A COMPUTER BASED QUESTION BANK ON OTOACOUSTIC EMISSIONS

Register No.M0124

An Independent Project submitted in part fulfillment for the
first year **M.Sc, (Speech and Hearing)**
University of Mysore, Mysore.

All India Institute of Speech and Hearing
Manasa Gangothri
Mysore

MAY 2002

CERTIFICATE

This is to certify that the Independent Project entitled : **"A Computer Based Question Bank on Otoacoustic Emissions"** is the bonafide work in part fulfillment for the degree of Master of Science (Speech and Hearing) of the student with Register No.MO 124.

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Mysore
May 2002

CERTIFICATE

This is to certify that this Independent Project entitled : "A **Computer Based Question Bank on Otoacoustic Emissions"** 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.

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DECLARATION

I hereby declare that this Independent Project entitled "A Computer Based Question Bank on Otoacoustic **Emissions"** is the result of my own study under the guidance of ***Dr. Vanaja,*** *C.S.*, Lecturer in Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier at any other University for the award of any Diploma or Degree.

Mysore **Reg. N0.M0124**
May 2002.

Dedicated to

The Shepard

of my soul....

and my family.

'The Lord is my Shepard and I

shall not be in want'

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Rambo, Teebeekie, Keibeecee, Choice, Kurgi and Savi — It's a long time bond that we share , . you all mean so much to me. . .. Lets stay together through thick and thin.

Rakhi, Mili, Amala— I don't blame t£e language …. I'*m just stuck to you guys !*

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CHAPTER I

INTRODUCTION

Otoacoustic emissions (OAEs) are narrow-band acoustical signals that can be detected in the ear canal. They are vibrations produced at various locations within the cochlea with and without stimulation (Kemp, 1997). Ever since the discovery of OAEs by Kemp (1978). OAEs have dominated the curiosity and clinical interests of researchers as well as audiologist. It is patently clear that OAEs provide valuable information on auditory function and can make an important and unique contribution to early detection of cochlear impairment and to diagnostic audiological assessment. OAEs are now an essential, and permanent, component of the clinical audiology test battery.

Different types of OAEs have been identified. While spontaneous otoacoustic emissions (SOAEs) occur without external stimulation, evoked otoacoustic emissions occur with stimulation (Kemp, 1978). Among the evoked OAEs, stimulus frequency OAEs (SFOAEs) are evoked with a constant puretone stimulus presented at a low intensity. SFOAEs are the least studied experimentally and clinically. There are no commercially available devices for recording

SFOAEs (Probst Lonsbury-Martin & Martin, 1991). The other types of evoked OAEs are transient evoked OAE (TEOAE) and the distortion product OAE (DPOAE). The most common stimuli for TEOAE are clicks, although tone bursts may also be used. DPOAEs are elicited by simultaneous presentation of two pure tones, closely spaced in frequency. Both TEOAEs and DPOAEs have been intensively studied and there is no consensus upon which is better applicable. Rather, together they give a corroborative view of the cochlear functioning (Probst, Martin & Lonsbury-Maitin, 1991).

The instrumentation of OAEs is fairly simple. Generally, OAE recording requires an acoustic ear-canal-probe assembly containing a loudspeaker to stimulate the ear, a microphone to record all sounds in the ear canal. Analyzing the signals requires a signal separating and averaging system (FFT), phase-locked averaging to discriminate between sounds emerging from the cochlea and other sounds such as stimulus and noise (Kemp, Ryan & Bray, 1990). With the introduction of the ILO_{88} (Otodynamics) as a clinical device for measurement of TEOAEs in 1988, at least a half dozen devices for TEOAE and DPOAEs are available in the market today.

The testing conditions are critical in the measurement of OAEs. Probe fit, ambient noise and patient movement are significant factors which may affect results. OAEs are more sensitive to middle ear dysfunction than ABR, as both forward and backward transmission of sounds through the middle ear is a prerequisite (Hall, 2000).

Measurement of OAEs is not a test of hearing, and they certainly will not supplant pure tone audiometry, immittance measures, or ABR. However. OAEs do offer information on auditory function that is not available from any other measure, behavioral or electrophysiologic literature is rapidly accumulating on assorted clinical applications of OAE, ranging from new born hearing screening to identification and differentiation of a host of auditory dysfunctions in children and adults.

This independent project is an attempt to compile a majority of the information on OAEs and to present it in the form of a self-assessment question bank which will be helpful to students, teachers and practicing audiologists. Its access as a software would muster the user's interest as well as offer the benefits of computer based tutorials (CBTs).

Aim of the study

The aim of the present study was to develop a software program which can be used by students, a practicing clinician or allied professionals to get acclimatize with OAE. The software consists of a question bank, which evaluates the user's knowledge of OAE and helps in improving the same.

Need of the study

The following statements justify the need of the study :

1. Where there is a plethora of literature on a subject, it becomes necessary to abridge and hive away the available information, especially for educational purpose.
2. Except for a few books, much of the information on OAEs are available in journal articles. These need to be compiled and collectively presented to ameliorate the reader's knowledge.
3. The formulated questions can be easily adopted for educational purposes such as tests, interviews, etc.
4. The access to a computer based tutorial helps to keep up with the growing dependence of todays student on modern technology. Further, it would make the learning of OAEs more exciting and innovative.

The advantage of this software include :

a) Helping to understand and learn OAEs in a more interesting and mind capturing manner.

b) To keep up with the advancing use of computers in education.

CHAPTER-2

METHOD

Collection of information:

Information was collected from various references such as textbooks, journals, the internet, etc. Articles from 1980s to 2001 were studied. Only human studies have been included so as to limit the scope of the study.

Formulation of questions

The following are the types of questions included -

a) Multiple choice questions

b) True/False

c) Fill in the blanks

d) Fill in the missing letters

e) Fill in the missing block

The entire question bank has been divided into the following sections -

1) Introduction and Basic Physiology

2) Instrumentation
3) SOAEs
4) TEOAEs
5) DPOAEs and SFOAEs
6) Suppression
7) Applications
8) Interpretation of OAEs

The questions are arranged from basic to complex in each section. The user can opt for any section of his choice and answer the questions.

Ambiguity verification

The questions were administered to ten students of graduate and under-graduate levels who were selected randomly. They were asked to mark each question for ambiguity and difficulty. The questions marked as ambiguous were corrected and clarified.

The software

As a user first logs onto the program, he will be acquainted with the purpose of the program and the instructions. Then user information will be acquired and he will be allowed to choose among the chapters and begin answering the questions. Each question can be answered once. Following each question, whether the answer was correct or wrong and at the correct answer along with a brief explanation of the answer will be given. References for detailed information will also be given, A final scoring of the number of correct responses upon the total number of questions will be given. Animated cartoons, catricages, etc. will be used intermittently as reinforcers.

CHAPTER-3

QUESTIONS AND SOLUTION

INSTRUCTIONS

The question bank has eight sections. Each section has a number of different types of questions: fill in the blanks, true/false, multiple choice questions, fill in the missing blocks and fill in the missing letters.

Among the four choices in multiple choice questions, only one is the appropriate answer. Two types of fill in the blanks are present; open ended ones where there are no choices for the answer and close ended ones with 2 choices to select from. Fill in the missing blocks are close ended, with 2 choices to choose from.

The questions are arranged in the order of increasing complexity. The user is advised to follow the same order for better understanding. The questions in each chapter are followed by the correct answers and brief explanation, along with the reference.

Enjoy, the voyage of learning OAEs !!

QUESTIONS
SECTION-1

INTRODUCTION AND BASIC PHYSIOLOGY

1. Otoacoustic emissions (OAEs) are generated from the outer hair cells. True/False

2. Discovery of OAEs is credited to Norton . True/False

3. OAEs are also called

   a) Kemp echoes

   b) Cochlear echoes

   c) (a) and (b)

   d) None of the above

4. OAEs are............(electrical/vibratory) responses

5. The major classification in OAEs are.......

   a) Spontaneous and evoked OAEs

   b) Spontaneous and electrical OAEs

   c) Vibratory and electrical OAEs

   d) All of the above.

6. EOAEs occur in response to

   a) Pure tones

   b) Clicks and tone bursts

   c) Pure tones and clicks

   d) Pure tones, clicks and tone bursts.

7. The types of evoked otoacoustic emissions are -

   a) Transient otoacoustic emission(TEOAEs)

   b) Distortion product otoacoustic emissions (DPOAEs)

   c) Stimulus frequency otoacoustic emissions (SFOAEs)

   d) All of the above.

8. Generation of evoked OAEs in response to low-moderate level stimuli depend on

   a) integrity of the VIIT nerve

   b) Normal middle ear function.

   c) Normal OHC function

   d) Normal brain stem function.

9. Brownell first demonstration the electro-motility of OHC.

   True/False

10. IHCs also demonstrate electro-motility. True/False

11. Outer hair cells by themselves can induce basilar membrane movement. True/False

12. The mechanism within the cochlear partition which increases the sensitivity of basilar membrane vibrations to low level sounds and increases the frequency selectivity of these vibrators is called

13. The production of OAEs does not require any metabolic energy supply to the ear. True/False

14. The delay of OAEs is associated with slow cochlear traveling wave velocity which is around.......

    a) 1 m/sec

    b) 25 cm/sec

    c) 1 m/ms

    d) 1 cm/sec

15. Otoacoustic emissions reflect the activity of active biological mechanisms in the cochlea which are responsible for

    a) exquisite sensitivity

    b) sharp frequenqy selectivity

    c) wide dynamic range of normal auditory system

    d) all of the above

16. When OHCs are damaged/absent

    a) Auditory sensitivity is reduced by 90-100 dB

    b) Tips of the tuning curves are elevated or absent

    c) Responses to the auditory stimuli as a function of stimulus level grow linearly.

    d) All of the above

SECTION-2

INSTRUMENTATION

1. The first commercially available OAR instrument was the ,,, ...which was used at TLO in London (1977 to 1984).

2. Closing the ear canal is not essential while measuring OAEs.

True/False

3. A change in the fitting of the probe, the ear canal volume or the middle ear characteristics, does not affect the OAE amplitude as long as the cochlear mechanics remains unchanged.

True/False

4. Instrumentation for measuring stimulus frequency emissions, uses vector substraction, in order to separate stimulus from response. The vector substraction is done in terms of

   a) amplitude and frequency

   b) frequency and phase

   c) amplitude and phase

   d) only phase

5. OAEs are unaffected by stimulus rate. True/False

6. Time domain averaging is used while recording TEOAE.

True/False

7. Fill in the missing alphabets to find out the currently available devices for DPOAEs measurement. The company name is given in brackets.

   1) - - 0 92 (Otodynamics)
   2) Model - - 0 (Virtual)
   3) - s - 60 (Grason-Stadler)
   4) C - - - st - 503 (Maden Electronics)
   5) C - B e D - - (Nimosa Acoustics)
   6) S - - -1 (Bio-logic)

8. Which of the following statements describe the effects of recording time window on TEOAE measurement?

   a) The removal of the first few millisecs. of the responses, in order to reduce stimulus artifact may result in loss of high frequency information.
   b) Long windows (eg more than 12 ms) leads to loss of low frequency information.
   c) Both (a) and (b)
   d) Neither (a) nor (b)

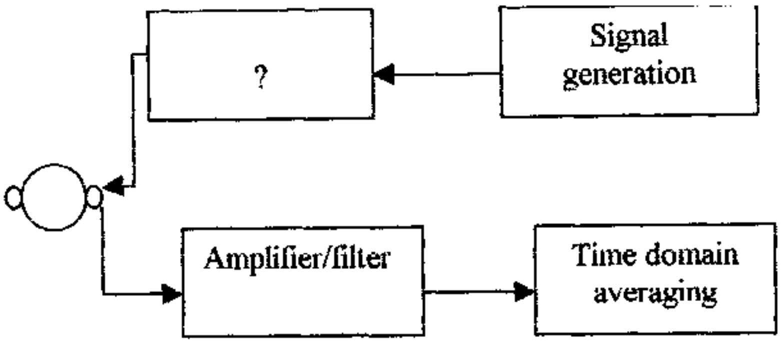
9. Interference of standing waves maybe a major problem in the measurement of DPOAEs in the high frequency region.

   True/False

10. In the following schematic diagrams of instrumentation for

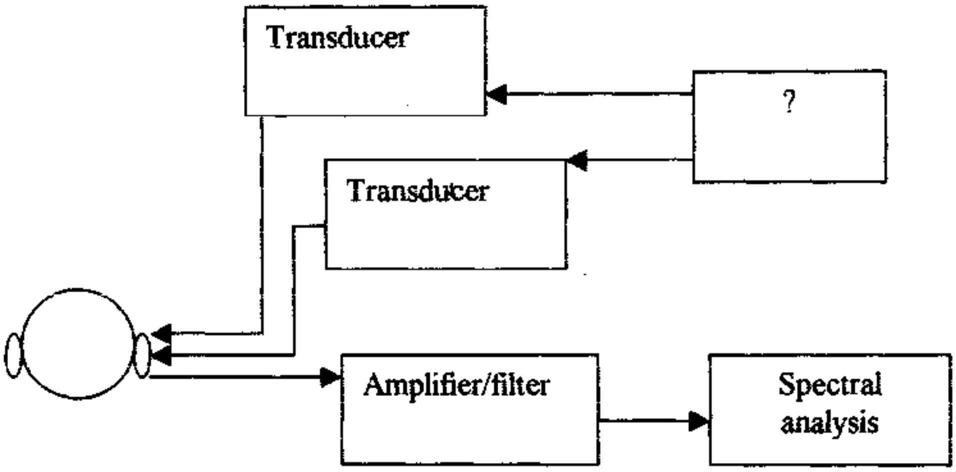
OAEs, fill in the missing block.

A. TEOAE



a) Transducer
b) Notch filter

B, DPOAE



a) Averager
b) Signal generation

C)SOAE

a) Spectral analysis
b) Signal generator

SECTION-3

SPONTANEOUS OTOACOUSTIC EMISSION

1. Spontaneous otoacoustic emissions

    a) are measured without external stimulation

    b) are more prevalent in males

    c) occur in 40-60% of unhealthy ears

    d) all of the above statements are true

2. SOAEs occur due to damage in the OHCs. True/False

3. Which of the following statements is true regarding the frequency composition and amplitude of SOAEs?

    a) They generally occur in the frequency range of 1-3 kHz.

    b) They are broad band signals

    c) They generally occur in the low frequency range (<500 Hz)

    d) None of the above.

4. Which of the following statements describes the appearance of an SOAE?

    a) SOAEs appear as a sinusoidal wave above the noise floor.

    b) SOAEs appear as a spike arising above the noise floor.

    c) SOAEs appear as a dense or intense wave, well differentiated from the noise floor.

    d) Any of the above.

