted from ANSI-S3.6-1969.
[b] Michael and Bienvenue, 1977, and in proposal revision of ANSI s 3.6-1969.
[c] Michael and Bienvenue, 1980.

Note : According to ANSI (1969). The standard tension for the headband is 5.4N /550 gms.

According to ANSI (1962). The diameter of the opening of the hole of the ear cushion should be 3/4 inches.

For Bone Vibrators

Table 21: Reference RMS equivalent Threshold force levels (dB rel N) for B-71 Vibrator used with a P-3333 Headband (ANSI S3.26-1981).

Frequency	Threshold Force level
250	61.0
500	59.0
1000	39.0
2000	32.5
3000	28.0
4000	31.0

Table 22: ISO DIS 7566 (1987) Specifications for the reference Equivalent Threshold force levels(RETFLs) Referenced to l uN for location of the vibrator on the mastoid bone based on a combined study using the B-71 and KH 70 bone vibrators with the mechanical output measured on a B & K 4930 Artificial mastoid.

	Frequency (Hz)							
	250	500	750[a]	1000	1500[a]	2000	3000	4000
RETFL[b]	67.0	58.0	48.5	42.5	36.5	31.0	30.0 J	35.5
[a] Values at these frequencies are derived from the results in one country. [b] Values rounded to the nearest 0.5dB.								

Note: According to ANSI (1972). The standard values for the head band tension and the contact tip area are 5.4 N/550gms and 1.75 cm2 ± 25 mm2

For insert earphones

Table 23: Interim reference sound-pressure levels (Re 20 uPa)for 0-dB hearing level as developed in a 2-cm3 (HA-1) coupler for the etymotic ER-3A insert earphone*

Frequency (Hz)	SPL
125	27.5
250	15.5
500	8.5
1000	3.5
2000	6.5
3000	5.5
4000	1.5
6000	-1.5
8000	-1.0
* Adapted from ANSIS3.6-1989.	

Tab!e 24: Indicates reference threshold levels Msted in ANSI S 3.6-1996 for the Etymotic ER-3A or Eartone-3A using HA-2 coupler with rigid tube specified in the ANSI S 3.7 (1995).

Frequency (Hz)	(In dB re: 20 pPa) dB
125	25.0
250	14.0
500	5.5
750	2.0
1000	0.0
1500	2.0
2000	3.0
3000	3.5
4000	5.5
6000	2.0
8000	0.0

Answers

Historical aspects

I. Word grid

R	E	T	E	M	O	N	O	S	C	I	R	T	C	E	L	E
P	L	S	R	O	I	S	U	Q	W	Y	A	R	O	R	Z	R
K	E	A	Q	T	C	L	I	F	T	E	R	O	E	O	I	E
J	C	N	T	E	O	Z	I	B	A	N	G	T	R	W	M	T
T	T	T	W	H	I	S	P	E	R	S	E	A	P	P	M	E
R	R	R	P	R	N	R	I	T	N	M	A	U	Q	I	E	M
G	I	O	S	B	C	T	O	S	U	Q	C	D	S	T	R	D
M	C	I	N	C	L	O	O	O	S	P	A	I	T	N	F	I
K	G	T	T	B	I	I	C	O	P	I	T	A	Z	A	F	D
T	E	E	A	D	C	A	A	P	R	Q	P	N	O	N	I	U
E	N	N	A	C	K	R	O	F	G	N	I	N	U	T	N	A
S	E	A	R	U	I	C	I	I	A	C	P	M	Z	I	I	E
L	R	C	U	L	F	G	H	L	T	R	U	T	P	O	T	B
O	A	U	D	I	O	A	M	P	L	I	F	I	E	R	A	U
M	T	P	L	R	E	T	E	M	O	R	A	G	A	I	E	T
N	O	O	C	R	E	A	T	I	C	A	C	E	M	T	Q	M
U	R	E	T	E	M	O	I	D	U	A	A	I	E	W	I	U
R	F	A	I	P	I	I	U	M	O	N	I	E	S	A	P	C
E	S	A	M	I	I	T	E	R	F	E	A	T	T	O	E	C
T	I	M	O	I	H	Y	Z	P	E	C	Z	O	K	I	T	A
A	M	F	E	A	R	F	E	L	O	K	I	T	E	N	A	V

II. Write in one sentence

1.He introduced the automatic self-recording audiometer in which the tone fluctuates around the threshold under the subject's control.

2.They contributed the audioamplifier, which used a speech circuit along with air conduction and bone conduction pure tone audiometry.

3. They contributed the principles towards the manufacturing of the first commercial audiometer - the Western EletriclA Audiometer.

4. He contributed the electric generator which produces an alternating current, which made the modern audiometer possible.

5.He contributed the acoumeter, which utilized a telephone receiver for the purpose of testing hearing.

III Match the following

[i]- [d]
[ii]- [f]
[iii]- [j]
[iv]- [b]
[v]- [i]
[vi]- [c]
[vii]- [a]
[viii]- [e]
[ix]- [g]
[x]- [h]

IV. Who am I?

[I] Acoumeter

[ii] Electric Sonometer

[iii] The pitch range audiometer

[iv] Sonotone Jones Knudsen Model 1

[v] Western Electric 1A

[v1] The otaudian

I True or False

(i) True
(ii) False
(iii) False
(iv) False
(v) True

II Choose the right one

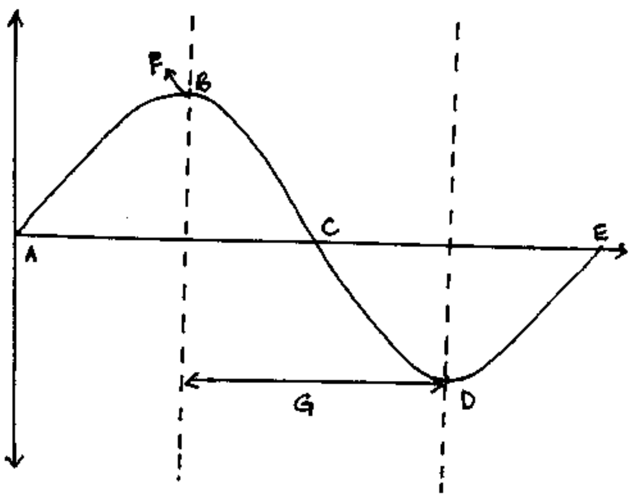
(i) -(a)
(ii) - (a)
(iii) -(d)
(iv) - (c)
(v) -(c)
(vi) -(b)

HI. Fill In The Blanks

(i) Inertia and elasticity
(ii) Loudness
(iii) Inversely, Inversely

IV. Fun With Figures

(i)



(ii) (b)

(iii) B Frequency would decrease increase.

C Frequency would decrease

V. Frequency

Intensity

Decibel

Mel

Pitch

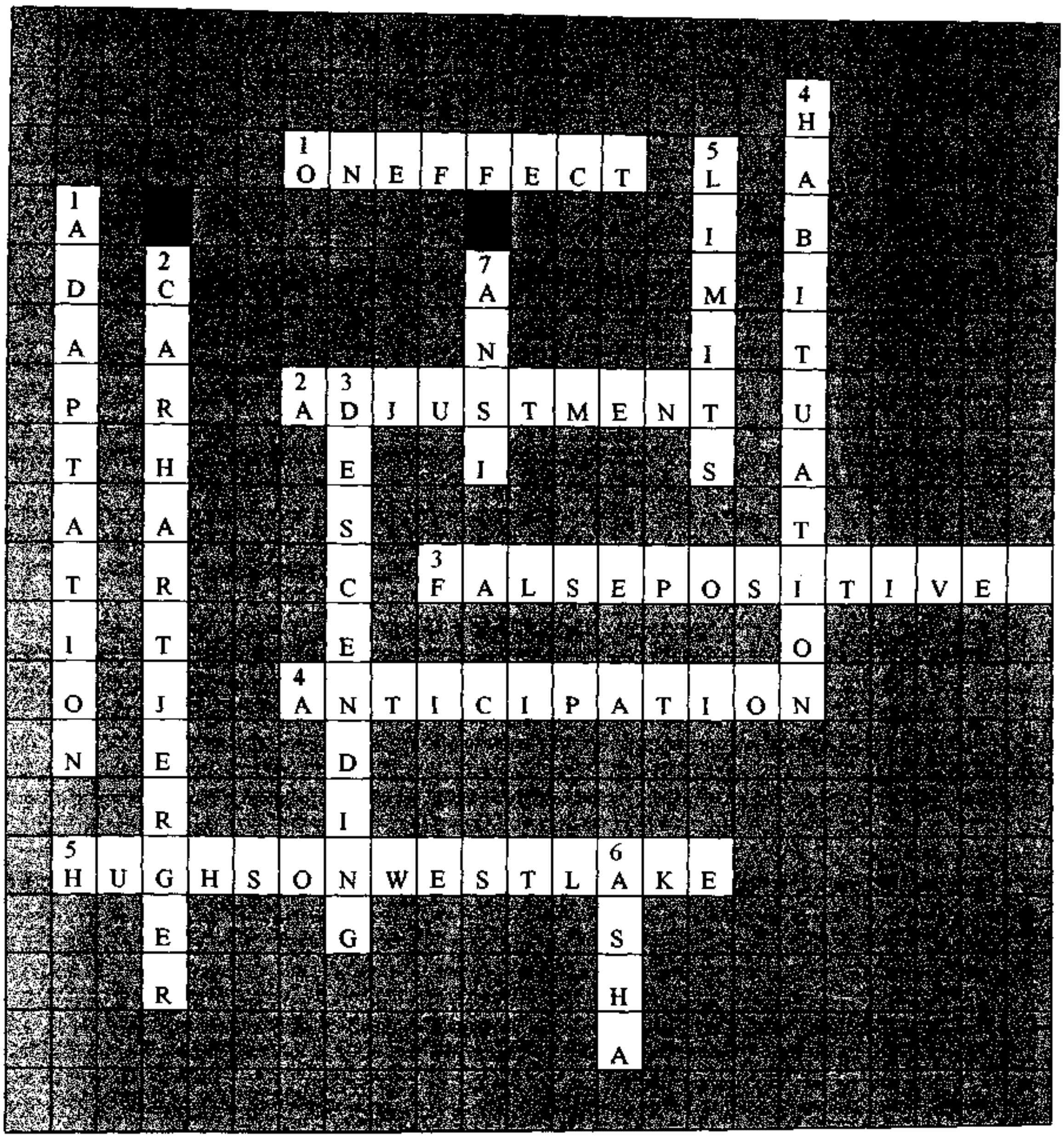
Loudness

Puretone

E	P	L	L	E	M	D	T	I	C	I	L
L	O	F	O	T	E	R	S	A	M	E	K
U	J	R	F	E	T	R	Q	P	B	O	L
S	S	E	N	D	U	O	L	I	L	I	A
A	P	Q	A	T	M	O	C	E	I	Y	T
E	Q	U	E	I	A	E		N	M	Z	O
A	A	E	O	C	D		L	O	E	P	M
I	I	N	T	E	N	S	I	T	Y	O	R
T	Z	C	T	E	P	O	L	E	S	E	E
O	R	Y	A	M	E	T	I	R	T	O	T
Q	N	E	Q	T	I	O	O	U	T	A	S
N	A	L	I	H	C	T	I	P	M	O	P

Pure tone air and bone conduction testing.