5. Spontaneous otoacoustic emissions are found in about ______ % of normal hearing adult ears.

   a) less than 30%
   b) 98%
   c) 40%-72%
   d) any of the above

6. Which of the following is true regarding the noise that interferes with SOAE measurement?

   a) It is concentrated in the low frequency region.
   b) It consists of ambient environmental noise and patient movement noise.
   c) It is associated with physiological noise.
   d) All of the above.

7. Which of the following statements is not a strategy to reduce ambient environmental noise?

   a) Do not seat probe tip deeply into external ear canal.
   b) Keep patient as near to the SOAE equipment as possible.
   c) Use least amount of signal averaging.
   d) All of the above.

8. Which of the following holds true in the recording of synchronized SOAEs.

   a) No stimulus is presented.

   b) Pure tone of 1 kHz is presented as stimuli.

   c) A single click is presented.

   d) None of the above.

9. Which of the following statements is not true?

   a) A low level pure tone with a frequency close to a SOAE frequency can cause beats or roughness to be perceived by the person,

   b) External tone which is close to SOAE frequency can cause the frequency of the SOAE to shift up or down.

   c) SOAEs are suppressed by frequencies far away from the SOAE frequency.

   4) SOAEs are used to evaluate the fine tuning ability of cochlea.

10. SOAEs are stable and replicable over a long-term period.

    True/False

11. If an SOAE measurement is extended beyond 20-30 minutes, there is a possibility of finding shifts in SOAE amplitude and frequency. True/False

12. Multiple SOAEs are a rare phenomenon and occur in pathological cases, where there is degeneration of OHCs in more than one discrete region in the cochlea. True/False

13. Which of the following statements refer to high level SOAE?

    a) High amplitude SOAEs up to 60 dB SPL, relatively in the high frequency region.

    b) They may be audible without amplification.

    c) It is pathological, especially at the emission frequency

    d) All of the above.

14. Which of the following is a potential use of SOAEs?

    a) To evaluate degree of hearing loss.

    b) To understand the type of hearing loss.

    c) To study cochlear functioning.

    d) To objectively evaluate tinnitus.

15. Incidence of SOAEs shows. . . . . .

    a) Gender difference

    b) Age difference

    c) Racial group difference

    d) All of the above

16. Which of the following characteristics of SOAEs are increased in neonates and children when compared to adults?

a) The prevalence

b) The number of SOAEs per ear, as well as the amplitude and frequency of SOAEs.

c) Both (a) and (b)

d) None of the above

17. Prevalence and number of SOAEs. . . . .(Increases/decreases) in subjects over 50 years of age.

18. SOAR frequencies shift from lower frequencies to higher frequencies over time as the age increases. True/False

19. Which of the following statements) is/are not true?

a) Twice as many women as men exhibit SOAEs.

b) SOAEs are observed more in the left ears than right ears.

c) The chances of women exhibiting bilateral and multiple SOAEs, is more than men.

d) All of the above.

20. SOAEs are found in subjects with moderate sensory-neural hearing losses. True/False

21 The hearing sensitivity of a ear with SOAEs may possibly be better than a ear without SOAEs. True/False

22. Changing middle ear pressure has no effect on SOAEs.

True/False

23. Which of the following statements indicate a correlation between tinnitus and SOAEs?

a) While SOAEs do not usually occur above 4000 Hz, tinnitus is usually perceived above 4000 Hz.

b) When tones are introduced to suppress SOA^Es, they also cause the tinnitus to become inaudible.

c) Suppression of SOAEs does not alter the perception of tinnitus.

d) Masking of tinnitus does not obliterate SOAEs.

24. SOAE frequencies shift with circadian and monthly periodicity.

True/False

SECTION-4

TRANSIENT EVOKED OTOACOUSTIC EMISSIONS

1. Transient evoked otoacoustic emissions (TEOAE) are OAEs recorded in response to

   a) Broad band clicks

   b) Broad band noise

   c) Tone bursts

   d) (a) and (c)

2. TEOAE are found in..............% of normal adults.

   a) 96-100%

   b) 50-60%

   c) 60-70%

   d) 100%

3. Tn TEOAE recording the latency of the response is used for identifying a response. True/False

4. The latency of TEOAE for high frequencies is longer than that for low frequencies. True/False

5. The TEOAE response amplitude grows linearly with increase in intensity. True/False

6. The presence of SOAEs affect TEOAEs in which of the following ways?

   a) Maximum amplitude in the TEOAE spectrum corresponds to the SOAE frequency in that ear.

   b) The more the number of SOAEs produced by an ear, the more increase in TEOAE amplitude.

   c) Both (a) and (b).

   d) None of the above.

7. The most common clinical application of TEOAE involves...... stimulus.

8. Pathological status of the middle ear may..........

   a) affect the TEOAE amplitude

   b) preclude TEOAEs from being measured.

   c) both (a) and (b)

   d) neither (a) nor (b)

9. TEOAE response is affected by.....

   a) evoking stimulus

   b) recording parameters

   c) status of peripheral auditory system

   d) all of the above

10. TEOAE amplitude

    a) Decrease with age from infants to adults.

    b) Increase with age from infants to adults

    c) Does not change from infants to adults

    d) Is very difficult to measure in children.

11. TEOAEs.........(increase/decrease) as hearing threshold increases.

12. There is no correlation between TEOAE response and audiometric thresholds. True/False

13. Inconsistent and unreliable TROAR responses from normal new boms is the primary factor in the failure of TEOAE in neonatal screening. True/False

14. Amplitude of TEOAEs grow idiosyncratically with age during the first few days of life of normal new borns. True/False

15. Neonatal TEOAEs have reported............

    a) a higher energy concentration in high frequency region when compared to adults.

    b) a higher energy concentration in low frequency region compared to adults.

    c) higher energy in mid frequency region compared to adults.

    d) similar energy concentration over frequencies as seen in adults.

16. Which of the following characteristics is seen in TEOAE responses of neonates?

   a) Better right ear responses in females, than left, when compared to males.

   b) Better left ear responses in females than right, when compared to males.

   e) More robust responses in both ears of males,

   d) No sex differences and no ear differences.

17. There is a significant decrease in click evoked OAE levels as age increases (from adults to geriatric), True/False

18. Click evoked OAEs

   a) are frequency dispersive (i.e. the higher the emission frequency, shorter its latency).

   b) their amplitude grows linearly with stimulus level.

   c) not affected by width of stimulus spectrum.

   d) all of above.

19. TEOAE responses show adaptation after a few minutes during stimulus delivery. True/False

SECTION-5

DISTORTION PRODUCT OTOACOUSTIC EMISSIONS (DPOAEs) & STIMULUS FREQEUNCY OTOACOUSTIC EMISSIONS (SFOAEs)

1. Distortion Product Otoacoustic Emissions (DPOAEs) arise from......(active/passive) processes of the cochlea.

2. Distortion product otoacoustic emissions are intermodulation distortions produced by the ear in response to two ....stimuli referred to as primary tones.

   a) simultaneous pure-tone

   b) alternating pure-tone

   c) simultaneous brief-tone

   d) alternating brief-tone

3. DPOAE amplitude plotted as a function of several different stimulus - related values is called a.......

4. DPOAE amplitude plotted as a function of the level of the primary tones for a set of discrete frequencies, it called .....

   a) input-output function

   b) response/growth function

   c) both (a) and (b)

   d) cellogram

5. Which of the following stimulus parameters are known to affect DPOAEs?

   a) Stimulus frequency, f1 f2 ratio

   b) Stimulus level

   c) none of the above

   d) both (a) and (b)

6. BPOAEs are presumably generated in the frequency region where energy for the two primaries overlaps. True/False

7. If 2 tones of frequenciesF1 and F_2 (F_2 > F1) are presented, which of the following combination tones will be produced?

   a) $f1+f_2, 2f1+f_2$

   b) $2f_1-f_2; 2f1-f_2$

   c) $\frac{2f_2 f_1}{3}$

   d) It occurs at the equation $/nf_1- mf_2/$, where m and n are any pair ofintergers.

8. When compared to the other combination tones, the cubic difference tone ($2f_1- f_2$) in DPOAEs is.......

   a) smaller and difficult to detect.

   b) least vulnerable to any cochlear insult.

   c) both (a) and (b)

   d) neither (a) nor (b)

9. What is the optimal ratio of frequencies of primaries which produce robust DPOAEs and lowest threshold in a majority of normal ears?

a) $f_2/f_1=1.22$

b) $f_1/f_2= 1.22$

c) $f_2/f_1 = 2.23$

d) $f_1/f_2 = 2.23$

10. The optimum ratio of f_2/f_1, is 1.22 for the whole range of stimulus frequencies used in DPOAE measurement. True/False

11. A …… dB separation between DP amplitude and noise floor value is the most lenient criteria for a valid DPOAE.

12. DPOAE amplitude increases as stimulus level is increased and reach a saturation above 75 dB SPL. True/False

13. Which of the following statements is not true?

a) The typically used DPOAE stimulus level in clinical situations is 65-75 dBSPL, when $L_1= L_2$.

b) The maximum reduction in DPOAE amplitude due to cochlear insult is seen when the stimulus level $L_2< L_1$.

c) Maximum DPOAE amplitude occurs at $L_2< L_1$

d) In $L_2< L_1$ condition there is a significant reduction in the DPOAE amplitude in normal subjects.

14. There is a........(negative/positive) correlation between DPOAE amplitude and hearing threshold levels.

15. Which of the following is not true regarding the stability of DPOAEs.

    a) DPOAEs are highly stable and reproducible over 24 hour period.

    b) DPOAEs are more consistent within mid and high frequency regions.

    c) DPOAEs are consistent below 1000 Hz.

    d) As stimulus level decreases, DPOAE amplitude decrease and variability/instability increases.

16. DPOAEs are best in detecting a threshold elevation due to SN loss, both below and above 4 kHz. True/False

17. Which of the following characteristics of DPOAE is true.

    a) Left ear amplitudes are lesser than right ear amplitudes.

    b) Females show significantly lower thresholds than men especially at low frequencies.

    c) Females show significantly higher amplitudes better thresholds than men at high frequencies,

    d) There are no age related changes in the DPOAE amplitude till about 80 years of age.

18. Broad band filtering is used to detect DPOAEs responses.

True/False

19. Which of the following measures can be carried out to confirm the cochlear origin of a DPOAE response?

a) In the same cavity, repeat at same stimulus level.

b) Measure the latency of the distortion- OAE component.

c) Use a simultaneous masking tone (f_3)

d) Any of the above.

20. Which of the following is the most important identifier of the DPOAE response at low and moderate intensities,

a) Latency of the response

b) Non-linearity of the response

c) Either (a) or (b)

d) Neither (a) nor (b)

21. In DPOAEs, the rate at which the emission amplitude increases as a function of increasing $L_1$and L_2 is represented by

a) Slope of input function

b) Maximum amplitude of emission

c) Dynamic range of emission

d) Detected threshold

22. DPOAE latency.............(increases/decreases) systematically as the intensity levels of the stimulating tones decrease.

23. Which of the following statements are incorrect with regard to DPOAE latency and stimulus frequency?

   a) Latency is less (i.e. below 3 ms) for frequencies above 6 kHz.

   b) Latency is increased (i.e. above 10 ms) for frequencies below 1 kHz.

   c) None of the above.

24. DP amplitude plotted as a function of............(f_1 or f_2) gives the best possible correlation with the pure tone audiogram.

25. Using lower stimulus levels of DPOAE,

   a) reduces the amplitudes of DPOAEs.

   b) increases the DPOAE vulnerability to cochlear trauma/damage.

   c) helps to detect profound hearing loss.

   d) all of the above.

26. The interaction of 2 SOAEs (f_1) and (f_2) can create a distortion product SOAE at 2 f_1 f_2. True/False

27. What is a DPOAE fine structure?

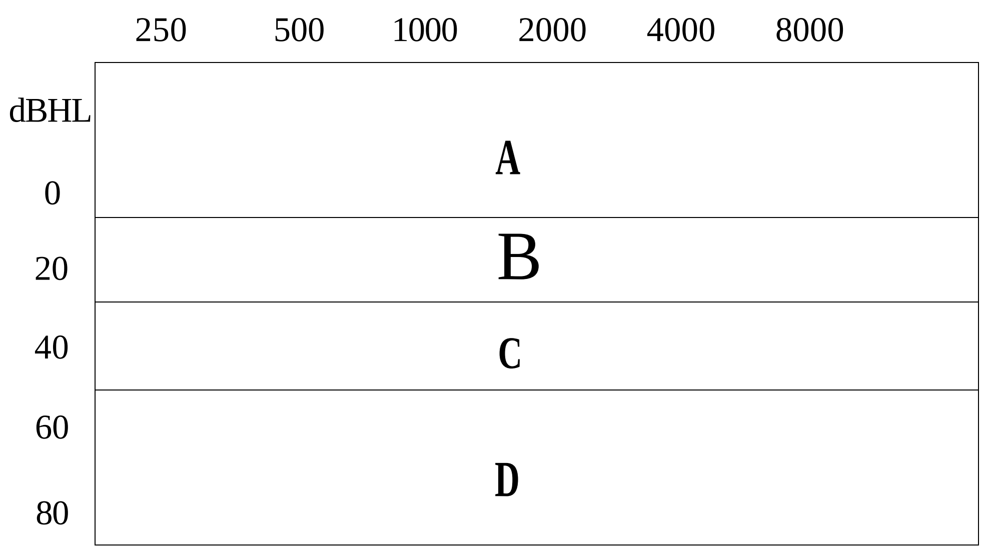
a) The DPOAE values averaged over more than 10 trials.

b) A DP gram in which the DPOAE measurement is done at octave frequencies.

c) A DP gram in which many stimulus frequencies are presented within an octave.

d) All of the above.

28. Match the biocks, A,B,C, D in the following illustrations, with the appropriate OAE response for sensory hearing losses of different degrees.



a. OAE probably not observed

b. OAE not observed

c. OAE amplitude within normal region.

d. OAE amplitudes below normal limits but >5 dB above noise floor.

29. The most frequency specific emissions are

a) distortion-product OAEs (DPOAEs)

b) Stimulus frequency emissions (SFEs)

c) Spontaneous otoacoustic emission (SOAEs)

d) None of the above.

30. In SFEs, the response occurs at a latency of 1.5 sec. after the onset of the pure tone stimuli. True/False

31 Which of the following is an incorrect statement of the stimulus - response relationship of SFOAEs.

a) Separation between adjacent peaks in stimulus frequency emissions increases with increasing frequency.

b) As the stimulus level increases, SFE pattern flattens and looses definition.

c) Threshold minima is found where SFE minima occurs.

d) SFE pattern across frequency is idiosyncratic i.e. unique for each ear.

SECTION-6

CONTRALATERAL ACOUSTIC SUPPRESSION

1, Contralateral suppression of TEOAE also called ,.........
effect.