I. Crossword



II. True or false

1. False
2. True
3. False

4. True
5. False
6. True
7. True
8. False

II. Choose the right one

1. (c)
2. (a)
3. (c)
4. (c)
5. (c)

III. Fill In the Blanks

1. Bone conduction
2. Minimum Audible Pressure, Minimum Audible field
3. Magnitude/pattern
4. 60 dB
5. 55 dB

The Audiometer

1. Match the Following

1. (g)
2. (i)
3. (h)
4. (b)
5. (a)
6. (f)
7. (e)
8. (c)
9. (d)
10. (h)

II. Fill In the Blanks

1. Type1,Type2, Type3, Type4, Type5.
2. Diagnostic and Puretone.
3. Wide range, Limited range, Narrow range.
4. Automatic / Bekesy.
5. Group.

II. Which would you choose?

1. Frequency dial
2. Masking noise selector
3. Bone vibrator
4. Tone switch
5. Attenuator dial
6. Earphone
7. On/off switch

IV True or False

1. False
2. False
3. True
4. True
5. False.

The Audiogram

I. Match the following

1. (a)
2. (e)
3. (h)

4. (i)
5. (f)
6. (c)
7. (k)
8. (d)
9. (j)
10: (g)

II. Fill in the blanks

1. Octave, inter octave
2. Air conduction
3. Left, Right
4. Moderate
5. Trough

III. True or False

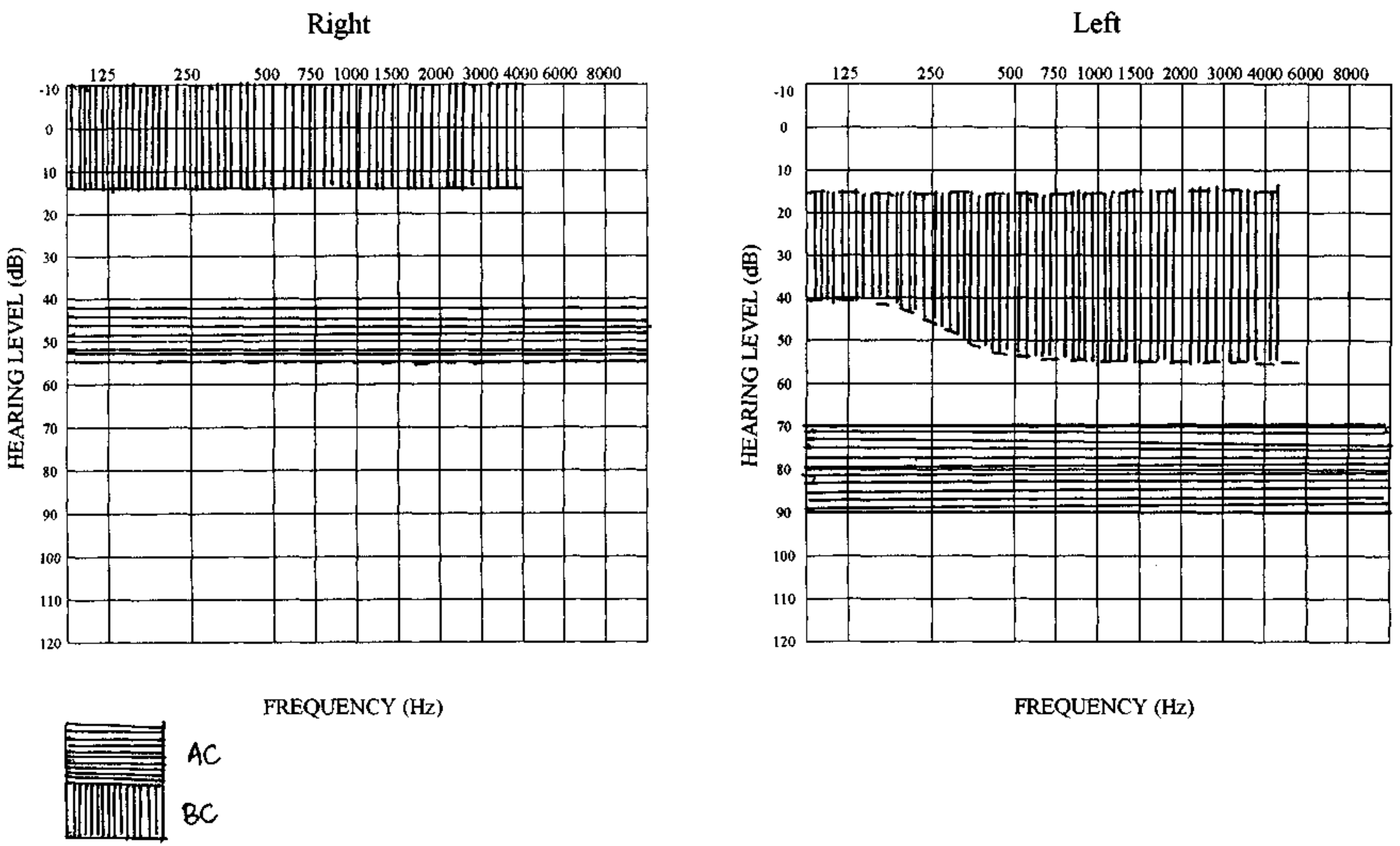
1. False
2. False
3. True
4. False
5. True

IV. Plotting of Audiograms

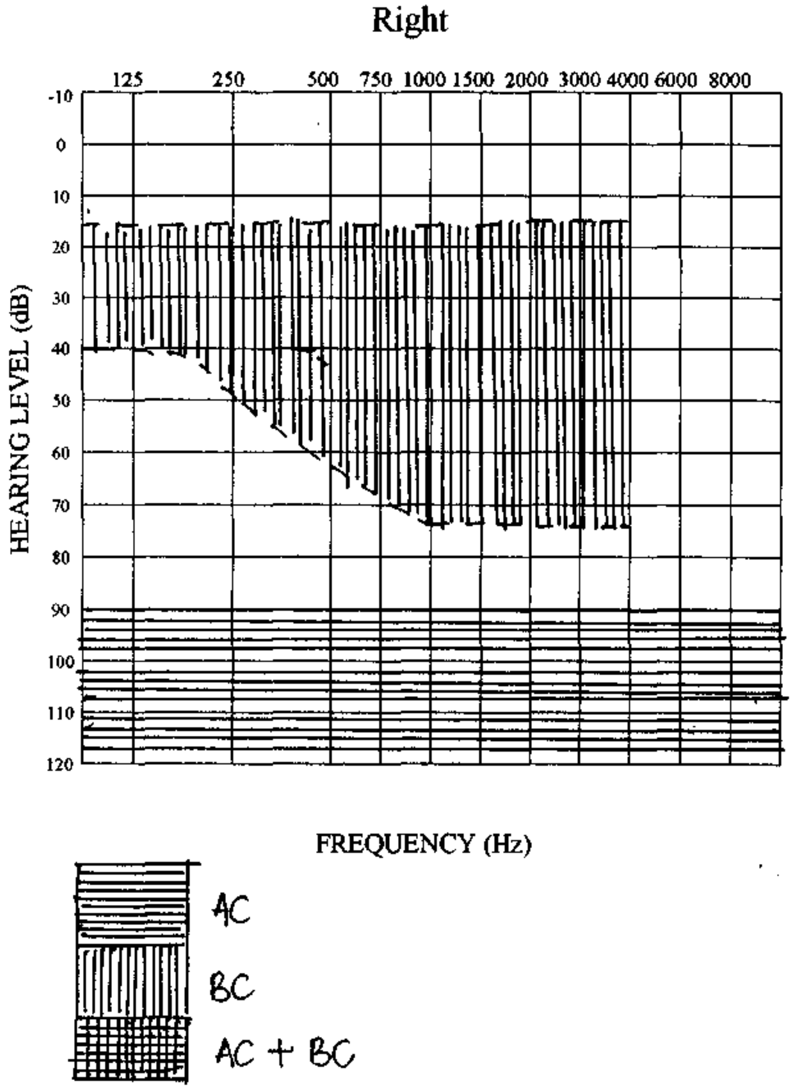
1. It should be noted that the Audiogram should most likely show this configuration. However, it being a subjective test variations may be obtained.

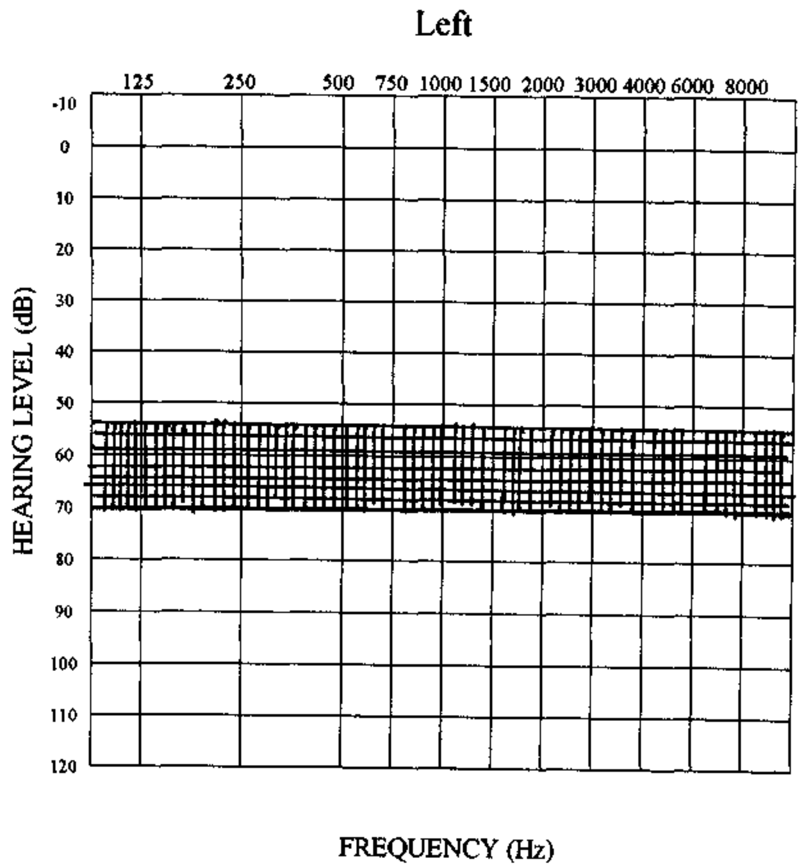
   a. Caharts notch i.e., 2000 Hz BC dip seen in Otosclerosis
   b. A 4 KHz dip or dip anywhere between 3-6 KHz seen characteristically in NIHL with probability of having high frequency SN hearing loss.
   c. A saucer shaped Audigram
   d. A gradually sloping hearing loss

IV. 2. (a) The thresholds may be plotted any where with the pure tone average for AC in the shaded region of the Audiogram.