2. Contralaterai acoustic suppression is

a. the suppression of the responses of the medial olivocochlear fibres when contralateral noise is presented.

b. the reduction in the OHC's ability to produce OAEs when contralateral noise is presented.

c. the masking effect caused due to cross over of stimuli from the contralateral ear,

d. all of the above.

3. Alterations of the emissions in the presence of contralateral stimulation can be mediated by the action of the........... (afferent/efferent) auditory system.

4. Contralateral acoustic suppression causes a reduction in TEOAEs by approximately 4 dB SPL.

True/False

5. TEOAEs have greater suppression than DPOAEs under equivalent conditions. True/False

6. The duration of the stimulus required to activate the olivocochlear bundle is negligible.

   True/False

7. Which of the following statements regarding contralateral suppression of OAEs is true.

   a) The noise in the contralateral ear should be high enough for cross over.
   b) The noise should be below the intensity level that might cause an acoustic reflex.
   c) The OAEs are totally abolished by contralateral acoustic signals.
   d) Pathway traveled is the same as in acoustic reflex.

8. In forward masking of TOAEs, maximum reduction of TEOAE amplitude occur in which of the following condition..

   a) Ipsilateral noise
   b) Contralateral noise
   c) Binaural noise
   d) Both ipsilateral and contralateral noise

9. Which of the following is not an effect of contralateral acoustic stimulation on OAEs?

   a) Phase of all OAEs shift with contralateral acoustic stimulation.
   b) Onset latency for suppression may range from less than 40 msecs. to more than 140 ms.

c) Suppression upto 100 msecs persists even after the suppressor signal ends.

d) Suppression effects are seen in SOAEs only as a reduction in amplitude.

10. Which of the following statements is not true?

a) Maximum suppression for TEOAEs is seen in the mid frequency region (1000-2000 Hz)

b) Suppression for moderate level stimulus is more pronounced than high level stimulus.

c) Broad band noise is a more effective suppressor compared to narrow band noise or pure tones.

d) None of the above.

11. Increased suppression effects are seen in infants when compared to adults.

True/False

12. Sectioning of the vestibular nerve surgically for patients with unilateral Meniere's disease. . . . . .(eliminates/increases) the Collet effect.

SECTION-7

APPLICATIONS OF OAEs

1, Which of the following OAEs gives the maximum information of the functioning of the cochlea?

a) SOAEs and SFEs

b) DPOAEs

c) Click evoked TEOAEs

d) All of the above.

2. Which of the following is an incorrect statement of the clinical application of OAE?

a) Screening for central auditory dysfunction in new born babies and infants,

b) Separating the cochlear and neural components of SN loss.

c) Monitoring the effects of noxious agents such as ototoxic drugs.

d) Assessing fluctuating hearing loss.

3. Evoked OAEs may be present in cases where behavioral and neural responses are depressed or absent because.

    a) Mechanism responsible for OAE generation is peripheral to the VIII nerve.

    b) They are unreliable indicators of cochlear status.

    c) Actual tuning of auditory stimuli occurs central to the cochlear mechanisms.

    d) COAE are only elicited at high stimulus levels.

4. Temperature is known to affect otoacoustic emissions.

    True/False

5. Which of the following factors lead to the developmental changes observed in OAEs?

    a) Resonance.

    b) Volume, length.

    c) Anatomy, compliance.

    d) All of the above.

6. Which of the following statements is true?

    a) ABR gives better frequency-specific information while OAEs gives a good threshold-estimation.

    b) OAEs .give better frequency - specific information while ABR gives a good threshold estimation.

    c) Neither OAEs nor ABR gives any frequency specific information.

    d) None of the above.

7. DPOAEs is preferred to TEOAEs for new born hearing screening.

Trae/Faise

8. If a new born baby shows absent OAE response, which of the following steps should be taken?

a) Immediately refer for audiological evaluation

b) Recheck probe fit and retest or wait for few hours or days and retest.

c) Immediately washout vernix from ear and retest,

d) Any of the above.

9. Why does testing for otoacoustic emissions have limited value as part of the test protocol to identify VIII nerve tumours.

a) Pathology of VIII nerve causes retrograde degeneration of cochlear hair cells.

b) EOAEs are often not present due to interference of the tumor on the cochlear blood supply, which results in hair cell damage.

c) Neither a or b

d) Both a & b

10. Advantages of testing for the presence of EOAEs for patients with VIII nerve tumours may include.

a) Testing for cochlear function in patients who are not candidates for ABR testing due to the severity of the audiometric hearing loss.

b) Measuring cochlear function both pre and post operatively.

c) Monitory cochlear function intro-operatively.

d) All of the above.

11. The absence of TEOAE in a ear with normal middle ear function as measured by tympanometry may be interpreted as

a) a mild-profound sensori-neural hearing loss

b) a moderate-profound sensori-neural hearing loss.

c) a severe-profound sensori- neural hearing loss.

d) a profound sensori-neural hearing loss.

12. A patient with a profound sensori-neural hearing loss showing normal tympanometry, normal ROAR and an absent ABR.

a) Should be fit with a power BTE.

b) Has pseudohypocusis

c) Has retrocochlear disorder.

d) Any of the above.

13. Which of the following statements is true

a) EOAEs are always present when audiometric thresholds are within normal limits.

b) EOAEs are indicative of normal to near normal cochlear function when present.

c) EOAEs are caused by the cochlear traveling wave reflecting from the apex of the cochlea.

d) EOAEs are helpful in generating an objective audiogram.

14. Patients with Waardenbrugs syndrome, who have normal audiometric thresholds may show

    a) Absent TEOAEs

    b) Reduced OAEs in the high frequencies

    c) DPOAE notches

    d) Increased OE amplitudes.

15. Of the following auditory tests used to evaluate obligate carriers of genes for hereditary herring loss, the most direct measure of cochlear function is............

    a) Middle ear muscle reflex.
    b) Bekesy audiometry
    c) Otoacoustic emissions
    d) Pure tone thresholds

16. Evoked OAEs have the potential of being detectors of ototoxicity and are more sensitive than ABR, mainly because

    a) The equipment is less expensive.

    b) They can be tested more quickly.

    c) They more specifically measure of status of OHC function.

    d) The instrumentation is easier to use.

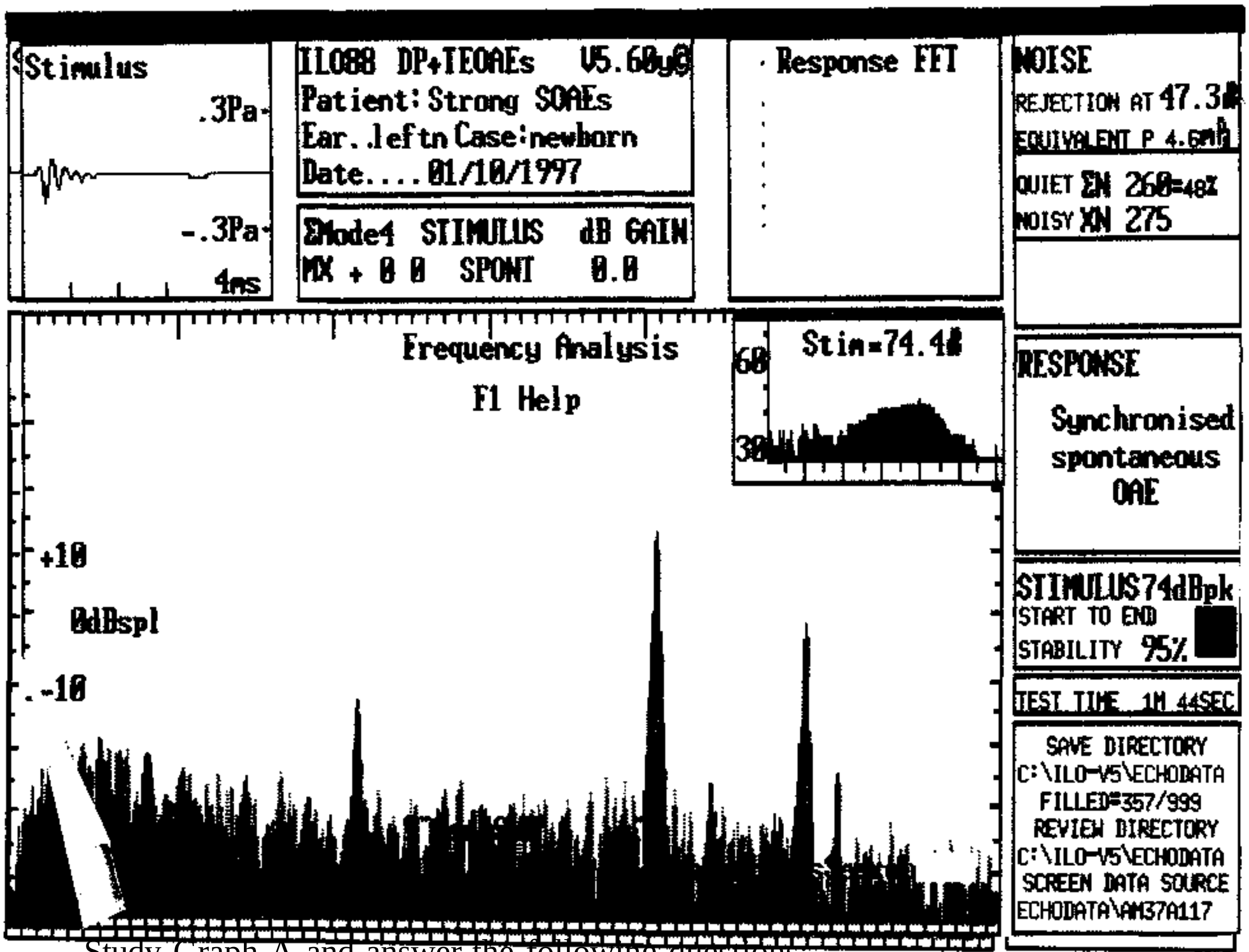
17. Which of the following diagnostic tools are most sensitive in detecting noise induced hearing loss?

    a) High frequency audiometry

    b) DPOAEs

    c) Pure tone audiometry and TEOAEs.

    d) High frequency audiometry and DPOAEs.



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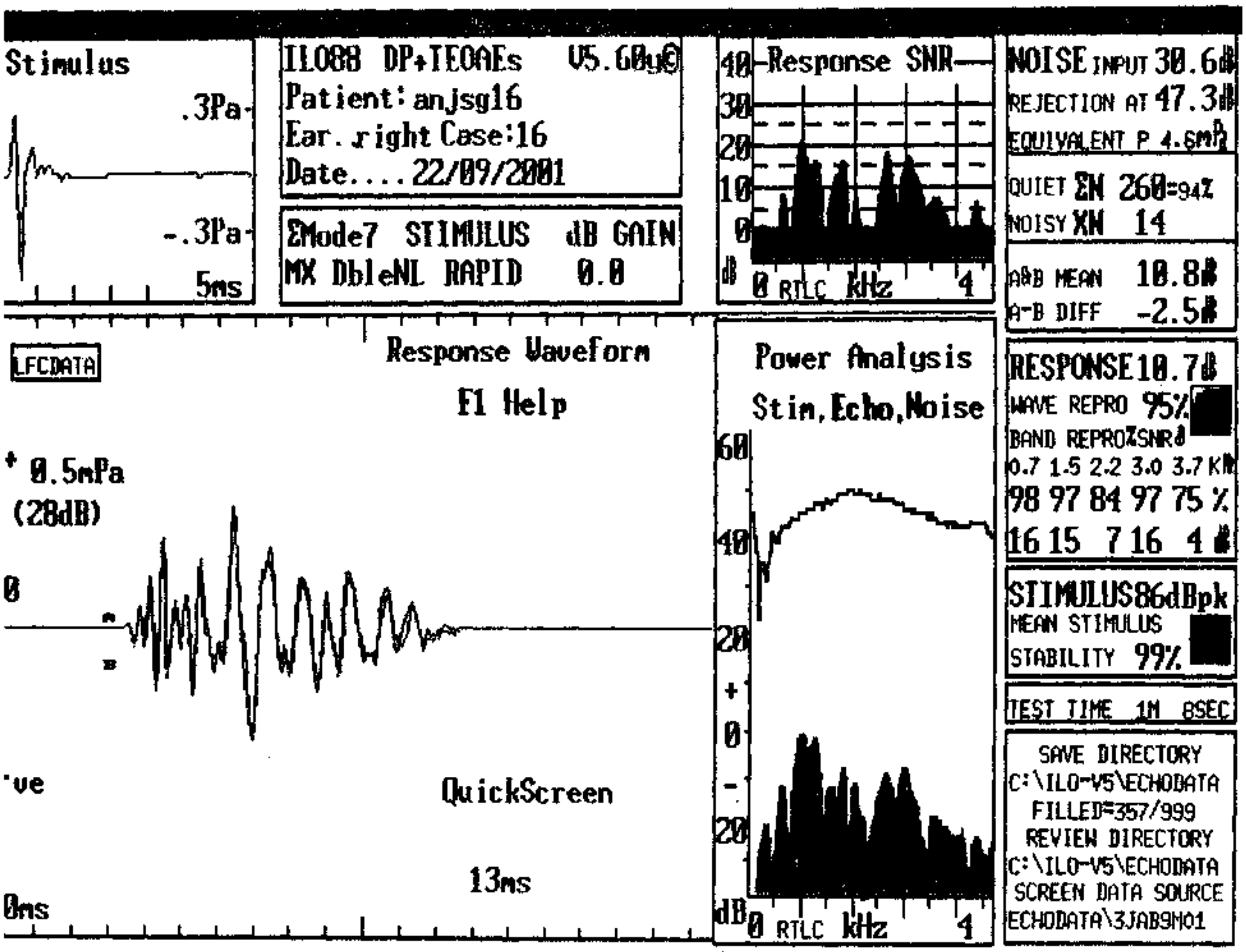
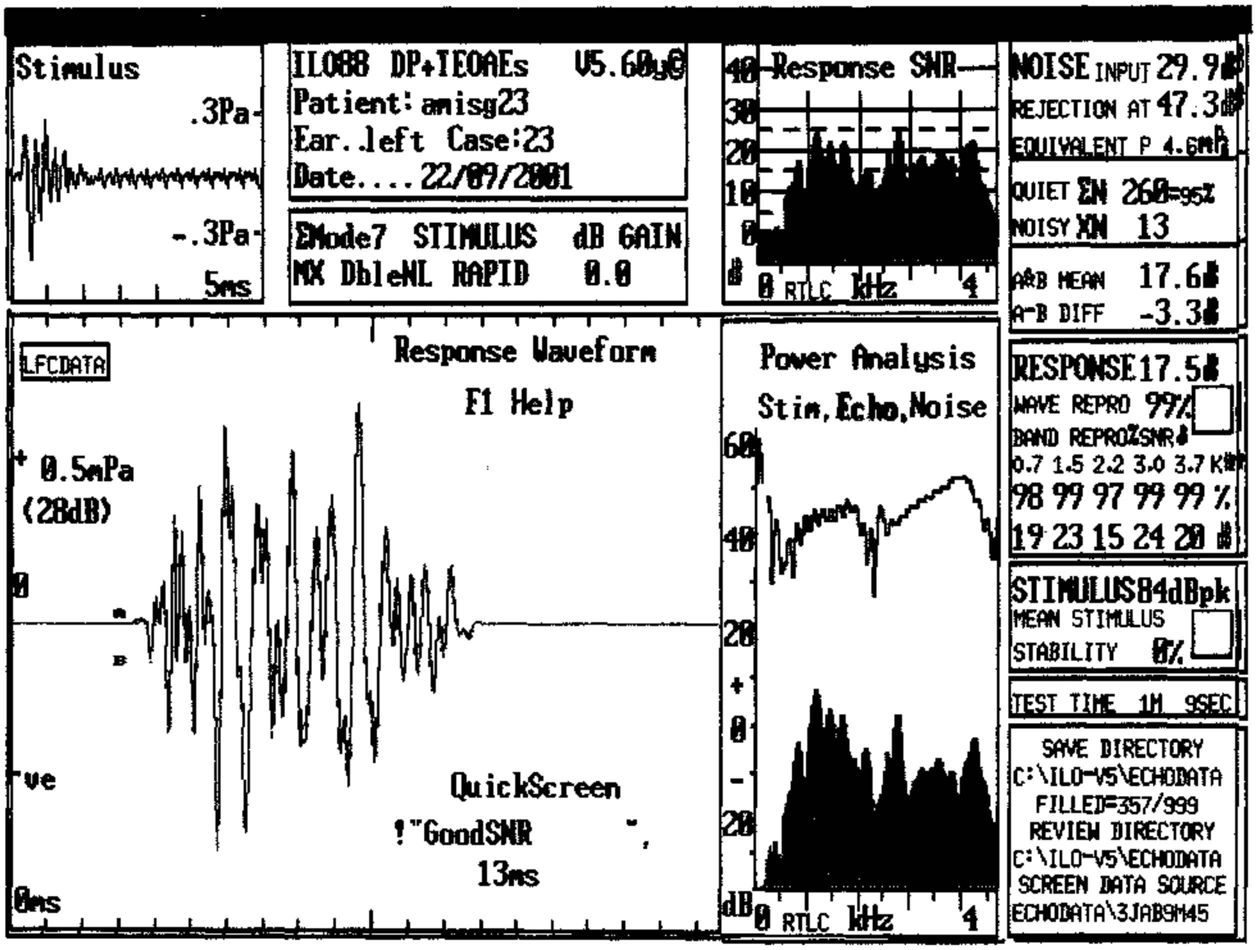
Study Graph-A and answer the following questions.