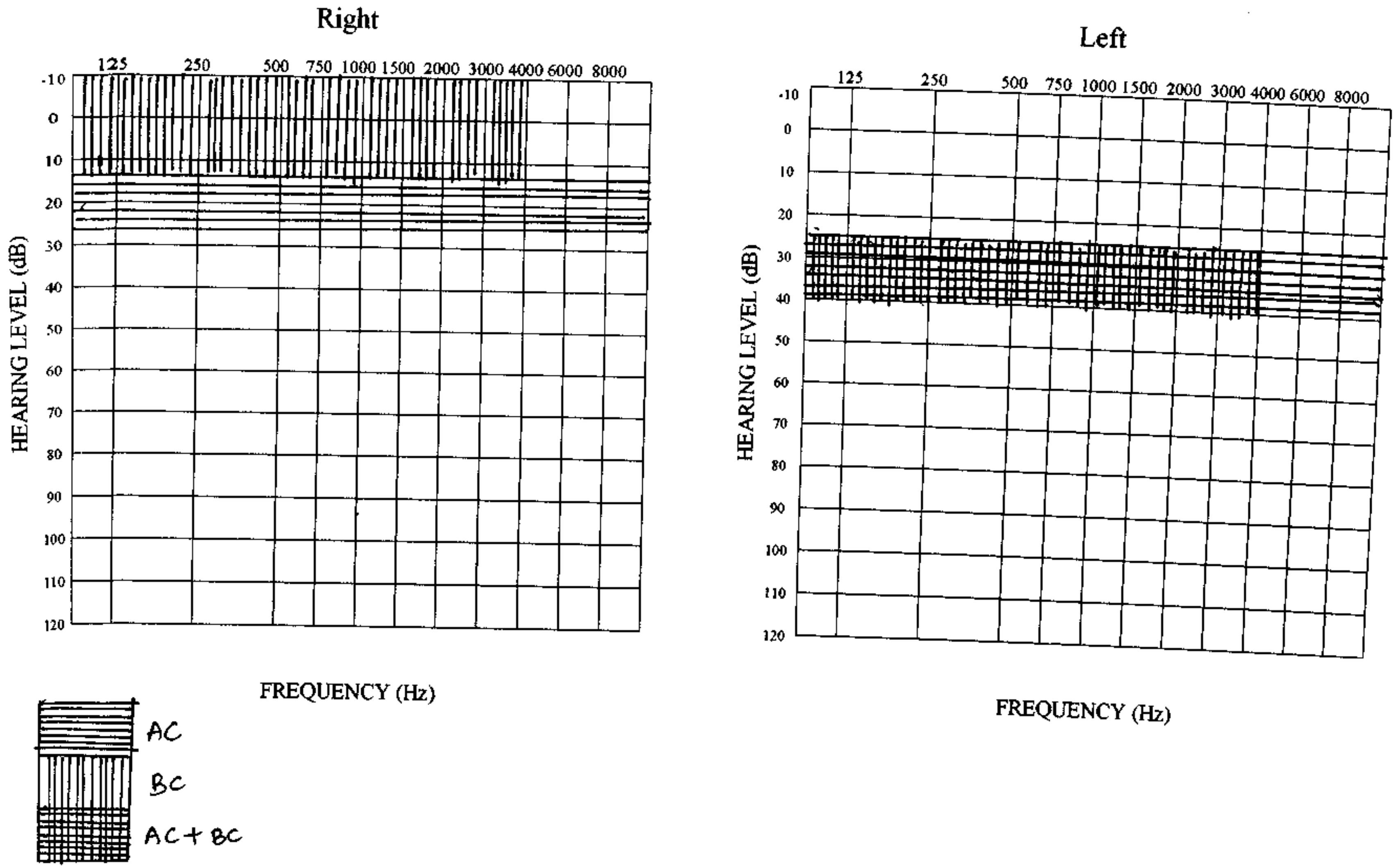


IV. 2. (b)

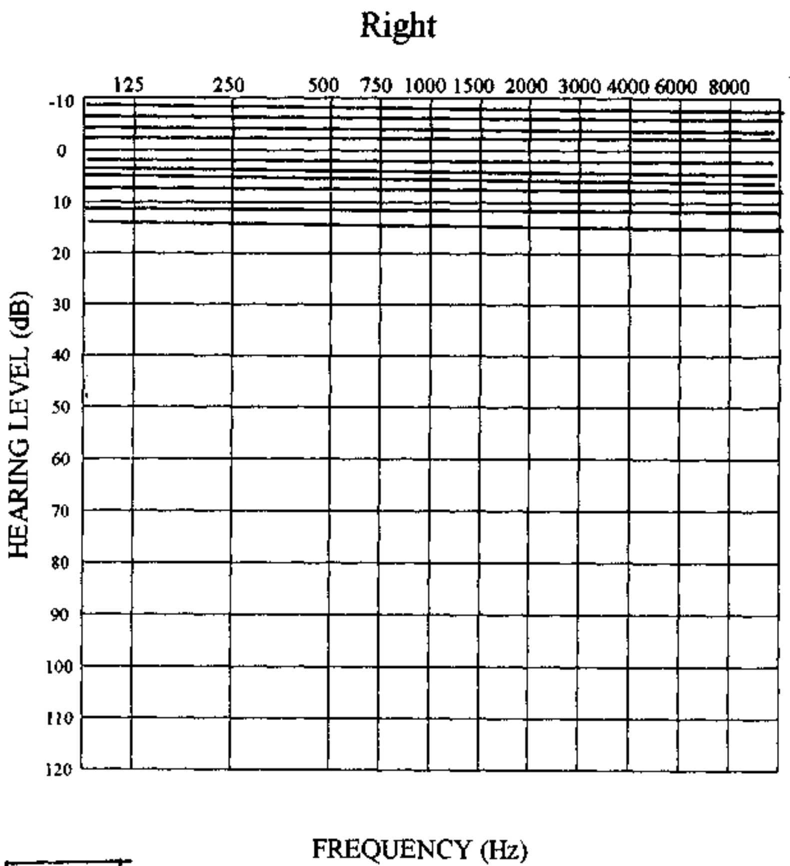

Right
125
250
500
750
1000
1500
2000
3000
4000
6000
8000
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
HEARING LEVEL (dB)
FREQUENCY (Hz)
AC
BC
AC + BC

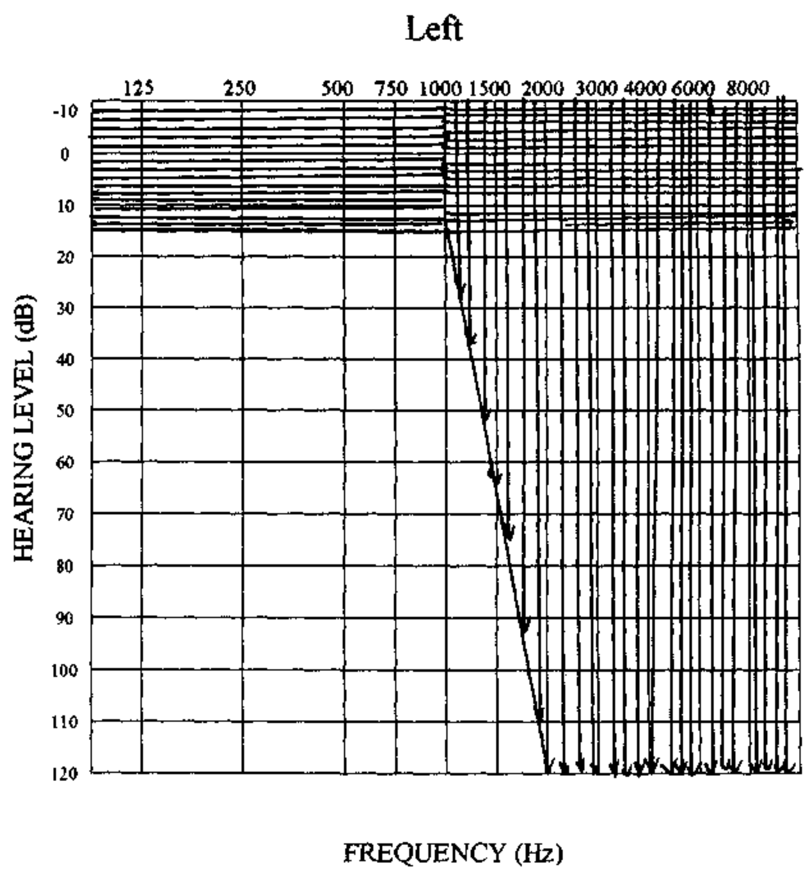

Left
125
250
500
750
1000
1500
2000
3000
4000
6000
8000
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
HEARING LEVEL (dB)
FREQUENCY (Hz)

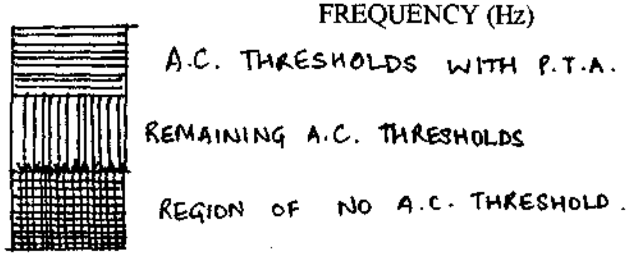
IV. 2. (c)