1. This is a graph of.......
   a) TEOAE
   b) SOAE
2. The graph shows
   a) multiple SOAEs
   b) single SOAE
3 The red portion at the bottom of the graph indicates
   a) concentration of the emissions
   b) concentration of noise in the recording
4. The peaks in blue indicate
   a) artifacts due to patient movement
   b) the presence of SO AEs.



Study Graph-B and answer the following questions:

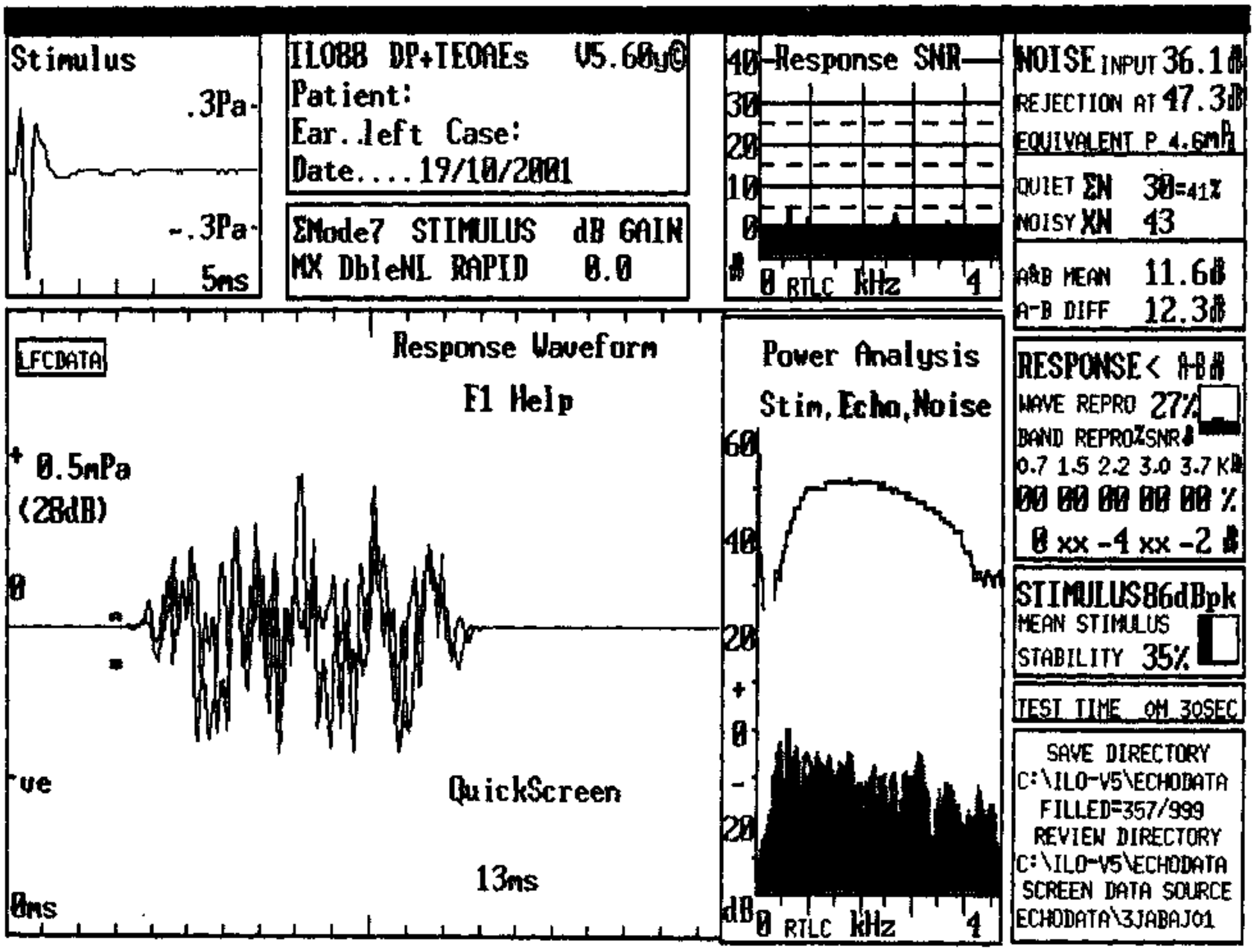
1. This is a graph of….
   a) DPOAE
   b) TEOAE
2. The reproducibility of the recording is
   a) 95%
   b) 99%
3. Maximum amplitude of emissions is at frequency
   a) 700Hz and 3000 Hz
   b) 3700 Hz
4. The total number of clicks presented is
   a) 86
   b) 260
5. This subject has
   a) GoodTEOAEs
   b) PoorTEOAEs



Study Graph-C and answer the following questions:

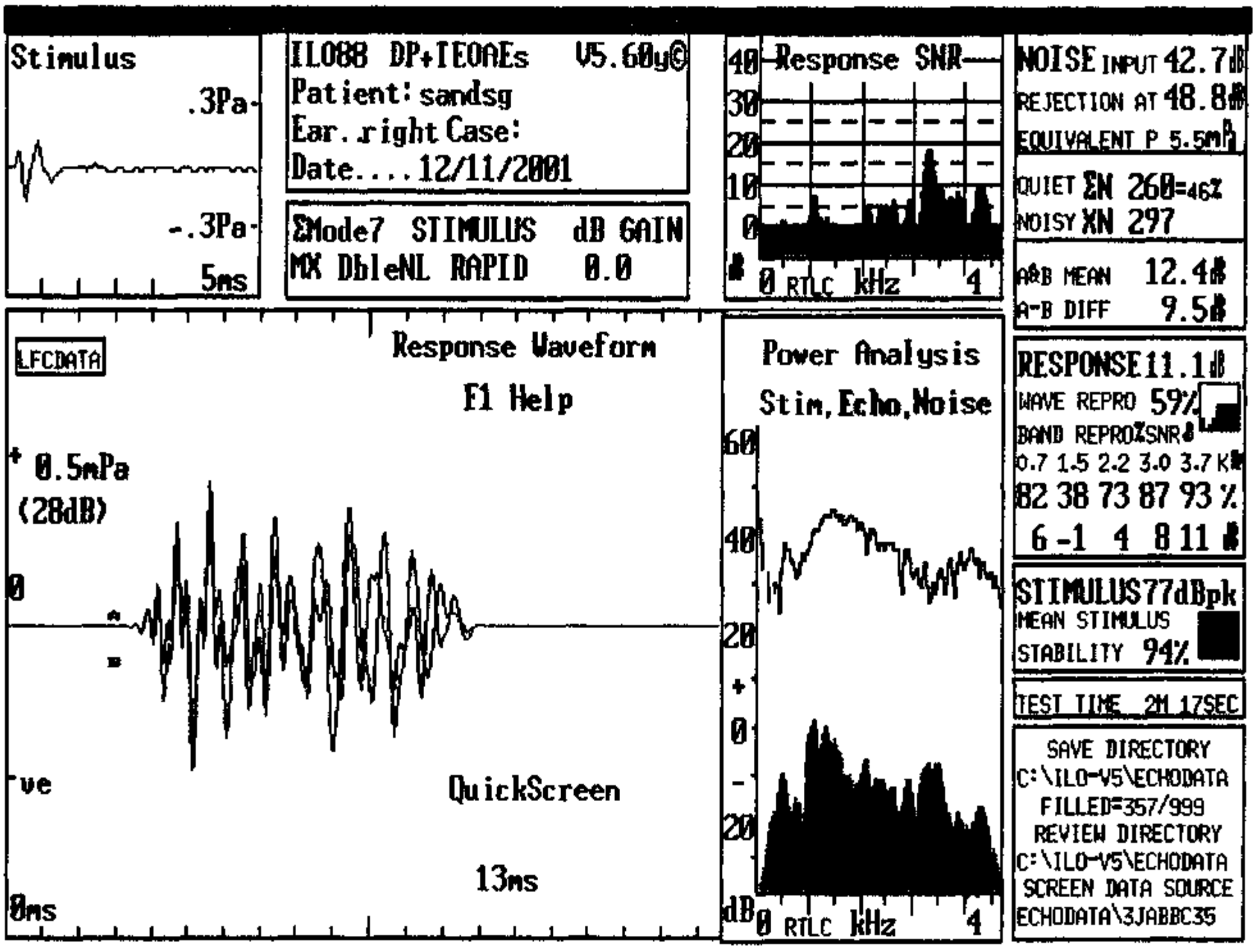
1. The blue portion in the response SNR stands for
   a) Kempechoes
   b) Noise
2. The red portion on the response SNR and power analysis stands for
   a) artifact
   b) noise
3. The probe fit of the recording is good.
   a) True
   b) False

***



Study Graph-D and answer the following questions:

1. Graph D shows
   a) Poor probe fit
   b) Absent TEOAEs
2. The QUIET 2N=30, stands for
   a) the amplitude of the noise in the recordig
   b) the number of responses accepted.
3. NOISY XN stands for
   a) the number of responses to stimuli rejected by the software.
   b) The amplitude below which the responses where rejected as noise.



Study Graph-E and answer the following questions:

1. TEOAE in Graph-E are

   a) present at low frequency

   b) present at high frequency

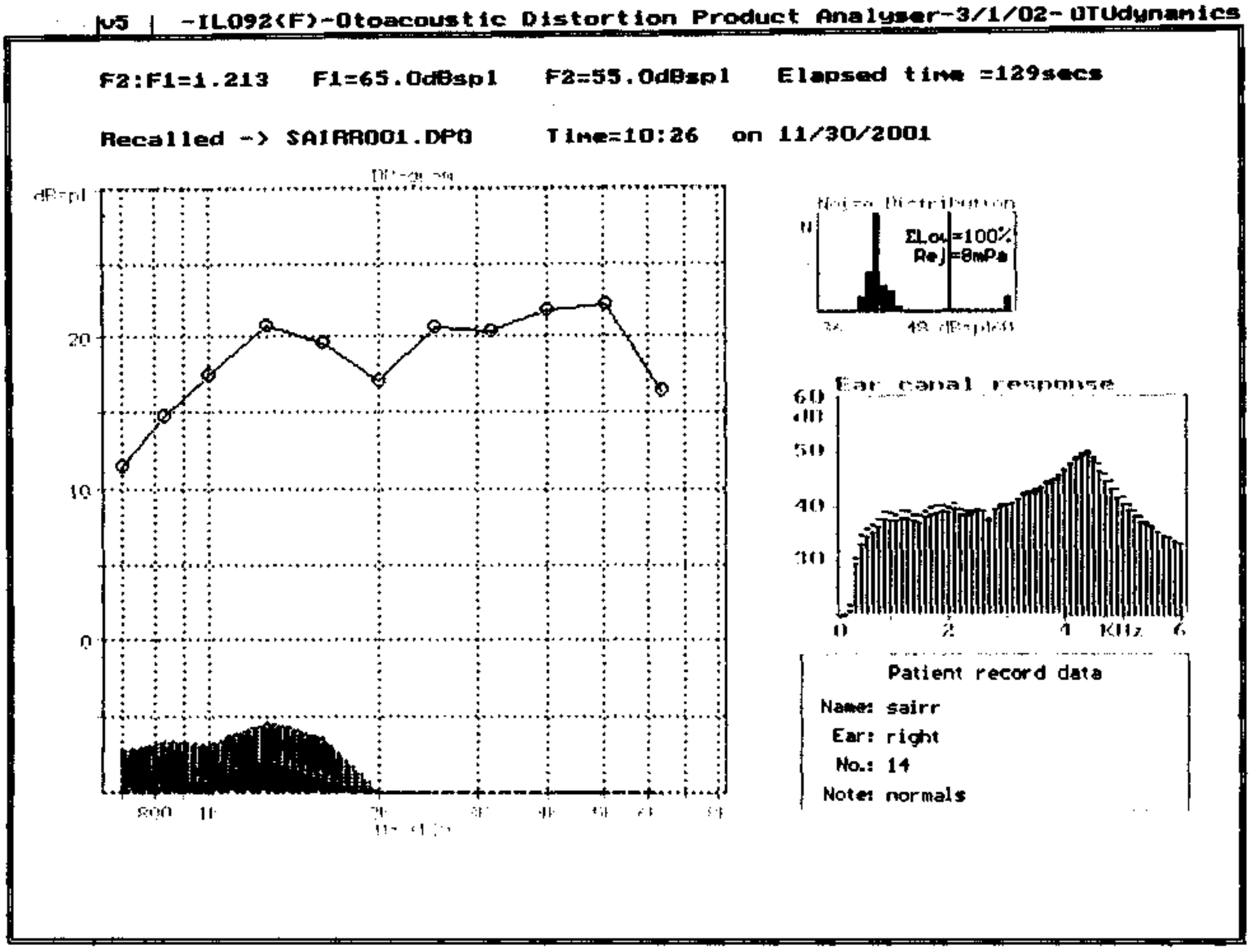
2. The subject would be diagnosed as having

   a) Poor TEOAEs

   b) Good TEOAEs

**

7%



Study Graph-F and answer the following questions:

1. Graph F shows a
   a) DP gram
   b) DP i/o function

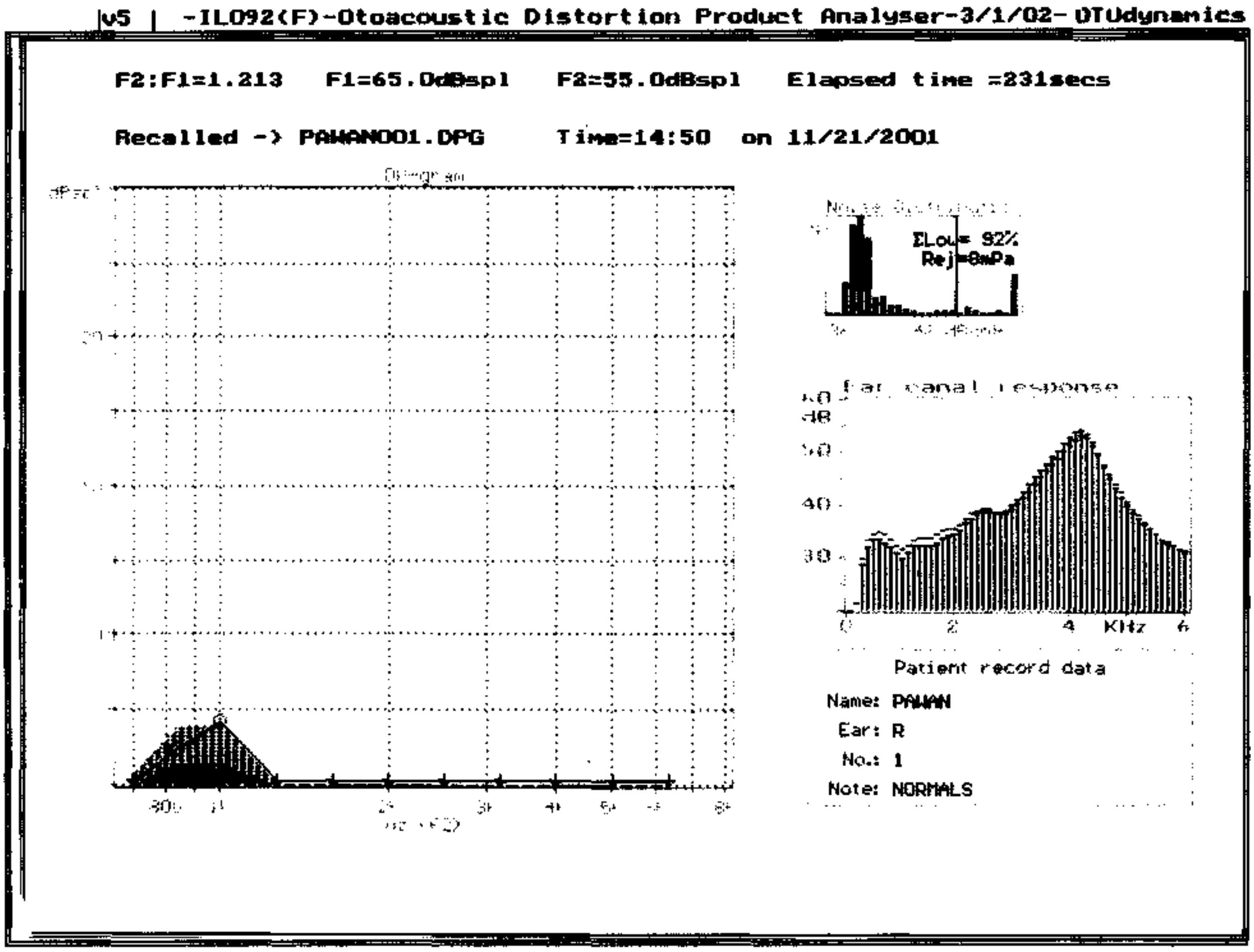
2 The F_2/ F_1 ratio used in the stimuli is
   a) 1
   b) 1.213

3 L_1L,=.....dBSPLandL$_2$=. . . . .dB SPL.
   a) 65 dB SPL and 55 dB SPL
   b) 55 dB SPL and 65 dB SPL

4. The signal-to-noise ratio is
   a) >6dB
   b) <6dB

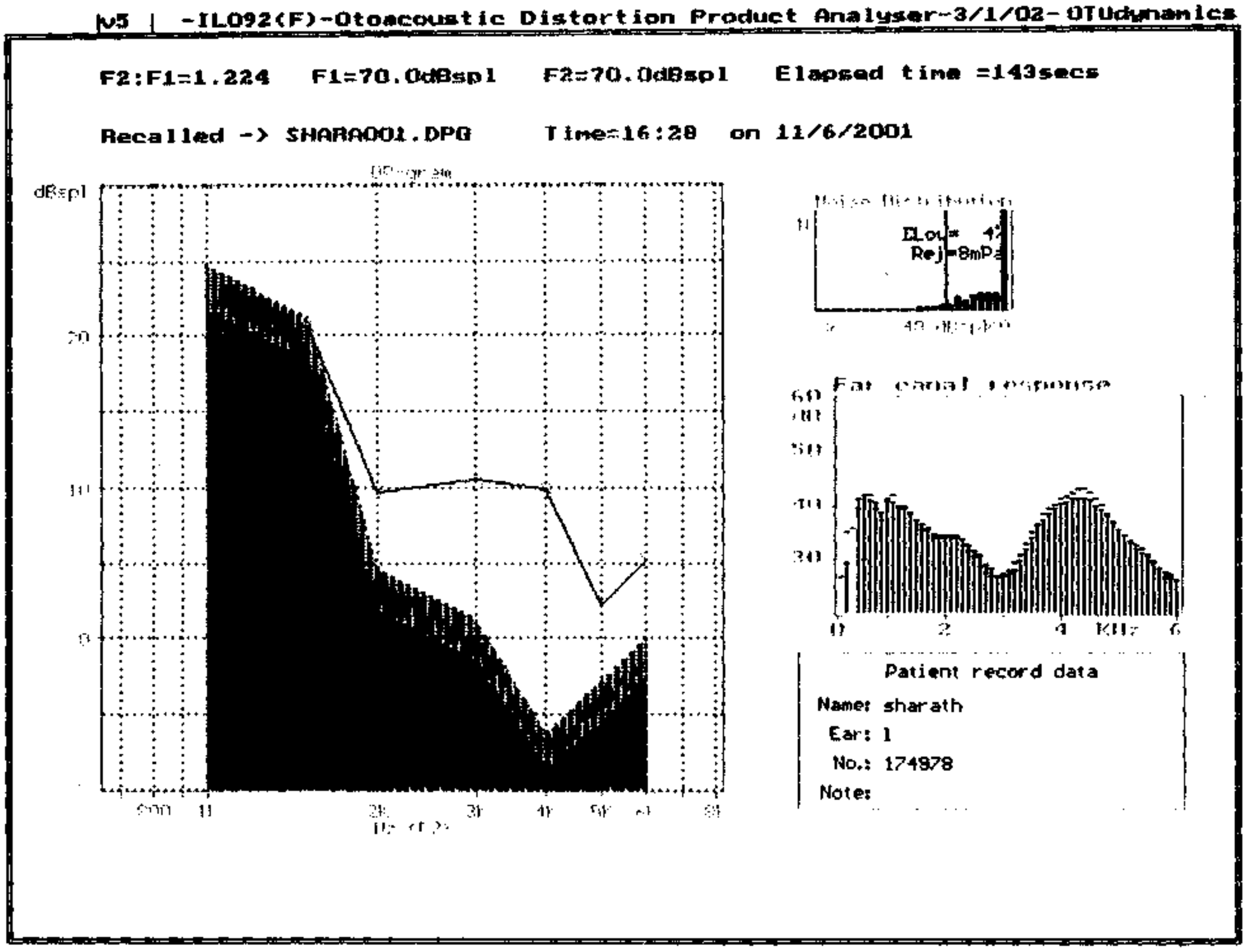
5. The maximum amplitude of response is at.... Hz
   a) 1500 Hz
   b) 5000 Hz

6. Noise concentration is less at the
   a) low frequencies
   b) high frequencies



Study Graph-G and answer the following questions:

1. The red portion shows the noise concentration in the recording.
   a) True
   b) False
2. The black line with pink markings stands for the average noise level.
   a) True
   b) False
3. The response - noise difference is >6 dB at all frequencies except 1 kHz.
   a) True
   b) False
4. This graph shows a normal but slightly reduced DPOAEs.
   a) True
   b) False



Study Graph-H and answer the following questions:

1. The noise concentration is too high in the low frequencies

    a) True

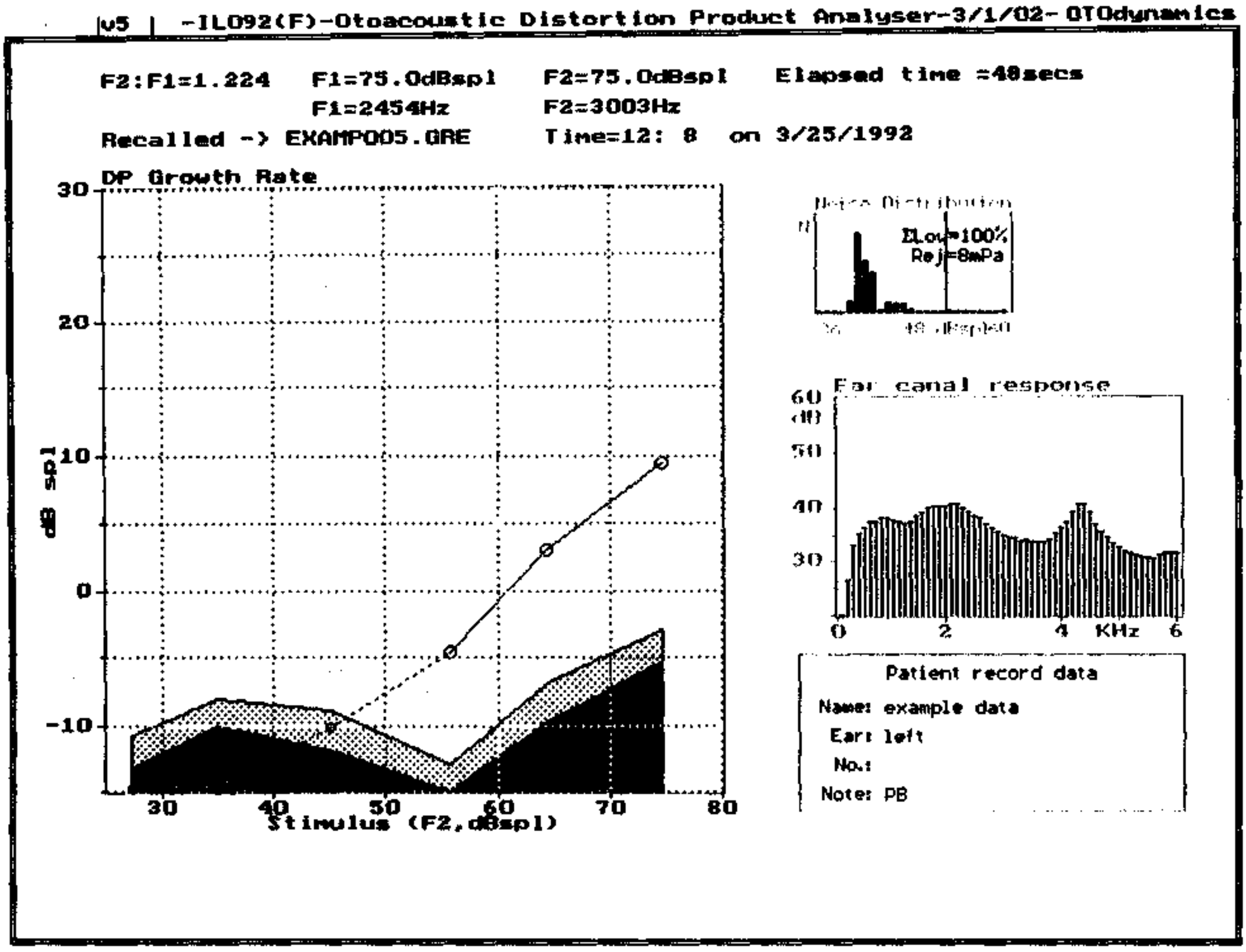
    b) False

2. This subject has absent DPOAEs as the emissions at low frequencies is absent.

    a) True

    b) False

**



Study Graph-I and answer the following questions:

1. The above graph shows.

    a) DP gram

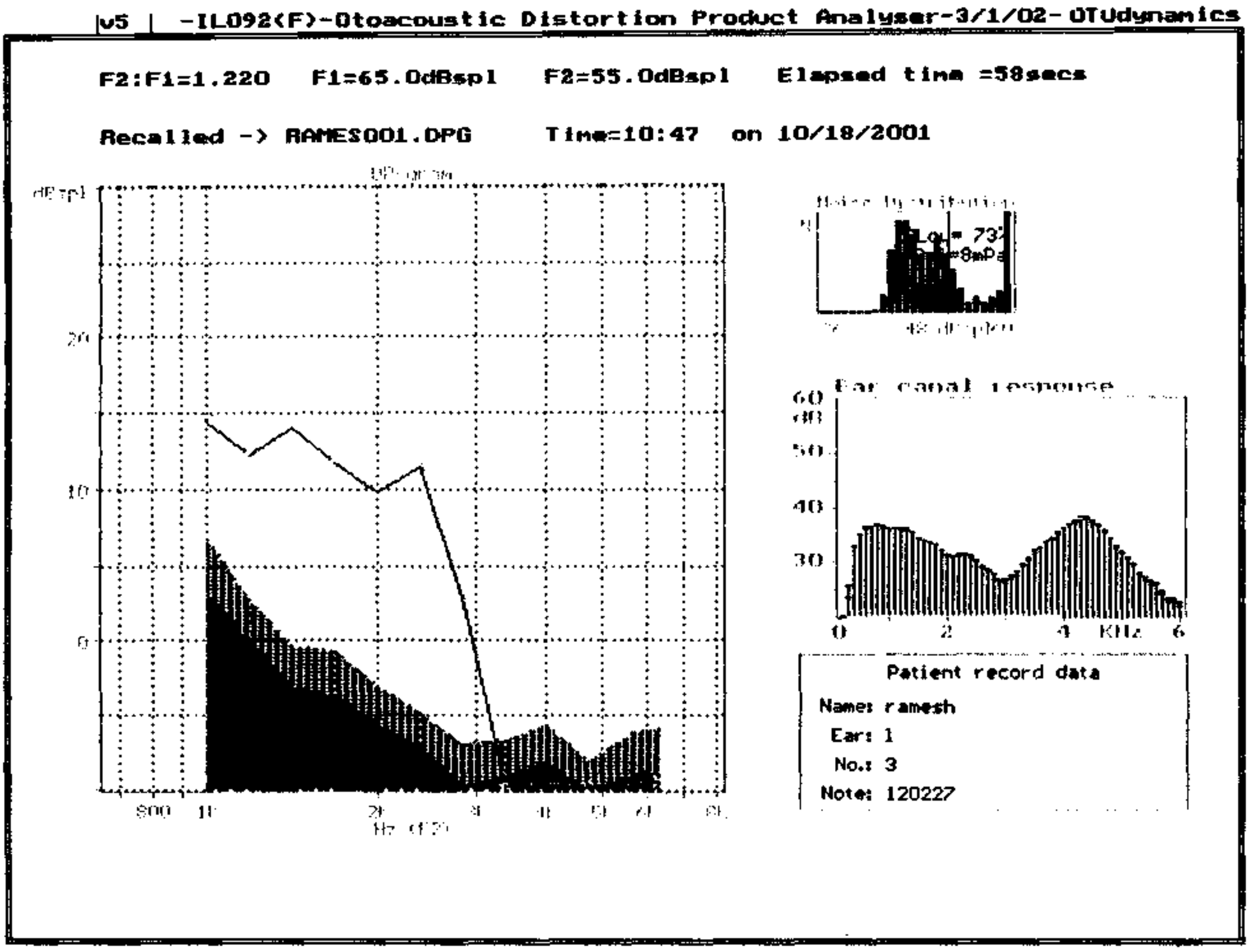
    b) I/O function

2. What is DP threshold in this I/O function?

    a) -5dBSPL

    b) 3dBSPL

**



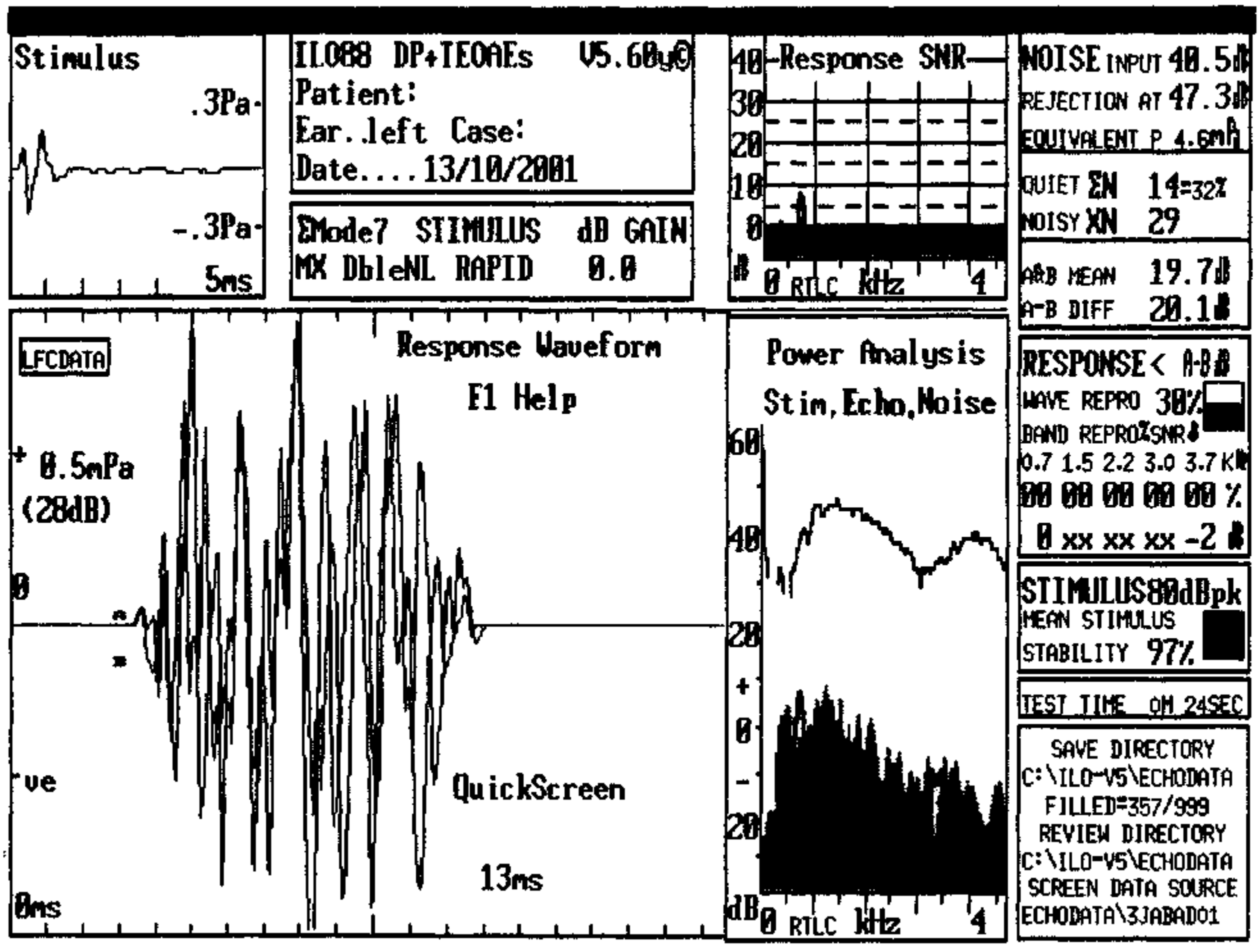
Study Graph-J and answer the following question:

1. The above TEOAE can be interpreted as

   a) normal

   b) abnormal

**



Study Graph-K and answer the following questions:

1. The above TEOAE can be interpreted as

   a) Normal

   b) Abnormal

**

ANSWERS

SECTION-1

INTRODUCTION AND BASIC PHYSIOLOGY

1. *True :* There is significant indirect evidence that the biological mechanisms responsible for OAEs lie in the outer hair cells (OHCs) (Khanna and Leonard, 1986).

2. *False* : David Kemp (1978) from Institute for Laryngology and Otology (ILO), London, England, is the discoverer of OAEs (Kemp, 1978). But long before Kemp actually discovered emissions from the cochlea. Gold, (1948 had predicted the now well-accepted notion of an active process in the cochlea (cited in Kemp, 1997).

3. *c* : OAEs, cochlear echoes, Kemp echoes are all synonyms. (Norton & Stover,-1994).

4. *Vibratory :* OAEs are vibratory responses, which are detected by microphones and converted into electrical signals for easy processing, OAEs are created by motion of the eardrum, driven by the cochlea through the middle ear chain (Kemp, 1997).

5. *a.* : The significant types of OAEs are spontaneous OAEs which occur without stimulation and evoked OAEs which occur with stimulation (Probst Lonsbury-Martin & Martin, 1991).

6. *d.* Puretones, clicks and tone bursts may be used to evoke otoacoustic emissions (Probst, Lonsbury-Martin & Martin, 1991).

7. *d* : TEOAEs, DPOAEs, SFOAEs are types of OAEs which differ based on the stimuli used to evoke them (Probst, Lonsbury-Martin & Martin, 1991).

8. *c* : Normal OHC function (Kemp, 1978; Zurek, 1985).

9. *True* : OHCs change shape in response to electrical stimulion on a cycle-to-cycle basis at audio frequencies. This is called electro-motility. It was discovered by Brownell, W,E. (1985). Electro-motility occurs due to changes in receptor potential of the OHC. (Brownell, 1990).

10. *False* : IHCs and other cells of the cochlea do not demonstrate electro-motility. (Brownell, 1990).

11. *True* : OHC can induce basilar membrane movement. Electro-motility of the OHCs is a well accepted phenomenon. When all the OKCs move in synchrony, their mechanical responses sum and leads to an amplification of basilar membrane motion in a narrow frequency range. This is the cochlear amplification. Electrical stimulation of OHC have induced motion in the basilar membrane. And this can explain the origin of otoacoustic emission. (Kemp, 1997).

12. *Cochlear amplifier.* This hypothesis was introduced by Hallowell Davis (1983).

13. *False* : The cochlear amplifier involves application of mechanical force to basilar membrane and this requires metabolic energy. OAEs are reduced or abolished by traumas and manipulation that reduce the action of cochlear amplifier (CA). (Lonsbury-Martin & Martin, 2001).

14. *a* : The cochlear traveling wave velocity is around lm/sec. (Kemp, 1997).

15. *d* : The actions of the cochlear amplifier are responsible for all the mentioned characteristics of the cochlea. (Lonsbury-Martin & Martin, 2001).

16. *b* : A damage to the OHCs leads to a loss of up to 60 dB and not beyond. The tips of the tuning curves are absent or elevated. And the responses to the auditory stimuli as a function of stimulus level grows abnormally. (Lonsbury-Martin & Martin, 2001).

SECTION 2

INSTRUMENTATION

1. *Cochlear sounder* : The cochlear sounder was battery powered, and it performed TEOAE measurement. (Kemp, 1997).

2. *False* : Closing the ear canal is an essential part of OAE techniques as it enables any oscillatory movement of the ear drum to efficiently compress and rarefy the air, and hence make it more measurable. Otherwise it would flow out of the ear canal silently, without creating sound. The tympanic membrane motions responsible for OARs are subatomic in scale. (Margolis & Trine, 1997).

3. *False* : There will be a change in the amplitude of OAE if the above mentioned factors are changed. The changes may not be very significant. (Robinette & Glattke, 1997).

4. e : The vector substraction requires a lock-in amplifier to specify the ear canal sound pressure both in terms of amplitude and phase, in order to aid spectral and temporal separation. (Kemp & Chum, 1980).

5. *True* . Changing the stimulus rate does not alter the OAE response (Norton, & Stover, 1994).

6. *True* : Synchronous time domain averaging is used in measuring TEOAEs. In order to improve signal-to-noise ratio, responses to several stimuli (eg. 500-2000) are averaged. The ear canal sound pressure is amplified by a factor of 100-10,000 and high pass filtered at 300-400 Hz. It is then digitized at a rate of 40-50 kHz. (Norton & Stover, 1994).

7. 1) *ILO92*
   2) *Model 330*
   3) *GSI60*
   4) *Celesta 503*
   5) *CUBeDIS*
   6) *Scout*

8. *a.* Removing first few millisecs of the window, results in loss of high frequency composition of the response. When short windows are used, low frequency information is lost. (Prieve & Fitzgerald, 2002).

9. *True* : Less reproducibility and high variability may be observed in DPOAEs recorded at high frequencies (above 4000 Hz). This could possibly be due to the interference of standing waves at high frequencies. The influence of standing waves may be minimized by using probe designs permitting deep insertion, within 5 mm from the tympanic membrane. Standing waves are not a concern in recording SOAE or TEOAE. (Siegel, 1994).

10. A. Ans. a) Transducer

    B. Ans. b) Signal generation

    C. Ans. a) Spectral analysis

(Norton& Stover, 1994).

SECTION 3

SPONTANEOUS OTO-ACOUSTIC EMISSIONS

1. *a)* : Spontaneous oto-acoustic emissions are low level tonal signal measured in the external ear in the absence of any known stimulus. (Probst, Lonsbury-Martin & Martin, 1991).

2. *False.* : SOAEs do not occur due to damage in the OHCs, they occur rather due to 'natural imperfections' in the organ of corti. Eg. Occurrence of a fourth row of OHCs when only 3 rows are normally observed or disruption in the OHC stereocilia at the apical ends of the cochlea. These imperfections are not associated with damage in the cochlea, but might cause a perturbation that initiates a reverse traveling wave. High level SOAEs occur due to abnormality (Kemp, 1986).

3. *a)* : SOAEs are narrow band signals that occur in the frequency range of 1-3 kHz and most commonly at 1-2 kHz. Their amplitude may range from -25 dB SPL to +20 dB SPL and is typically 0-5 dB SPL. (Wier, Norton & Kineaid, 1984).

4. *b)* : A single SOAE appears almost as a spike at one frequency arising sharply above the noise floor in the ear canal. (Hall, 2000).

5. *c) :* Earlier studies had indicated that prevalence of SOAEs in individuals is less than or about 50%. But with improvement of instrumentation, noise control, algorithms, etc. the percentages have improved. Researchers have reported of a number of different percentage owing to factors like whether number of ears or number of persons were considered. A range of 40-72% have been reported in the 1990s. (Talmadge, Long, Murphy & Tubis, 1993; cited in Strickland, Burns & Tubis, 1985).

6. *d. :* Noise floor in the ear canal unrelated to SOAEs is unavoidable. The noise consists of ambient environmental noise, patient movement and physiological noise. These are usually concentrated in the frequency region below 1000 Hz . (Hall, 2000).

7. *d.* : The probe has to be deeply inserted into the ear canal. Increasing the number of signal averaging only increases the responses and reduces noise interference. Place the patient as far away from the equipment as possible. Further, minimizing patient movements, keeping the door closed, using sound treated

chambers or rooms also reduce ambient noise in SOAE recording. (Hall, 2000).

8. c: When a single click is presented to the ear and SOAEs time-locked to the click are averaged, it is called synchronized SOAEs. SOAEs measured without an acoustical signal are called free averaged SOAEs. (Hall, 2000; Long, Tubis & Jones, 1986).

9. *c.* : SOAEs are suppressed by tones of frequencies at the SOAE frequency. A low level pure tone with frequency near an SOAE frequency can cause beats or roughness to be perceived by a person previously unaware of the SOAE. An external tone may cause the frequency of the SOAE to shift either up or down when sufficiently close to the SOAE frequency. SOAEs may be suppressed by pure tone near the frequency of the SOAE. The tuning curves that show the amount of suppression for various combinations of suppressor level and frequency are similar to the physiological and psychological tuning curves. (Rabinowitz & Widin, 1984; Frick & Mathies, 1992; Zizz & Glattke, 1988).

10. *False.* : SOAEs may have short-term stability for frequencies, while the amplitudes vary considerably even within a day. (Zurek, 1981; Wit, 1985).

11. *True.:* It has been observed thit under conditions such as extended measurement with the probe continuously inserted in the external ear canal may lead to changes in SOAEs in terms of slight increase in SOAE amplitude and frequency shifts of 6 to 10 Hz (higher or lower). New SOAEs may appear and already existing ones may disappear. This is called the initializing effect. (McFadden & Pasanen, 1994).