Right
125
250
500
750
1000
1500
2000
3000
4000
6000
8000
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
HEARING LEVEL (dB)
FREQUENCY (Hz)
Left
HEARING LEVEL (dB)
FREQUENCY (Hz)
AC
BC
AC+BC

IV. 2. (d)

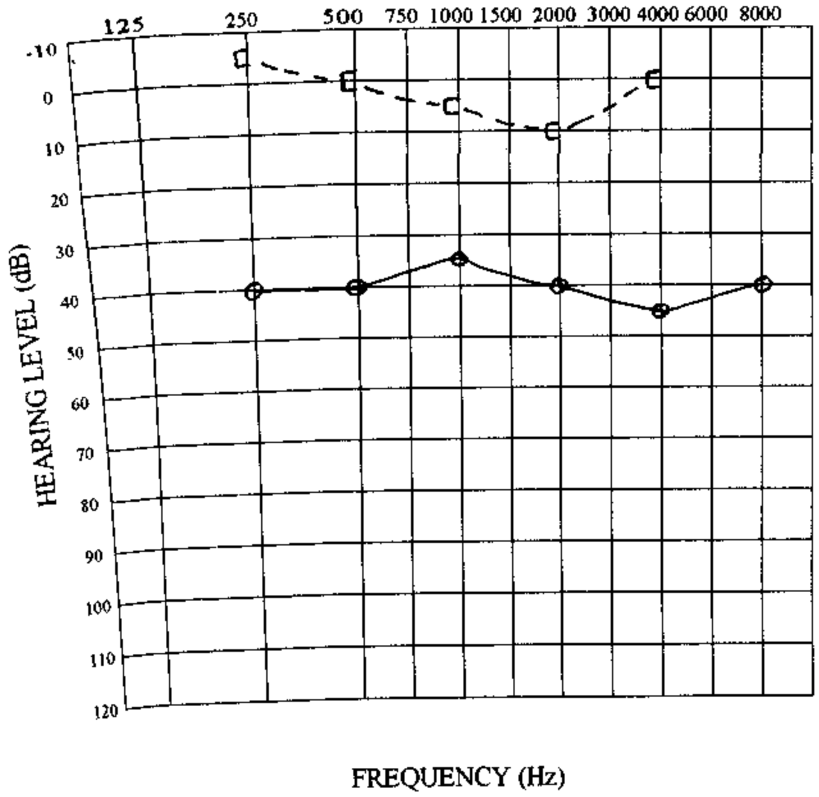

Right
125
250
500
750
1000
1500
2000
3000
4000
6000
8000
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
HEARING LEVEL (dB)
FREQUENCY (Hz)


Left
125
250
500
750
1000
1500
2000
3000
4000
6000
8000
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
HEARING LEVEL (dB)
FREQUENCY (Hz)

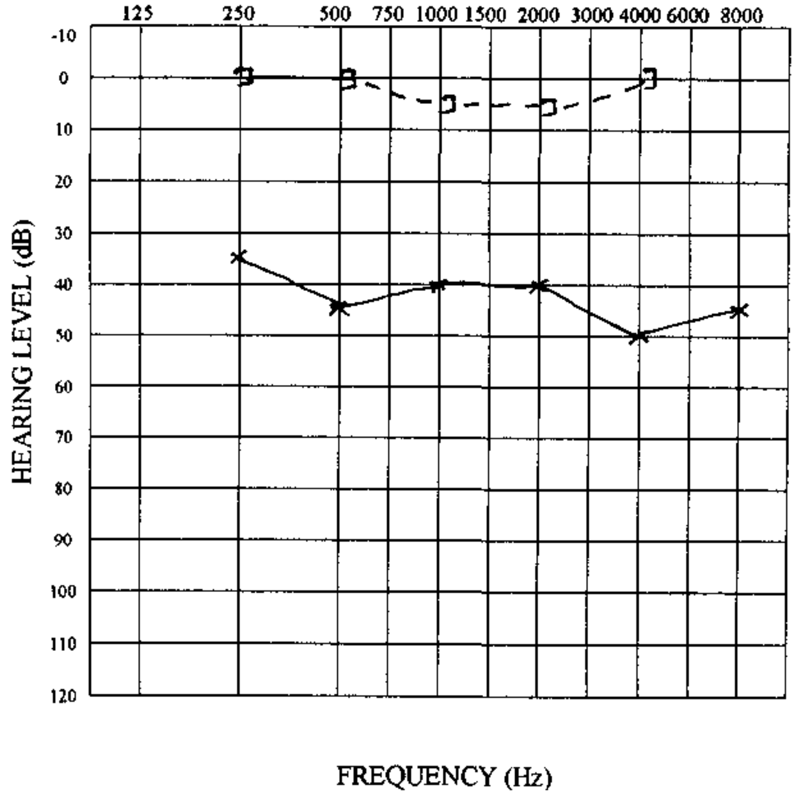

A.C. THRESHOLDS WITH P.T.A.
REMAINING A.C. THRESHOLDS
REGION OF NO A.C. THRESHOLD.

V. 1. (a)

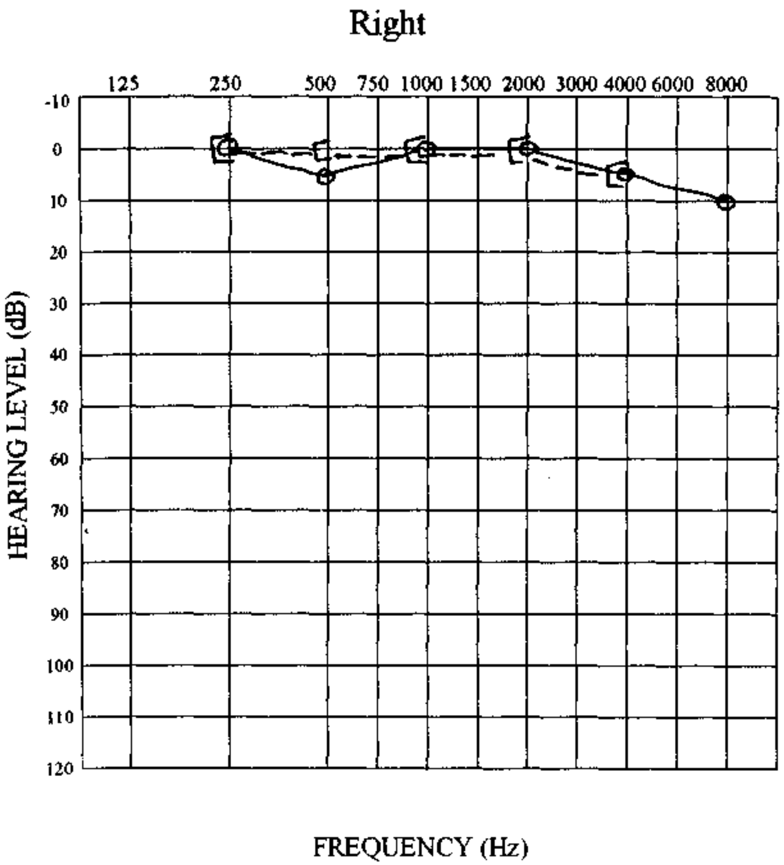
Right



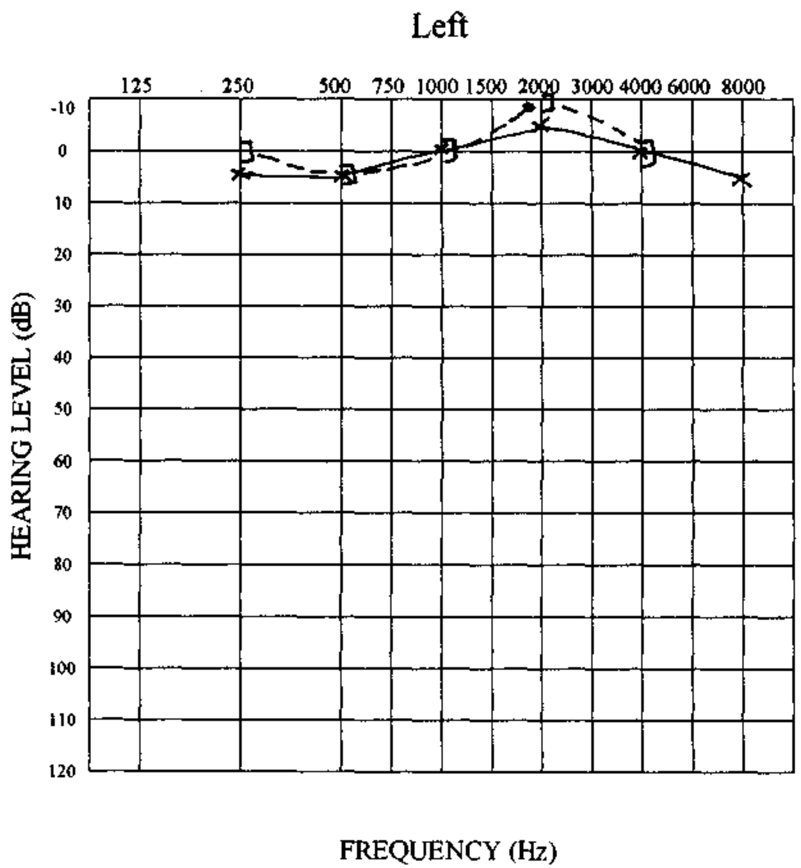
Left



V. 1. (b)



Right
125
250
500
750
1000
1500
2000
3000
4000
6000
8000
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
HEARING LEVEL (dB)
FREQUENCY (Hz)



Left
125
250
500
750
1000
1500
2000
3000
4000
6000
8000
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
HEARING LEVEL (dB)
FREQUENCY (Hz)

V. 2.Diagnose the following

A.

1. The child has bilateral mild conductive hearing impairment.
2. The significant difference between the air and bone conduction thresholds (i.e., the BC is nil while the AC is affected) indicates this along with ME disease.

B.

1. Yes the man has a moderate bilateral hearing impairment with gradually falling configuration .
2. There is not enough information to determine what type of impairment is present because the AC results alone are not sufficient to make the judgement.

C.

1. This woman has bilateral minimal conductive hearing impairment
2. The age of onset of the problem usually becomes evident in late adolescence or young adulthood, is familial & is more prevalent in females than males. Conductive type impairments with using audiometric configurations are frequently caused by stiffness type problems, e.g. restricted movement of the ossicular chain which is consistent with a diagnosis of otosclerosis.