12. *False* : Multiple SOAEs are common and may be seen in one or both ears. It is seen in a normal cochlea. According to Talmadge, et al. (1993), the minimal frequency difference between SOAEs in the ear with multiple SOAEs is about 50 Hz. That is a distance along the basilar membrane of roughly 0.4 mm. (Talmadge, Long, Murphy & Tubis, 1993, cited in Bright, 1997).

13. *d.* : Typical level of SOAEs are around 0 dBSPL and range from -10 to 20 dBSPL. These are called low level SOAEs. High level SOAEs are a rare phenomenon and may have an amplitude of 60

dBSPL. They may be audible without amplification. Case reports of such emissions indicate that,as a rule they are present at birth and may be inherited. Hearing threshold at the frequency of the emission is pathological. (Mathis, Probst, DeMin & Hauser, 1991).

14. *c.* SOAEs cannot be a viable clinical procedure to delineate the diagnosis of a hearing loss. On the other hand, they are more useful in basic sciences and in understanding cochlear processes. (Bonfils, 1989).

15. *d.* : With development in children, the prevalence, number of SOAEs per ear and amplitude level decrease from neonates to older children. Higher prevalence, more number per ear and higher amplitude of SOAEs are found in women than men. There are also reports that SOAEs are most common in African-Americans, less common in Asians and least common in Caucasians. (Whitehead, Kamal, Lonsbury-Martin and Martin, 1990).

16. *c. :* The above characteristics are highest in neonates and decrease as they grow and is definitely reduced in adults. (Lamprecht-Dinnesin, et al. 1998).

17. *decreases* : Above the age of 50-60 years, the prevalence of SOAEs appears to decrease even when hearing loss remains within normal limits. But in most cases presbycusis maybe an associated factor. (Stover & Norton, 1993).

18. *False.* : SOAE frequencies shift from higher values to lower values over time. Higher frequency SOAEs are seen in infants and children than in adults. (Kohler & Fritz, 1992; Whitehead, Kamal, Lonsbury-Martin & Martin, 1993).

19. *b.* :SOAEs are observed more right than left ears. All the other statements given are true. (Bilger, Matthies, Hammel & Demorest, 1990).

20. *False. :* SOAEs are absent even if there is mild sensory-neural loss, i.e. around 25 dBHL. Presence of SOAEs suggests that the hearing in that frequency region is within normal limits. (Moulin, Collet Delli & Morgon, 1991).

21. *True.* There are evidences of hearing sensitivity being better in the region of SOAEs, It has been reported that there is an enhancement of about 3 dB in ears with SOAEs when compared to ears without them.

22. *False.* : Studies have reported shifts in frequency of SOAEs when the middle ear pressure is changed. It is usually an increase in frequency by about 50 Hz. There may be a decrease in SOAE amplitude. (Hauser, Probst & Harris, 1993, cited in Bright, 1997).

23. *b.* : SOAEs were believed to be physiological correlates of tinnitus. Penner (1990)said that only about 4% of tinnitus sufferers exhibit related SOAEs. In his study only 3 females had tinnitus associated SOAEs. Tones that suppressed SOAEs also caused tinnitus to be suppressed. He suggests that most SOAEs are inaudible because the auditory system adapts to the constant signal, while in a few, it is audible and annoying if it is fluctuating in nature, though these factors support a correlation between SOAEs and tinnitus, other studies draw upon a lack of correlation between the two. (Penner & Coles, 1992; Zurek, 1981).

24. *True.* : Monthly fluctuations in SOAE frequencies consistent with menstrual cycle is seen. These change could be due to change of cerebrospinal fluid pressure or some other metabolic or hormonal changes. (Strickland, Burns & Tubis, 1985; Penner, 1995; Wit, 1985).

SECTION 4

TRANSIENT EVOKED OTOACOUSTIC EMISSIONS

1. *d.* : Transient evoked OAEs are recorded in response to a very abrupt (click or tone burst) stimulus. Clicks are more commonly used and they have a total duration in the order of 0.1 ms or 100 ms. They also have a broader frequency spectrum. (Kemp, 1978).

2. *a.* :96-100% of normal hearing adults exhibit TEOAE, (Probst, Coats, Martin & Lonsbury-Martin, 1986; Steven, 1987).

3. *True.* : OAE latency is used as the primary identifier and OAE non-linearity is used as validator. Time gating is used for separating stimulus from OAE response. The first 3 ms of the response is eliminated to remove the stimulus. The distortion present are also extracted and proportional or linear responses are cancelled, as a result of which we measure non-linear OAEs. (Kemp, 1997).

4. *False.* : The latency for higher frequencies is shorter as they are represented basally on the cochlea. Hence, they have a iesser travel time compared to low frequencies which are located apically. This is called the frequency dispersive characteristic of TEOAEs. (Kemp, Ryan & Bray, 1990).

5. *False.* : The response amplitude grows slowly as the stimulus intensity is increased. There is more gain at low intensity stimuli and it saturates for stimuli in the mid-intensity range. (Probst, Lonsbury-Martin & Martin, 1991)

6. *c.* Both (a) and (b) (Kulawiec & Orlando, 1995).

7. *Click 80 dB (Glattke &Robinette*, 1997).

8. *c.* TEOAE are not measured in ears with middle ear pathology because the forward and/or the backward transmission of stimulus are emissions is affected. (Kemp, Ryan & Bray. 1990).

9. *d.* : The frequency of the stimulus, the fitter setting, time window and of course the status of the OHC determine the type of response seen in OAE measurement. (Zurek, 1985).

10. *a.:* Significant difference in TEOAE levels exist between infants under 1 year and other age groups. The COAE (Click evoked OAE) levels are larger in children than adults and the difference is frequency dependant i.e. the difference is noted more between the

age groups for mid-high frequencies, but not for frequencies of 1000 Hz and below. Hence, separate norms are necessary for children under 6 years of age, regardless of stimulus level. (Prieve, Fitzgerald & Schulle, 1997)

11. *decrease.* : As the threshold of hearing increases, the TEOAE amplitude decreases (Bonfils, Piron, Uziel and Puyol, 1988).

12. *False. :* Though earlier studies have reported that there is no correlation between TEOAE response and audiometric threshold, the prospects are brighter today. Strong correlation in the mid frequencies (500 Hz -2 kHz) have been reported. Recent studies suggest that we can arrive at the threshold from the tone-burst or click evoked emissions using advanced statistical techniques. (Vinda, Van Cauwenberge, Corlhals & DeVel, 1998).

13. *False* : The robust TEOAE amplitude in normal new newboms is the primary factor in the success of neonatal screening. (Robinette and Glattke, 1997)

14. *True.:* It has been reported that the found that the success rate of getting a TEOAE is 75% for infants less than 36 hours old

and 95% for infants greater than 108 hours old, using a reproducibility score greater than 50%. Kok, Van & Brocaar (1992) found the amplitude was approximately 16 dB SPL for those who were 24 hours old and approximately 20 dB SPL at 48 hours and 22 dB SPL at 72 hours, while adult amplitude was about 12 dB.

15. *a.* : This may be due to differences in sizes and shape of the middle and outer ear systems and their effects on the resonance characteristics of the ear. (Norton & Widen, 1990)

16. *d).* : No significant responses have be reported between right or left or male or female in neonates. (Salamy, Eldredge & Sweetow, 1996).

17. *False.* .Age does not significantly reduce COAE level or increase COAE threshold. Other factor such as presence of SOAEs and hearing loss undoubtedly have more influence on COAEs than the factor of age. When the factors like hearing loss were rigorously controlled in subjects, no difference in TEOAE levels were found. But in general, as TEOAEs are very sensitive, a reduction of

TEOAE specificity is found with age (Prieve & Falter, 1995; Parthasarthy, 2000).

18. *a.* :TEOAEs are frequency dispersive, which means that the high frequency emissions occur at short latencies and low frequency emissions at long latencies (Zurek, 1985).

19. *False.* : There is a lack of the neural phenomenon of adaptation in TEOAEs (Rutten, 1980).

SECTION 5

DISTORTION PRODUCT OTOACOUSTIC EMISSIONS (DPOAEs) & STIMULUS FREQUENCY OTOACOSTIC EMISSIONS (SFOAEs)

1. *Active* : DPOAEs arise from the fundamental processes within the cochlea, particularly those associated with non-linearity of outer-hair cell motility. These active processes respond to low-sound levels by using metabolic energy to increase the sound induced motion of the basilar membrane vibration (Davis, 1983).

2. *a.* DPOAEs are intermodulation - distortions produced by the ear in response to two simultaneous pure-tone stimuli. The stimuli are called primaries or primary tones and are represented as f_1 and f_2 where $f_2 > f_1$. The response is described as distorted because of its non-linear characteristics, with respect to the stimuli. In other words, the response originates in the cochlea as a tonal signal that is not present in the eliciting pure tone stimuli. (Probst, Lonsbury-Martin & Martin, 1991).

3. I DP gram, DP Audiogram, outer-hair cellogram/ It is usually plotted with f_2 primary or geometric mean of f_1 and f_2 along the x-axis. (Probst, Lonsbury-Martin & Martin, 1991).

4. *c.* The level of the primaries is varied and the frequencies of the primaries are set at particular values, usually the audiometric test frequency. The level of the DPOAE response is plotted on the graph where the x-axis indicates primary intensities and the y-axis marks the DPOAE amplitude. In the input function, the DPOAE threshold i.e. emission which is 3 dB above the noise floor is determined. (Probst, Lonsbury-Martin & Martin, 1991).

5. *d.* The major stimulus parameters in the measurement of distortion product OAEs are the frequencies of the primaries (f_1 and f_2) the intensity level of these stimuli (L_1 and L_2) and the spacing between the two frequencies, which is described as f_2/f_1 ratio. (Probst, Lonsbury-Martin & Martin, 1991).

6. *True.* : Maximum DPOAE amplitude occurs when mere is an overlap of the primary tone basilar membrane excitation patterns. DPOAEs are generated in the region of overlap of f_1 and f_2 excitation patterns. (Whitehead, Stagner, McCoy, Lonsbury-Martin & Martin, 1995).

7. *d.* Spectral analysis of sound in the ear canal after the stimuli are presented will reveal stimulus - induced sounds at predictable frequencies. These combination tones can be found at frequencies defined by the equation $/nf_1-mf_2/$ where n and m are any pair of integers, which can be explained as non-linearities. Harmonics like $2f_1$ and 3f, etc. are also produced. Linear responses are also found. But in humans most robust DPs are found at $2f_1 - f_2$. (Goldstein, 1967).

8. *d.* Spectral analysis of sound in the ear canal after the stimulus are presented will reveal stimulus - induced sounds at predictable frequencies. In humans, the most robust DPs are found at $2f_1$-f_2. Hence, this frequency most accurately reflects the cochlear functioning. Further it is more vulnerable to cochlear insults. (Harris, Lonsbury-Martin, Stagner, Coats, Martin, 1989; Hall, 2000).

9- *a)* f_2/f_1 = *1-22.* : The separation between the two frequencies is defined by the ratio of the higher to lower frequency i.e. f_2 and f_1. DPOAE will not be generated if these two frequencies are too far apart or too close together. Research has shown that out of the various ratios, f_2/f_1 = 1.22 produces the 'best' DPOAEs. (Gaskill & Brown, 1990).

10. *False.* : It has been reported that above 2000 Hz, optimal ratio decreases from 1.22 to 1.17. Between 1000 to 3000 Hz, maximum DP amplitudes are recorded with f_2 and f_1 ratio near 1.3. Below that frequency, ratio of 1.2 produces largest DP. But if ratio of 1.2 is used for all stimulus frequencies, the DP amplitude will still be within 3dB of what it is at the different optimal ratios. (Nielson, Popelka, Rasmussen & Osterhammel, 1993, cited in Hall, 2000).

11.3 *dB. :* The DPOAE might be considered present if the amplitude is 3 dB or more above the level of the surrounding noise floor or if its amplitude exceeds 2 standard deviations above the mean noise. (Hall, 2000).

12. *True.* : DPOAE amplitude increases by about 1 dB till 75 dB SPL and then saturation occurs (Norrix & Glattke, 1996).

13. *d:.* In $L_2 < L_1$ conditions there is an increased reduction in DPOAE associated with permanent cochlear trauma without reducing normative DPOAE amplitude. This ability to increase the vulnerability of DPOAEs to traumas producing permanent sensory-neural hearing loss has the potential to enhance the performance of clinical test utilizing DPOAEs. These may be important in

longitudinal monitoring of persons at risk for hearing loss. (eg. Ototoxicity). (Whitehead, Stagner, McCoy, Lonsbury-Martin & Martin, 1995).

14. *negative.* : As the threshold levels increase, there is a decrease in DPOAE amplitude. Though there is high variability of DPOAE amplitude, a significant correlation between DPOAE amplitude and healing threshold is seen above 3 kHz. DPOAEs give better information about the audiometric thresholds when compared to TEOAEs and SOAEs. (Lonsbury-Martin, Martin & Whitehead, 1995).

15. *c:* DPOAEs are highly variable below 1000 Hz. as the response at mis frequency range is greatly influenced by background noise. The rest of the characteristics described are true. As a result, DPOAEs have high potential for successful implementation in the clinics. (Cocace, McCelland, Weiner & McFirland, 1996).

16. *False.* : While DPOAEs detect threshold elevation above 4 kHz, TEOAEs do a better job below 4 kHz. This is because in TEOAEs, high frequency OAEs have shorter latency and are lost due to a time gating. In DPOAEs the response occurs at

frequencies of 2/3 octave below the test frequency f2. So lower frequency observations are more easily influenced by low frequency noise. To be more specific, neither TEOAEs nor DPOAE can distinguish between normal hearing and hearing-impaired subjects at 500 Hz. TEOAEs more accurately distinguishes normal and impaired subjects at 1000 Hz. At 2000 Hz DPOAEs and TEOAEs may be comparable. DPOAEs are more successful above 4000 Hz (Gorga, et al. 1993).

17. *c:* DPOAEs show no ear differences i.e. the right and left ear DPOAE thresholds are not significantly different. Females have better DPOAE amplitudes than men at high frequencies i.e. 5 kHz, 5.3 kHz and 5.7 kHz. And just like hearing threshold increase with age, especially above 3 kHz, DPOAE amplitudes also decrease with age. The variations between age group (for eg. 15-24 years, 25-34 years, >35 years) were large. Frequency changes are more prominent than amplitude changes at high frequencies. Hence, age-adjusted norms for clinical applications of DPOAEs is required (Lonsbury-Martin, Martin & Whitehead, 1997).

18. *False. :* Narrow band filtering is used to separate the DPOAEs which are different from the stimuli in frequency and amplitude. (Lonsbury-Martin, Martin & Whitehead, 1997).