D.

1. The man appears to have essentially normal hearing sensitivity for the middle and lower frequencies with a moderate sensorineural impairment of the high frequencies bilaterally
2. This audiometric configuration is typical of the loss resulting from noise exposure. The sensorineural nature of the loss, the maximum loss at 4000 Hz and the partial recovery at 800 Hz are all indications of this etiology.

This man's history of noise exposure makes this diagnosis more probable. However, diagnosis should not be made on the basis of the audiometric pattern alone other etiologic factors can produce similar patterns although it is highly unlikely that any of the other etiologic factors listed would produce the audiometric pattern

E.

1. The lady has a moderate sensorineural loss with a rising configuration in her ear and normal hearing in her left ear.
2. Based on otologic examination, case history and audiological tests this woman's impairment has been diagnosed as Meniere's disease.

F.

1. This man has high frequency sloping hearing loss

This audiometric configuration is typical of presbycusis (hearing loss associated with aging) but a diagnosis should not be made on the basis of the audiometric pattern alone. This pattern can be associated with other etiologies and other audiometric patterns can be associated with presbycusis. However, the case history information indicating late onset of loss and no other apparent etiologic indications supports the diagnosis of presbycusis

VI Are the following audiograms possible?

a. Unlikely, because the BC threshold should have been obtained for the right ear
b. Unlikely as AC is always poorer than BC. In cases of mastoiditis and temporal bone fracture it is possible, but the difference may not be so much. In geriatric cases with mastoid bone ossification, this may be seen.
C. Possible, it is a usual Audiogram that is commonly obtained.

d. Unlikely, because AC loss generally does not exceed 60 dB HL because beyond this level the whole skull vibrates resulting in a direct stimulation of the cochlea.

Factors affecting pure tone audiometry.

I Match the following:

1. (i)
2. (j)
3. (h)
4. (b)
5. (c)
6. (d)
7. (g)
8. (a)
9. (f)
10. (e)

II. Fill In the Blanks

1. Mastoid, forehead
2. 5-10 dB
3. False positive, False negative
4. 1 meter, 45°
5. 5.4 N/ 550gm, 1.75 cm^2 ± $25mm^2$

III. True or false

1. False
2. True
3. True
4. False
5. True

IV. Find the 10 factors, which are known to affect air and bone conduction thresholds.

L	A	N	A	C	R	A	E	D	E	S	P	A	L	L	o	C	C	M	E	E	O	C
A	A	R	F	I	L	O	S	T	I	o	N	L	T	C	I	M	o	I	F	E	C	E
P	R	A	U	G	Y	I	T	I	E	c	M	A	O	M	A	E	T	T	I	L	c	U
I	I	S	T	L	U	N	O	I	T	I	S	O	P	R	E	N	E	T	S	I	L	Q
C	T	T	S	A	R	T	T	I	N	M	E	L	o	O	G	I	T	U	L	E	U	c
K	A	I	I	M	A	A	A	M	E	s	T	I	c	I	M	I	E	T	O	S	s	o
T	T	C	L	I	T	P	R	M	E	T	I	C	o	c	P	Q	U	R	I	E	I	T
U	U	Q	U	T	U	R	E	G	F	H	I	J	K	L	L	M	N	O	R	S	o	F
M	R	B	o	N	E	V	I	B	R	A	T	O	R	P	L	A	C	E	M	E	N	T
I	I	Q	u	O	M	R	I	M	E	O	L	K	O	S	I	T	I	F	E	R	E	I
T	C	o	p	I	I	A	R	O	Q	P	T	U	R	P	M	I	N	I	L	A	F	L
A	Q	u	E	T	T	M	I	s	U	u	Q	M	S	I	T	T	J	A	0	L	F	N
L	A	T	c	A	A	K	A	T	E	o	O	I	N	A	0	O	U	N	T	O	E	A
O	S	P	I	R	R	N	I	M	N	M	E	S	O	L	L	Y	K	C	I	P	C	E
P	S	O	R	B	U	T	R	W	C	A	R	E	T	T	L	U	F	C	O	S	T	T
R	E	T	A	I	P	E	A	T	Y	R	A	K	M	I	T	L	A	M	I	N	R	O
S	T	I	S	L	E	M	U	Q	S	E	V	A	W	G	N	I	D	N	A	T	S	T
S	A	N	o	A	T	P	E	p	E	A	T	E	I	T	R	T	E	S	M	I	A	M
P	I	T	I	C	M	E	L	u	Q	J	P	O	K	S	E	F	I	G	U	S	T	I
E	L	A	M	E	I	R	I	T	U	K	L	E	M	E	T	R	U	R	T	E	E	L
S	E	F	E	G	E	A	R	S	E	L	E	C	T	I	O	N	o	M	I	L	M	K
S	R	O	G	U	E	T	I	N	N	E	S	s	F	A	T	E	E	T	I	S	I	A
T	W	I	G	M	A	U	U	L	C	Z	o	T	X	T	S	M	N	O	P	Q	C	T
1	I	N	E	T	I	R	A	S	I	A	L	I	V	U	R	E	M	A	C	I	A	I
C	F	R	O	G	I	E	I	M	N	O	I	T	A	V	I	T	0	M	A	N	D	R
M	R	O	T	I	C	A	T	I	G	T	E	M	I	c	A	L	I	O	N	E	E	0

Masking

1. Choose the right one

1. (b)
2. (c)
3. (a)
4. (a)
5. (b)

II. Fill In The Blanks

1. Cross Hearing
2. Shadow curve
3. 40, 70 & 0 dB
4. Plateau seeking method
5. Audiometric weber

III. Unscrambling of words

1. Cross hearing
2. Aerial radiations
3. Shadow curve
4. inter aural attenuation
5. Plateau seeking method
6. Audiometric meter
7. Presentation level
8. Air bone gap

IV. In the following cases would masking be necessary? If yes what masking is required?

1. Yes, BC masking is required because the AC_{TE} - $BC_{NT}E$ > 10 dB
2. Yes, AC & BC masking is required because AC_{TE} - $BC_{NT}E$ > 40 dB, AC_{TE} - BC_{NTE} > 10 dB
3. Yes AC & BC masking is required AC_{TE} - BC_{NTE} > 40 dB, AC_{TE} - BC_{NTE} >10dB
4. No masking is not required.

Transducers

I. Fill In The Blanks

1. B-71
2. B-71
3. B-72
4. Stability, flat frequency response, high intensity
5. Electric, acoustic.

II. Match the following

1. (e)
2. (h)
3. (d)
4. (g)
5. (c)
6. (b)
7. (i)
8. (d)
9. (f)
10. (j)

Bekesy Audio met ry

I. Answer in one word

1. Retrocochlear
2. Intensity
3. Frequency
4. Normal
5. Mid point
6. Signal
7. Reverse

8. Automatic
9. Pseudohypercusis

High frequency audiometry

I. Match the following.

1. (d)
2. (e)
3. (f)
4. (c)
5. (a)
6. (b)

Difficult -to -test population

I. Which method would you use

1. Ear choice Method
2. Behavior Observation Audiometry
3. Play audiometry
4. Tangible reinforcement Audiometry.

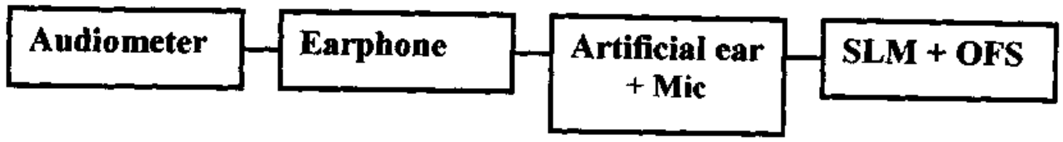
II. True or False

1. False
2. False
3. True
4. True

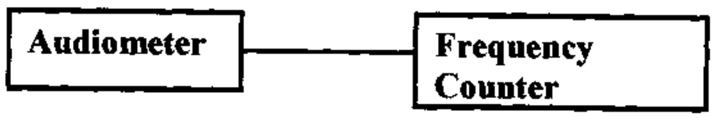
Calibration

I. Rearrange the block diagram

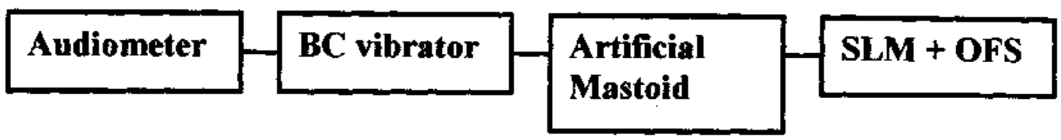
(i)



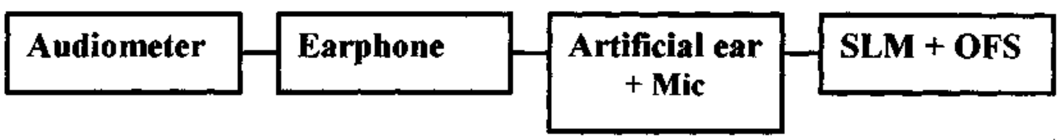
(ii)



(iii)



(iv)



III. True or false

1. False
2. False
3. True
4. True
5. False

I. Fill In The Blanks

1. M.N. Vyasamurthy
2. Level indicator, Spring balance
3. Condensor/pressure
4. Impedance
5. $\pm 3\%$ $\pm 4\%$.

REFERENCES

AAO - ACO (American Academy of Otolaryngology and American Council of Otolaryngology) (1979). Guide for evaluation of hearing handicap. *Journal of the American Medical Association.* 241, 2055-2059.

Allen, G.W., and Fernandez, C. (1960). The mechanism of bone conduction. *Annals of Otolaryngology.* 69, 5-29.

American Academy of Ophthalmology and Otolaryngology Committee on Hearing and equilibrium and the American council of Otolaryngology committee on the medical aspects of noise. (1979) Guide for the evaluation of hearing handicap. *Journal of the American Medical Association,* 241, 2055-2059.

American Medical Association (1942) Tentative Standard procedure for evaluating the percentage of useful hearing loss in medical cases. *Journal of the American Medical Association.* 199: 1108-1109.

American National Standards Institute (1969). American National standard specifications for audiometers (ANSI S3. 6-1969; R 1973). New York: Author.

American National Standards Institute (1972) American National Standard for
* an artificial headbone for the Calibration of audiometer bone vibrators. (ANSI S3.13-1972) New York: Author.

American National Standards Institute (1973) American National Standard Psychoacoustical Terminology (ANSI S3.20 1973) New York: Author.

American National Standards Institute (1973). American National Standard
^ method for coupler calibration of earphones (ANSI S3 7-1973) New York: Author.

American National Standards Institute (1977). American National Standard Criteria for permissible ambient noise audiometric testing (ANSI S3.1-1977) New York: Author.

American National Standards Institute (1977). Criteria for Permissible Ambient Noise during Audiometric testing. ANSI S3.11-1977 (R 1986). New York: Author.

American National Standards Institute (1978). Manual for Pure-tone threshold audiometry (ANSI S3.21-1978, R86) New York: Author.

American National Standards Institute (1981). American National Standard reference equivalent threshold force levels for audiometric bone vibrators (ANSI) S3-26-1981) New York: Author.

American National Standards Institute (1982). American National Standard specification for a mechanical coupler for measurement of bone vibrators. (ANSI S3.1987) New York: Author.

American National Standards Institute (1982). American National Standard specifications for sound level meters (ANSI SI 4-1983). New York: Author.

American National Standards Institute (1984). American National Standard specification for acoustical calibrators (ANSI SI.40-1984). New York: Author.

American National Standards Institute (1986). Methods for Manual Puretone Threshold Audiometry. ANSI 33.21-978 (R 1986). New York: Author.

American National Standards Institute (1987a). American National Standard specification for a mechanical coupler for measurement of bone vibrators (ANSI S3. 13-1987). New York: Author.

American National Standards Institute (1989). American National Standards Institute specifications for audiometers. (ANSI S3.6-1989). New York: Author.

American Speech and Hearing Association, Committee on Audiometric Evaluation (1974) guidelines for audiometric symbols. American Speech and Hearing Association, 17, 260-264.

American Speech and Hearing Association, Committee on Audiometric Evaluation (1978) guidelines for manual Pure-tone threshold audiometry. American Speech and Hearing Association, 20, 297-301.

American Speech-Language-Hearing Association (1988). Guidelines for audiometric symbols American Speech and Hearing Association, 30, 39-40.

American Speech-Language-Hearing Association (1990). guidelines for audiometric symbols. American Speech and Hearing Association, 20, (Suppl 2), 25-30.

American Standards Association (1951). American Standard specifications for audiometers for general diagnostic purposes (Z24. 5-1951). New York: Author.

Arlinger, S.D. (1979) Comparison of ascending and bracketing methods in puretone audiometry. *Scandinavian Audiology,* 8, 247-254.

Atkinson C.J. (1960) Cited in Lloyd, L.L. Puretone Audiometry In : R.T. Fulton. L.L. Lloyd and R. Hoyt, (Eds.). Auditory Assessment of the Difficult to test, (pp. 01-37) Baltimore : Williams and Wilkins.

Barany, E.A. (1938) A contribution to the physiology of bone conduction *Ada Otolaryngologica* (Stockholm), supplement 26, 12-23.

Basavaraj, S. (1980). Calibration of the Audiometer How to do it instruction manual. An independent project submitted in part fulfillment for the degree of Master of Science, Speech and Hearing, University of Mysore, Mysore.

Beiter R C and Talley J.N. (1976). High Frequency Audiometry above 8000Hz. *Audiology* 15, 207-214.

Bekesy, G.V. (1932) Cited in S. Silman and C.A. Silverman, *Auditory diagnosis - principles and applications.* San Diego, Academic Press.

Bekesy, G.V. (1947). A New Audiometer. *Acta Otolaryngologica* (Stockholm), 35,411-422.

Bekesy, G.V. (1960) Experiments in Hearing New York, Macgraw-Hill.

Berkowitz, A.O. (1975). Audiologic Rehabilitation of the geriatric patient, *Hearing Aid Journal.* 8, 32-34.

Bess, F.H. and Humes, L.F.(1990). *Audiology: The Fundamentals,* Baltimore: Williams and Wilkins.

Blake, C.J. (1913). Cited in Glorig, A and Downs, M. "Introduction to Audiometry" In : Glorig (Ed.), *Audiometry : Principles and Practices,* (pp. 01-14) Baltimore : Williams and Wilkins.

Bricker , D.D. and Bricker, W.A. (1969a). A programmed approach to operant audiology for low-functioning children. *Journal of speech and Hearing Disorders,* 34, 312-320.

Bricker W.A. and Bricker, D.D., (1969b). Cited in Lloyd, L.L., Puretone Audiometry : In : Fulton, R.T., Lloyd, L.L. and Hoyt, R. (Eds.). *Auditory Assessment of the Difficult to test* (pp. 01-37). Baltimore : Williams and Wilkins.

Bunch, C.C. (1941) Cited in Glorig, A and Downs, M. "Introduction to Audiometry" In A, Glorig (Ed.). *Audiometry: Principles and Practices.* (pp 01-14), Baltimore : Williams and Wilkins.

Bunch, C.C. (1943). Cited in Glorig, A and Downs, M. "Introduction to Audiometry" In A, Glorig, *Audiometry : Principles and Practices,* fpp 01-14), Baltimore, Williams and Wilkins.

Burkhard, M.D. and Corliss, E.L. (1954). The response of ear phones in ears and couplers. *Journal of Acoustic Society of America,* 26, 679-685.

Carhart, R. (1945). Classifying Audiograms: An improved Method for classifying audiograms. *Laryngoscope,* 55, 640-662.

Carhart, R. and Jerger, J.F. (1959). Preferred method for clinical determination of pure-tone thresholds *Journal of Speech and Hearing disorders,* 24, 330-345.

Chaiklin, J.B. (1967). Interaural attenuation and cross hearing in air-conduction audiometry. *Journal of Auditory Research,* 7, 413-424.

Chaiklin J.B., and Mc Clelland M.E. (1971). Audiometric Management of Collapsible ear canals. *Arichives of Otolayngology* 93, 397-407.

Cheval V. (1990). Cited in Glorig, A and Downs, M. "Introduction to Audiometry" In A, Glorig. (Ed.). *Audiometry : Principles and Practices* (pp 01-14) Baltimore : Williams and Wilkins.

Clark K.E. (1957). Cited in L.L. Lloyd and H. Kaplan (1978) Audimetric Interpretation: A manual of basic audiometry. Baltimore: University Park Press.

Clark J.G. (1981). Cited in Yantis, P.A.. Pure-tone Air Conduction Threshold testing. In J. Katz. (Ed.). *Handbook of Clinical Audiology,* Fourth Edition (pp. 97-108). Baltimore : Willams and Wilkins.

Clark J.L. and Roeser, R.J. (1988). Three studies comparing performance of the ER - 3 A tubephone with the IDH-50p earphone. *Ear and Hearing,* 9, 268-274.

Corso J.F. (1963). Age and Sex differences in Pure-tone thresholds. *Archives of Otolaryngology,* 77, 385-405.

Corliss, E., and Koidan, D. (1955). Mechanical impedance of the forehead and mastoid. *Journal Acoustical Society of America,* 27, 1164-1172.

Curry E.T. and Kurtzrock, G.H. (1951). A preliminary investigation of the ear-choice technique in threshold audiometry. *Journal of speech and Hearing disorders,* 16, 340-345.

Dadson, R.S., Robinson, D.W. and Grieg, R.G.P. (1954). Cited in Silman and Silverman, *Auditary Diagnosis Principles and Applications.* San Diego, Academic Press.

Dadson, R.S. and King, J.H. (1952). A determination of the normal threshold of hearing and its relation to the standardization of audiometers. *Journal of Laryngology and Otology,* 66, 366-378.

Dale, D.M.C. (1962). Cited in L.L. Lloyd and Kaplan H. (1978) Audiometric Interpretation: A manual of basic audiometry. Baltimore: University Park Press.

Davis H., and Silverman, S.R. (1970). *Hearing and Deafness.* New York Holt, Rinchart, and Winston.

Dean, L.W. and Bunch, C.C. (1919). Cited in Glorig, A and Downs, M. "Introduction of Audiometry" In A, Glorig (Ed.). *Audiometry: Principles and practices,* (pp. 01-14), Baltimore : Williams and Wilkins.

Delk, J.H. (1973). Comprehensive dictionary of audiology. Sioux city, IA: *Hearing Aid Journal.*

Dillon, H., and Wacker, G. (1980). The Perception of normal hearing persons of intensity fluctuations in narrow band stimuli and its implications for sound field calibration procedures. *Australian Journal of Audiology.* 2, 72-82.

Dirks, D.D. and Malmquist, C.W. (1964). Changes in bone - conduction thresholds produced by masking in the non-test ear. *Journal of Speech and Hearing Research,* 7, 271-278.

Dirks D. (1964a). Factors related to bone conduction reliability. *Archives of Otolaryngology,* 79, 551-558.

Dirks D. (1964b). Bone Conduction measurements. *Archives of Otolaryngology,* 79, 594-599.

Dirks, D.D and Swindeman, J.G. (1967). The variability of occluded and unoccluded bone conduction thresholds. *Journal of Speech and Hearing Research,* 10, 232-249.

Dirks. D.D. and Kamm, C. (1975). Bone Vibrator Measurements. Physical Characteristics and behavioural thresholds. *Journal of Speech and Hearing Research,* 18, 242-260.

Driks, D.D., Lybarger, S.F., Olsen, W.O. and Biullings, B.L. (1979). Bone conduction calibration : Current status. *Journal of Speech and Hearing Disorders,* 44. 141-155.

Dix, M.R. and Hallpike, C.S. (1947). Cited in Lloyd, L.L. Puretone Audiometry : In R.T, Fulton, L..L, Lloyd, and R, Hoyt, (Eds.). *Auditory Assessment of the Difficult to test* (pp. 01-37). Baltimore : Williams and Wilkins.

Dreschler, W.A., Van der Hulst, R.J. A.M., and Tange, R.A. (1984) Ototoxicity and the role of high-frequency audiometry. *Journal Acoustical Society of America* Suppl. 76, 74.

Dreschler, W.A. Van Der Hulst, R.J., Tange, R.A. and Urbanus, N.A. (1985). The role of high frequency audiometry in early detection of ototoxicity. *Audiology,* 24, 387-395.

Elpern, B.S. and Naunton, R.F. (1963). The Stability of the Occlusion effect *Archives of Otolaryngology,* 77, 376-382.