19. d*.:* Repeating the test at the same level, helps to assure that there is no comparable instrumental distortion. Measuring the latency, helps to confirm cochlear origin as the cochlear traveling take around 20 ms to travel. Using the simultaneous masking tone (f3), we can confirm the frequency specific nature of the non-linearity, which is unique to the cochlea. Most DPOAE instruments use latency for validation of the true response (Kemp, 1997).

20. *b.:* Unlike TEOAEs which uses latency, DPOAE extract the non-linear response component before looking for a cochlear origin in terms of latency (Kemp, 1997).

21. *a. :* The growth of response with intensity can be derived from the slope of the input/output function, (Nelson & Kimberly, 1992),

22. *Increases.* This may result from the low velocity of the traveling wave or displacement wave by which low to moderate levels of

acoustic energy propagate along the basilar membrane. (Whitehead, Stagner, Martin & Lonsbury-Martin, 1996).

23. : In DPOAEs, for stimulus frequencies above 6 kHz, latency of response is less than 3 ms and for frequencies below 1 kHz, latency is more than 10 ms. (Mahoney & Kemp, 1995).

24. f_2. : At low and moderate stimulus intensity level (up to 70 dB), when $L_1 > L_2$ by about 10 dB or more, cochlear stimulation is mostly at f_2 place in the basilar membrane. Hence, DPOAE amplitudes plotted as a function of f_2 would be expected to agree maximally with audiogram. Though $2\ f_1\text{-}f_2$ reflects the place on the basilar membrane where the DPOAE is expected, it provides no information on the cochlea in that region. DPOAE maybe recorded at $2f_1\text{-}f_2$ frequency even when the OHCs in the place are non-functional. (Hall, 2000).

25. *b,* : Maximum amplitude of DPOAEs appear when primary are at low-moderate levels in an input/output function. In such cases, a larger number of OHC active mechanisms are stimulated and maximum amplitude DPOAEs are observed. Micro-mechanics of the cochlea act differently at high and low stimulus levels. The

DPOAE sensitivity to cochlear influences increases as stimulus intensity decreases. Thus lower stimuli are more useful to detect mild losses (Norrix & Glattke, 1996).

26. *True.* : DPOAEs may be produced by the interaction of 2 external tones, one external tone and an SOAE and also by interaction between 2 SOAEs (Burns, Strickland, Tubis & Jones, 1984).

27. *c.* : The fine structure of a DPOAE is studied by giving many stimulus frequencies within an octave eg. 15 frequencies/octave. Tt is characterized by peak-to-peak distances of approximately 3/32 octave (10 peaks/octave) and peak to valley excursions of up to 20 dB. (He & Schmeidt 1993).

28. *A-C*
B-d
C-a
D-b

We expect normal OAE amplitudes for persons with audiometric thresholds better than 15 dBHL. Abnormal OAE amplitude values, or even the lack of detectable OAE activity is anticipated whenever there is a mild-to-moderate hearing loss (15-40/45 dB). OAE activity is inevitably not observed for sensory hearing loss exceeding 40-50 dBHL. Generally, OAEs are of little or no value in estimating the degree of hearing loss, as absence of OAEs is associated with mild-moderate to profound hearing loss. (Hall, 2000).

29. *b.* : SFEs are most frequency specific, as responses occur simultaneously and at the same frequency as the eliciting stimulus. The responses occur temporally and spectrally similar to the stimulus, hence separating response and stimulus requires very sophisticated equipment and processing. Moreover, response for each ear is unique and a specific response pattern is not very clearly seen. (Kemp & Chum, 1980, cited in Probst, Lonsburty-Martin, & Martin, 1991).

30. *False.* : Unlike all the other emissions, SFE responses are not temporally or spectrally distinguished from stimulus. The response occurs simultaneously with same spectra as that of stimuli. (Probst, Lonsbury-Martin & Martin, 1991),

31. *c* : In SFEs, the lowest threshold is found corresponding to the frequency where the SFE maxima occurs. (Zwicker & Schlothe, 1984).

SECTION 6

CONTRALATERAL ACOUSTIC SUPPRESSION

1. *Collet effect,* : **Tt** is **called the Collet effect as it was Collet, et al** (1990) who first used contralateral broadband noise and clicks to investigate the suppression of transiently evoked OAEs from click stimulus (Norman & Thornton, 1993).

2. *b).* : Contralateral acoustic suppression is the reduction in the OHC's abilities to produce emissions when noise is presented to the contralateral ear. (Collet, Veuillet, Chanal & Morgon, 1991).

3. *efferent.* : Sound induced suppression OAEs is a normal phenomenon mediated by the efferent auditory system, especially the medial olivocochlear system (Collet, Veuillet, Bene & Morgon, 1992).

4. *True.* : TEOAE suppression associated with contralateral stimuli between 70 and 75 dB SPL is relatively small, on an average close to 3 dB. The suppression is elicited consistently. Individual variations with a range of 0.5 - 10 dB have been reported (Veuillet, Collet & Duclaux, 1991; cited in Parthasarthy, 2000).

5. *True.* : In human adults, TEOAEs show an average reduction of 3.7 dB with presentation of moderate levels of BBN in contralateral ear (Veuillet, et al. 1991). Contralateral suppression of DPOAEs has been minimally studied in humans. Most reports show an average 0.5 to 2 dB reduction in DPOAE amplitude with noise in contralateral ear, depending on level and frequency of primary tones. (Abdala, Sininger & Ma, 1998. cited in Abdala, Ma, Sininger, 1999).

i

6. *False.* : Tt takes rather long stimulus duration of 50ms or longer (upto 500 ms) to activate the olivocochlear bundle (Monson, Durrant, Galleneau, Micheyl, Collet, 2001).

7. *b.:* The contralateral signal is presented at a relatively low intensity level, especially below the level which would cross over to the test ear. It is also below the intensity level that would cause an acoustic stapedial reflex. There is a similarity of the anatomic bases of acoustic suppression of OAEs and acoustic stapedius reflex but the final descending pathways and destinations are different. Acoustic reflex utilizes facial nerve and innervation of stapedius muscle while the former uses efferent fibres of the olivocochlear bundle and innervate the OHCs. (Hall, 2000).

8. c: TEOAE suppression is of approximately same magnitude (0.5 dB) in presence of ipsilateral and contralateral noise stimulation. A binaural noise stimulation caused more prominent reduction of TEOAE amplitude (1-15 dB). Similar suppression from ipsilateral and contralateral stimulation is because in awake human beings, a significant portion of the medial olivocochlear neurons is expected to be bilaterally activated. (Berlin, Hood, Murley, Wen & Kemp, 1995, cited in Robinette & Glattke, 1997).

9. *d* .In SOAEs amplitudes reduce with contralateral suppression and the SOAE frequency is also shifted upward. This is not seen in TEOAEs or DPOAEs. Frequency shift upward by 2 to 20Hz in SOAEs has been observed. (Harrison & Burns, 1993).

10. *d.* All the given statements are true (Abdala, Ma, Sininger,1999; Berlin, et al. 1993, cited in Parthsarthy, 2000).

11. *False.* There are many controversies regarding suppression in neonates. Some authors suggest that almost negligible suppression is observed in infants when compared to adults. While some investigators suggest that the medial efferent system

is immature until well after 1 year of age, others believe that it is mature by 40 weeks of gestation and show contralateral suppression. Whatsoever the magnitude of suppression increase in the order; preterm infants, term infants and adults (Abdala, Ma & Sininger, 1999).

12. *eliminates.* : The vestibular portion of the eighth cranial nerve as well as fibres from the olivocochlear bundle lie near each other as they run through the internal auditory canal. Sectioning the vestibular nerve also severs the efferent pathway. Hence contralateral suppression disappears in such individuals. (Williams, Brooks & Prasher, 1993).

SECTION 7

APPLICATIONS OF OAEs

1, *c:* Clicks are wide band stimuli while pure tones are narrow band. Hence with tonal stimuli only part of the cochlea is tested at once and a series of measurements need to be made to cover the whole frequency range. With click-evoked OAEs, data is collected from a substantial length of cochlea simultaneously, and the response is broken down into separate frequencies afterwards. (Kemp, Ryan & Bray, 1990).

2, *a.* : OAEs help to screen for peripheral auditory pathway disorders and do not assess central auditory disorders. (Bonfils, 1989).

3. *a.* : OHCs, which are a part of the peripheral hearing system are responsible for the production of OAEs. They do not depend on higher or central functioning. (Lonsbury-Martin & Martin, 1990).

4. *False.* : Authors have found that normal temperature fluctuation (33° to 39° centigrade) does not alter DPOAE or TEOAE amplitudes (Cacace, McCelland, Weiner & McFarland, 1996).

On the other hand if extreme variations in temperature are induced, then OAEs are effected. (Seifert, et al. 1998).

5. *d.*: Ear canal volume increases as a function of age from infancy to childhood. And as sound intensity is inversely related to volume, we observe a decrease in sound pressure level created in ear canal with age. And, hence, a decrease in OAE amplitude. Further we see the resonance frequency of neonates is about 6000 Hz, children is around 4000 Hz and for adult is 2500-3000 Hz. Hence the increase high frequency energy observed in infants. Age effects of middle ear function (reflectance, phase and transfer function) also should be considered in the analysis of OAE amplitude and spectra. (Burns, Keefe & Ling, 1998; Westbrooke & Banford, 1992).

6. *b.* : ABR has a wide dynamic range of 120 dB, while OAE have only around 30 dB or so. This limits OAEs to frequency specific screening ABR does not have frequency place specificity. ABR detection threshold is well correlated with the audiometric threshold, but OAE detection threshold is not. Accurate threshold predictions can be made with ABR but not with OAE (Kemp, 1998).

7. *False.* : TEOAEs have a specificity of 95% and take lesser time (2 mins) for completion of the test when compared to DPOAEs. (Robinette and Glattke, 1997).

8. *b. :* One of the most important instrumental factors in new born screening is probe fit. Referring immediately for audiological evaluation is not advisable. Truly vernix gives failure results in neonatal OAE screening, but washing vernix off is not possible. (Hall, 2000).

9. *d.* : Both the above statements justify the limited function of OAEs in identifying an acoustic neuroma (Robinette, 1999).

10. *d.* These statements justify the use of OAEs. (Robinette, 1999).

11. *a :* TEOAEs are absent if the hearing loss is above 30 dB HL. Hence we can classify individuals into two groups - those with hearing sensitivity within 30 dB HL and those with hearing sensitivity above 30 dB HL. (Robinetts,1999).

12. *c:* A normal OAE, absent ABR in conjunction with PTA and presenting symptoms indicate the possibility of a neural hearing loss.

13. *b.:* OAEs (Spontaneous as well as evoked) are not present in 100% of normal population. The specific sites of generation of OAEs in the cochlea is not only from the apex. OAE threshold do not have a one to one correspondence with the audiometric thresholds. They reflect the integrity of the cochlea, especially the OHCs. (Robinett, 1999).

14. c: DPOAE notches have been identified in some cases of genetic hearing loss (Liu & Newton, 1997).

15. *c:* Many authors have used Bekesy audiometry, pure tone audiometry, ABR, etc. While some studies reports of differences between carriers and control subjects, other don't. Hence there is a failure to find reliable audiologic abnormalities in normally hearing obligate carriers. Findings suggest that OAEs may provide insight into cochlear function in carriers of abnormal genes related to hearing loss and that auditory function differs in carriers. OAEs may help to clarify relationships between

genotype and phenotype and contribute to enhanced understanding of the mechanism responsible for hereditary hearing loss. (Hood, 2001).

16. *c:* Irreversible injury or destruction of crucial structural elements that constitute the cochlear portion of the inner ear by ototoxic drugs initially occurs to the base of the cochlea. The damage systematically progresses along the organ of corti both apically and laterally to the inner hair cells. The effect is limited to the neurosensory epithelium of cochlea rather than central auditory pathways. Hence the use of OAEs is more advantageous. (Lonsbury-Martin & Martin, 2001).

17. *d.* : DPOAEs alone are not sufficiently sensitive in identification of NIHL. In some cases with hearing losses up to 75 dB HL DPOAEs are present. Hence the discrete frequency information from DPOAEs have to be combined with other tools like high frequency audiometry. (Bresloff, Reshef, Horowitz & Furman, 1998).

SECTION-8

INTERPRETATION OF OAEs

Graph-A

1. a) *SOAE* : It is a graph of synchronized SOAEs measured in ILO 296
2. a) *multiple SOAEs* :
3. b) concentration of noise in the recording
4. b) the presence of SOAEs.

Graph-B

1. b) TEOAE
2. a) 95% : is the overall reproducibility of TEOAE. 99% indicates the stability of the stimulus presented.
3. a) Band analysis indicates that at 700Hz and 3000 Hz, the amplitudes of the emissions are 16 dB SPL each,
4. b) 260clicks are presented. The intensity of the stimuli was 86 dB peSPL.
5. a) Good evoked emissions. We can arrive at this conclusion based on the good reproducibility percentage which greater than 80%, and the SNR which is 10.7 dB.

Graph-C

1. a) Kempechoes or TEOAEs.

2. a) noise during the measurement.

3. b) False. The probe fit in Bis poorer than that of A. This is shown in the box titled stimulus. A good probefit is one in which there a single sharp raise and fall of peak followed by a relatively straight line. Graph B shows irregularities through out, which indicates a poor probe fit.

Graph-D

1. Absent TEOAEs. This can be attributed to the low value of reproducibility, i.e. 27% which is much lesser than 50%.

2. b) stands for the number of responses accepted. Here only responses to 30 stimulus sets or 41% of the responses where accepted.

3. a) the number of responses rejected. In this recording the responses to 43 stimulus sets where rejected,

Graph-E

1. a) present at high frequencies

2. a) As the reproducibility value is greater than 50%, but lesser than 80%, the TEOAEs are poor. The amplitudes of response at each frequency are also relatively low.

Graph-F

1. a) DP gram
2. b) 1.213
3. a) L_1 = 65 dB SPL and 55 dB SPL
4. a) < 6 dB
5. b) 5000 Hz
6. At low frequencies (<2 kHz) we find more amplitude of noise,

Graph-G

1. a) True
2. b) False. It stands for the DPOAEs.
3. b) False. The difference is lesser than 6 dB at all frequencies.
4. b) False. This graph shows absent DPOAEs, as the DPOAE noise floor difference is very low and the amplitudes of DPOAEs is also reduced.

Graph-H

1. a) True. The noise is above acceptable range.
2. b) False. The low frequency responses cannot be considered as absent, as the noise level during the recording is very high.

Graph-I

1. b) I/O function or DP growth rate. Observe the x-axis and y-axis. Note that the responses increase as the stimulus increase.

2. a) -5 dB SPL.

Graph-J

b) Abnormal the emissions are present below 3 kHz and absent above 3 kHz, Hence the subject possibly has high frequency hearing loss.

Graph-K

1. b) Abnormal. The reproducibility is below 30%. Emissions are absent at all frequencies

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