Ewing, A.W.G. (1930). Cited by Lloyd, L.L., Puretone Audiometry : In R.T, Fulton, L.L, Lloyd, and R, Hoyt, (Eds.). *Auditory Assessment of the Difficult to test.* (pp. 01-37). Baltimore : Williams and Wilkins.

Fausti S.A., Erickson D.A., Frey, R.H. Rappaport, B.Z. and Schecter, M.A. (1981). The effects of the noise upon human hearing sensitivity from 8000hz to 20,000Hz, *Journal of the Acoustical Society of America,* 69, 1343-1349.

Fechner, G.T. (1860). Cited in Silman and Silverman in *Auditory Diagnosis Principles and Applications.* San Diego, Academic Press.

Feldman, S.A. (1963). Hearing Loss, *Journal of Speech and Hearing Disorders,* 6, 157-163.

Fletcher H. (1929). Cited in Yantis, P.A. Pure-tone Air Conduction. Threshold testing. In : J. Katz, (Ed.). *Handbook of Clinical Audiology,* Fourth Edition (pp. 97-108). Baltimore, Williams and Wilkins.

Fowler, E.P. and Wegel R.L (1922). Cited in Glorig, A and Downs, M. "Introduction to Audiometry" In A. Glorig *Audiometry: Principles and practices* (pp. 01-14). Baltimore : Williams and Wilkins.

Frisina, R. (1973). Measurement of hearing in children. In J. Jerger. (Ed.). *Modern developments in Audiology* (2nd ed). New York : Academic Press.

Fulton, R.T. (1967). Cited in Lloyd, L.L., Puretone Audiometry : In R.T. Fulton, L.L. Lloyd, and R. Hoyt, (Eds.). *Auditory Assessment of the Difficult to test* (pp. 01-37). Baltimore : Williams and Wilkins.

Gardner, M.B. (1947). A pulse-tone clinical audiometer. *Journal of the Acoustical Society of America,* 19, 592-599.

Goldstein, D.D. and Hayes, C.S. (1965). The occlusion effect in bone conduction hearing. *Journal of Speech and Hearing Research,* 8, 137-148.

Goodhill, V., Guggerheim, P. (1971). Cited in Travis L.E. (Ed.) *Handbook of Speech Pathology and Audiology,* Englewood Cliffs : Prentice Hall.

Goodman A. (1965). Reference zero levels for pure-tone audiometer. *American Speech and Hearing Association. 7,* 262-263.

Green D.S. (1978). Cited in Yantis, P.A. Pure-tone Air conduction Threshold testing. In : J. Katz. (Ed.). *Handbook of Clinical Audiology,* Fourth Edition (pp. 97-108). Baltimore : Williams and Wilkins.

Green J.D. (1880). Cited in Glorig, A and Downs, M. "Introduction to Audiometry". In A. Glorig, *Audiometry: Principles and practices, (*pp 01-14), Baltimore: Williams and Wilkins.

Hallmo, P., Sundby. A. and Mair. Hallmo W.S. (1994). Extended high frequency audiometry - Air and bone conduction thresholds, age and gender variations. *Scandinavian Audiology,* 23, 165-170.

Hannley M. (1986). *Basic Principles of auditory assessment.* San Diego: College - Hill Press.

Haughton P.M. (1982). A system of generating a valuable mechanical impedance and its use in an investigation of the electromechanical properties of the B-71 audiometric bone vibrator. *British Journal of Audiology* 16, 1-7.

Hirsh, I., Reynolds, E., and Joseph. M. (1954). Intelligibility of different speech materials. *Journal Acoustical Society of America,* 26, 530-538.

Hodgson W.R. (1980). Cited in Yantis, P.A. Pure-tone Air Condition Threshold testing. In J. Katz, (Ed.). *Handbook of Clinical Audiology,* Fourth Edition (pp. 97-108). Baltimore: Williams and Wilkins.

Hood. J.D. (1960). The principles and practice of bone conduction audiometry, a review of the present position. *Laryngoscope.* 70, 1211-1228.

Hughes D.E. (1978). Cited in Glorig, A and Downs, M. "Introduction to Audiometry". In A. Glorig, *Audiometry: Principles and practices, (*pp 01-14), Baltimore: Williams and Wilkins.

Hulka, J. (1941). Bone conduction changes in acute otitis media. *Archives of Otolaryngology.* 33, 333-346.

Huzing E.H. (1964). Cited in Silman and Silverman, in *Auditory Diagnosis - Principles and Applications.* San Diego : Academic Press.

International Electrotechnical Commission (1971). An IEC mechanical coupler for the calibration of bone vibrators having a specified contact area and being applied with a specific static force. IEC - 373 1971. Geneva : International Electrotechnical Commission.

International Standards Organization (1975). Acoustics - Standard referece zero for the calibration of pure-tone audiometers. ISO R 389. Geneva, Switzerland. Addendum ISO DAD-1, 1981. Geneva : International Standards Organization.

International Standards Organization (1987). Acoustics - Standard reference zero for the calibration of pure-tone bone-conduction audiometers and guidelines for its practical application. ISO/DIS 7566. Geneva : International Standards Organisation.

Ishisawa, H.A. (1960). Cited in Lloyd, L.L. Puretone Audiometry : In R.T. Fulton, L.L. Lloyd, and R. Hoyt, (Eds.). *Auditory Assessment of the Difficult to test.* (pp. 01-37). Baltimore: Williams and Wilkins.

Jacobson, L. (1885). Cited in Glorig, A and Downs, M. "Introduction to Audtiometry" In A. Glorig, *Audiometry: Principles and practices,* (pp 01-14), Baltimore: Williams and Wilkins.

Jerger, J. (1973). Diagnostic audiology. In J. Jerger (Ed.). *Modern developments in audiology,* 3d ed., (pp. 75-115). New York : Academic Press.

Jerger J.A. (1976). Proposed audiometric symbols system for scholarly publications. *Archives of Otolaryngology,* 102, 33-36.

Jerger, E.H. and Kerivan, J.E. (1983). Influence of physiological noise and the occlusion effect on the measurement of real-case attenuation at threshold. *Journal of the Acoustical Society of America,* 74, 81-94.

Jones I. H. Kundsen V. O. (1924). Cited in Golig, A and Downs, M. "Introduction to Audiometry" In A. Glorig (ed). Audiometry: Principles and Practices, (pp. 01-14). Baltimore: Williams **and Wilkins.**

Katz j . , (1991). ***Handbook of Clinical Audiology,*** **4* Edition, Baltimore: Williams** and Wilkins.

Killion, M.C., Wilber, L.A. and Dunmundsen, G.I. (1985). Insert earphones for more interaural attenuation. *Hearing Instruments,* 36, 34-36.

Knox, E.L. (1960). Cited in Lloyd, L.L. Puretone Audiometry : In R.T. Fulton, L.L. Lloyd, and R. Hoyt, (Eds.). *Auditory Assessment of the Difficult to test.* (pp. 01-37), Baltimore: Williams and Wilkins.

Langenbeck, B. (1950). Cited in Glorig. A and Downs. M. "Introduction to Audiometry". In A. Glorig, *Audiometry: Principles and Practices,* (pp 01-14), Baltimore: Williams and Wilkins.

Laukli, E., and Mair, I.W.S. (1985). High - Frequency audiometry : Normatives studies and preliminary experiences. *Scandivian Audiology.* 14, 151-158.

Lesak, J. (1970). Cited in Lloyd, L.L. Puretone Audiometry : In R.T. Fulton. L.L. Lloyd, and R. Hot, (Eds.). *Auditory Assessment of the Difficult to test.* (pp. 01-37), Baltimore: Williams and Wilkins.

Liden, G., Nilsson, G. and Anderson H. (1959b). Masking in clinical audiometry. *Acta Otolaryngolog\ca,* 50, 125-136.

Liden G., Nilsson, G. and Anderson, H. (1974). Minimum Effective Masking levels in threshold Audiometry. *Journal of Speech and Hearing Disorders,* 39, 280-285.

Lloyd, L.L., (1966). Behavioural Audiometry viewed as an operant procedure. *Journal of Speech and Hearing disorders.* 31, 128-136.

Lloyd, L.L. and Cox. B.P. (1975). Cited in Lolyd, L.L. Puretone Audiometry : In R.T. Fulton, L.L. Lloyd, and R. Hoyt. (Eds.). *Auditory Assessment of the Difficult to test.* (pp. 01-37). Baltimore: Williams and Wilkins.

Lloyd, L.L. and Kaplan, H. (1978). *Audiometric interpretation: A manual of basic audiometry.* Baltimore: University Park Press.

r

Lloyd L.L. Reid, M.J. (1967). Cited in Lloyd, L.L. Puretone Audiometry : In R.T. Fulton, L.L. Lloyd., and R. Hoyt, (Eds.). *Auditory Assessment of the Difficult to test* (pp. 01-37), Baltimore: Williams and Wilkins.

Lloyd L.L. and Reid, M.J., MacManis D.L. (1968). Cited in Lloyd, L.L. Puretone Audiometry : In R.T. Fulton, L.L. Lloyd, and R. Hoyt. (Eds.). *Auditory Assessment of the Difficult to test.* (pp. 01-37). Baltimore: Williams and Wilkins.

Lybarger, S.F. (1966). Interim bone conduction thresholds for audiometry. *Journal of Speech and Hearing Research,* 9, 483-487.

Martin, F.N. (1980). The masking plateau revisited, *Ear and Hearing,* 112-116.

^ **Martin, F.N. (1991).** Introduction to Audiology, 5th edition, Englewood Cliffs: Prentice Hall.

Martin, F.N., Butler, E.C. and Burns, P. (1974). Audiometric Bing test for determination of minimum masking levels for bone conduction tests. *Journal of Speech and Hearing Disorders.* 39, 148-152.

* **Martin, F.N. and Sides, D.G. (1985).** Survey of current audiometric practices. *American Speech and Hearing Association,* 27, 29-36.

Mauren J. and Rupp, R.R. (1976). Cited in J. Maurer and R.R. Rupp, *Hearing and Aging, tactics for intervention.* New York; Grune and Stration.

Michael, P.L., and Bienvenue, G.R. (1976). Calibration data for a circumaural headset for hearing testing. *Journal of Acoustic Society of America,* 6, 944-950.

Michael, P.L., and Bienvenue, G.R. (1977). Real-ear threshold level comparisons between the Telephonics TDH - 39 earphone with a metal outer shell and the TDH-39, TDH-49, and TDH-50. earphones with plastic outer shells. *Journal of the Acoustical Society of America,* 61, 1640-1642.

Michael, P.L., and Biervenue, G.R. (1980). Calibration data for the Telex 1470-A Audiometer earphones. *Journal of the Acoustical Society of America,* 67, 1812-1815.

Michael, P.L. and Bienvemue, G.R. (1981). Noise attenuation characteristics for superannual audiometric headsets using the models MX-41/AR and 51 earphone cushions. *Journal of the Acoustical Society of America,* 70, 1235-1238.

Miller, A.L., (1962). Cited in Glorig, A Downs, M. "Introduction to Audiometry". In A. Glorig, *Audiometry: Principles and practices,* (pp 01-14). Baltimore: Williams and Wilkins.

Moore, J.M. Wilson, W.R. and Thompson, G. (1975). Cited in Lloyd, L.L. Puretone Audiometry : In R.T. Fulton, L.L. Lloyd, and R. Hoyt, (Eds.). *Auditory Assessment of the Difficult to test.* (pp. 01-37). Baltimore: Williams and Wilkins.

Naunton, R.F., and Fernandez, C. (1961). Prolonged bone conduction observations on man and animals. *Laryngoscope.* **71,** 306-318.

Naunton, R.F. (1963). The measurement of hearing by bone conduction. In J. Jerger (Ed.). *Modern Developments in Audiology,* (pp. 1-29). New York: Academic Press.

Newby, H (1964). *Audiology,* 2rd Edition, Engle wood cliffs : Prentice hall.

Newby, H (1972). *Audiology,* 3rd Edition, Engle wood cliffs : Prentice hall.

Newby, H (1992). *Audiology,* 6th Edition, Engle wood cliffs : Prentice hall.

Nober, E.H. (1970). Cutile air and bone conduction thresholds of the deaf. *Exceptional children,* 36, 571-579.

O'Neill, J., Oyer, H. J. (1970). *Applied audiometry,* New York: Dodd Mead Co.

O'Neill, J., Oyer, H. J., and Hillis, J.W. (1961). Audiometric procedures used with children. *Journal of Speech and Hearing Disorders,* 26, 61-66.

Orlandsson, B., Hakausson, H., Iversson, A and Nilsson, P. (1980). Cited S. Silman and C.A. Silverman in *Auditory Diagnosis - Principles and Applications.* San Diego, Academic Press,

Pascoe, D. (1978). An approach to hearing aid selection. *Hearing Instruments,* 29, 12-16.

Poltzer, A (1883). Cited in Glorig, A and Downs, M. "Introduction to Audiometry" In A. Glorig, *Audiometry: Principles and practices,* (pp 01-14), Baltimore: Williams and Wilkins.

Reger, S.N. (1950). Standardization of pure-tone audiometer testing technique. *Laryngoscope,* 60, 161-185.

Reger, S.N. (1952). A clinical and Research version of the Bekesy audiometer. *Laryngoscope,* 62, 1333-1351.

Reger, S.N. (1970). Bekesy audiometry and the method of limits. International Audiology 9, 24-29. Cited in Silman and Silverman, in *Auditory Diagnosis - Principles and Applications.* San Diego: Academic Press.

Richards, W.D., and Frank, T. (1982). Frequency response and output variations of Radioear B-71 and B-72 bone vibrators *Ear and Hearing,* 3, 37-38.

Rintelmann, W.F. (1991). *Hearing Assessment,* Second Edition Boston. Allyn and Bacon.

Roach R. amd Carhart, R. (1956). Cited in Wilber, L.A. Calibration Puretone, Speech and Noise Signals, pp. 73-94, J. Katz, Handbook of Clinical Audiology. Baltimore: Williams and Wilkins.

Rose, D.E. (1978). *Audiological assessment,* 2nd edition, Englev\jpod Cliffs: Prentice Hall.

Rudmose, W. (1964). Cited in Wilber, L.A. Calibration Puretone, Speech and Noise Signals, pp. 73-94, J. Katz, Handbook of Clinical Audiology. Baltimore: Williams and Wilkins.

Sanders, T.W. and Rintelmann, W.F. (1964). Masking in Audiometry. *Archives of Otolaryngology.* 80, 541-556.

Sataloff, J., Sataloff. R.T. and Vassallo. L.A. (1980). *Hearing Loss,* (2nd Edn). Philadelphia Lippincott.

Schwartz, A. (1952). Cited in Glorig, A and Downs, M. "Introduction to Audiometry" In A. Glorig, *Audiomery: Principles and practices,* (pp 01-14), Baltimore: Williams and Wilkins.

Seashore C.E. (1899). Cited in Glorig. A and Downs, M. "Introduction to Audiometry". In A. Glorig, *Audiometry: Principles and practices,* (pp 01-14), Baltimore: Williams and Wilkins.

Shaw E. (1966). Ear canal pressure generated by circumaural and supraaural earphones. *Journal of Acoustical Society of America,.* 39 , 471-479.

Shipton, MS., John, A.J., and Robinson, D.W. (1980). Air radiated sounds from bone vibrator transducers and its implications for bone conduction audiometry. *British Journal of Audiology,* 14, 86-99.

Silman S. and Silverman C.A. (1991). *Auditory Diagnosis - Principles and Applications,* San Diego, Academic Press.

Skinner M., and Miller, J. (1983). Amplification bandwidth and intelligibility of speech in quiet and noise for listeners with sensorineural hearing loss. *Audiolology,* 22, 253-279.

Spradlin J.E., and Lloyd, L.L. (1965). Cited in R.T.Fulton, L.L. Lloyd, and R. Hoyt, (Eds.). *Auditory Assessment of the Difficult to test.* (pp. 01-37). Baltimore: Williams and Wilkins.

Stach, B.A. (1988). Computes and Audiologic Instrumentation. *Hearing Instruments.* 39, 13-16.

Statten, P. and Wishart, D.E.S. (1950). Puretone audiometry in young children : Psychogalvanic skin-resistance and peep - show. *Annals of Otology, Rhinology and Laryngology,* 65, 511 -534.

Stefanini, A. (1914). Cited in Glorig, A and Downs, M. "Introduction to Audiometry" In A. Glorig, *Audiometry: Principles and practices,* (pp 01-14), Baltimore: Williams and Wilkins.

Stephens M.W. and Rintelmann W.F. (1978), Cited in Glorig, A and Downs, M. "Introduction to Audiometry" In A. Glorig, *Audiometry: Principles and practices,* (pp 01-14), Baltimore: Williams and Wiikins.

Stewart, J.M., and Downs, M.P. (1984). Medical management of the hearing handicapped child. In J.L. Northern (Ed.) *Hearing Disorders,* (2nd Ed) (pp. 267-278). Boston: Little, Brown.

Streng, A., Fitch W.A., Hedgecock, L.D., Philips, J.W. and Carrell, J.A. (1955). Cited in Lloyd, L.L. and Kaplan, H. (1978). *Audiometric interpretation: A manual of basic audiometry.* Baltimore: University Park Press.

Studebaker, G.A. (1962). On masking in bone-conduction testing. *Journal of Speech and Hearing Research,* 215-227.

Studebaker, G.A. (1964). Clinical Masking in air and bone conducted stimuli. *Journal of Speech and Hearing Disorders,* 29, 23-35.

Studebaker, G.A. (1967a). Clinical masking of the Non Test Ear. *Journal of Speech and Hearing Disorders,* 32, 360-371.

Studebaker, G.A. (1967b). Interest variability and the air bone gap. *Journal of Speech and Hearing Disorders,* 32, 82-86.

Simonton K.M. (1965). Audiometry and Diagnosis In A. Glorig (Ed.). *Audiometry: Principles and Practices.* Baltimore: Williams and Wilkins.

Villchur, E. (1970). Audiometer - earphone mounting to improve intersubject and cushion - fit reliability. *Journal of Acoustical society of America,* 48, 1387-1397.

Tange, R.A., Dreschler, W.A. and Vander Hulst, (1985). The importance of high-tone audiometry in monitoring for ototoxicity. *Archives of Otorhinolaryngology.* 242, 77-81.

Thompson, G. and Weber, B.A. (1974). Response of infants and young children to behaviour observation audiometry (BOA). *Journal of Speech and Hearing Disorders.* 39, 140-147.

Tonnodorf. J. (1972). Cited in Silman and Silverman, in *Auditory Diagnosis - Principles and Applications.* San Diego, Academic Press.

Tonndorf, J., and Kurman, B. (1984). High frequency audiometry. *Annals of Otolaryngology,* 93, 576-582.

Watson, L.A. and Tolan, T. (1949). *Hearing Tests and Hearing Instruments.* Baltimore: Williams and Wilkins.

Weaver, R.M. (1965). Cited Glorig. A and Downs. M. Introduction to Audiometry" In A. Glorig, *Audiometry: Principles and Practices,* (pp 01-14), Baltimore: Williams and Wilkins.

Webb. C.E. Kindi, S.W., Webber, B.A. and Beedle, R.K. (1964). Cited in Glorig, A and Downs. M. "Introduction to Audiometry" In A. Glorig, *Audiometry: Principles and practices,* (pp 01-14), Baltimore: Williams and Wilkins.

Wilber, L.A. (1979). Pure tone audiometry : Air and bone conduction. In W.F. Rintelmann (Ed.). *Hearing assessment* (pp. 29-49). Baltimore: Williams and Wilkins.

Wilber, L.A. (1985). Calibration : Purtetone, speech and noise signals. In J. Katz (Ed.), *Handbook of clinical audiology,* 3rd ed, pp. 115-150.

Wilber, L.A. Kruger, B., and Killion, M.C. (1988). Reference thresholds for the ER-3A insert earphone. *Journal of Acoustic Society of* America, 83, 669-676.

Wolfe, W.G. and Mac Pherson, J.R. (1959). Cited in Glorig, A and Downs, M. "Introduction to Audiometry" In A. Glorig, *Audiometry: Principles and practices,* (pp 01-14), Baltimore: Williams and Wilkins.

Yantis, P.A. (1985). Puretone air-conduction testing. In J. Katz (Ed.). *Handbook of clinical audiology,* pp. 153-169. Baltimore : Williams and Wilkins.

Zwislocki, J. (1953). Acoustic attenuation between ear. *Journal of the Acoustical Society of America,* 25, 752-759.

Zwislocki, J., Maire, R., Feldman, A., and Ruben, a (1958). One the effect of practice and motivation on the threshold of audibility. *Journal of Acoustic Society of America,* 30, 254-262.