NOISE CONTROL IN MECHANICAL SYSTEMS

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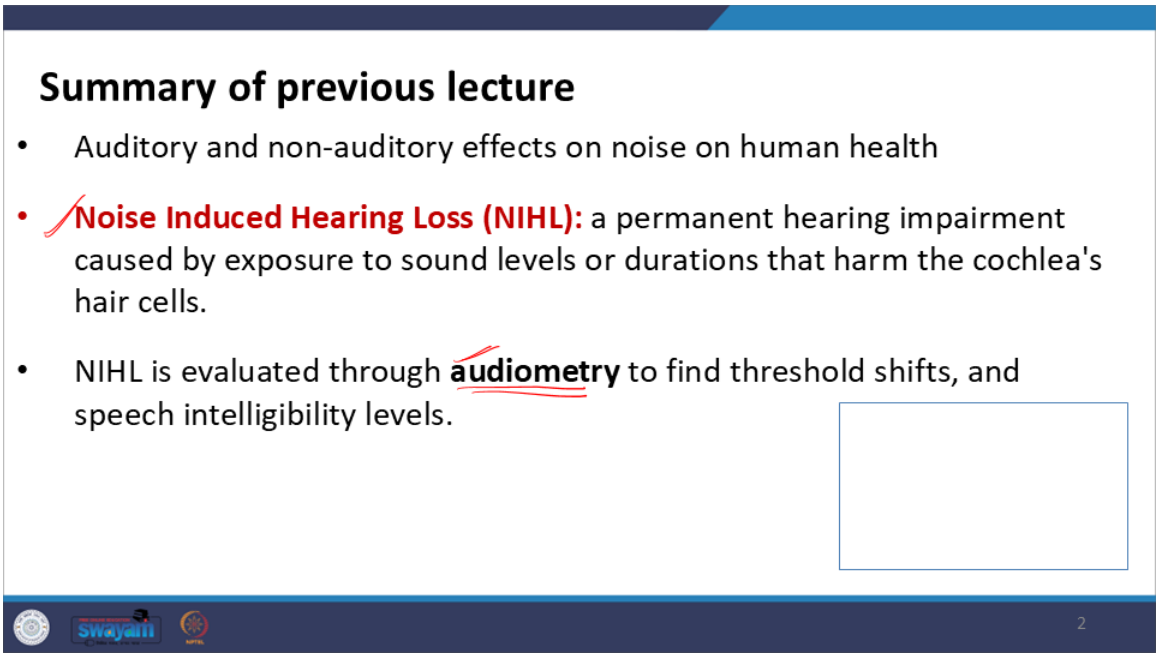
Week: 05

Lecture: 21

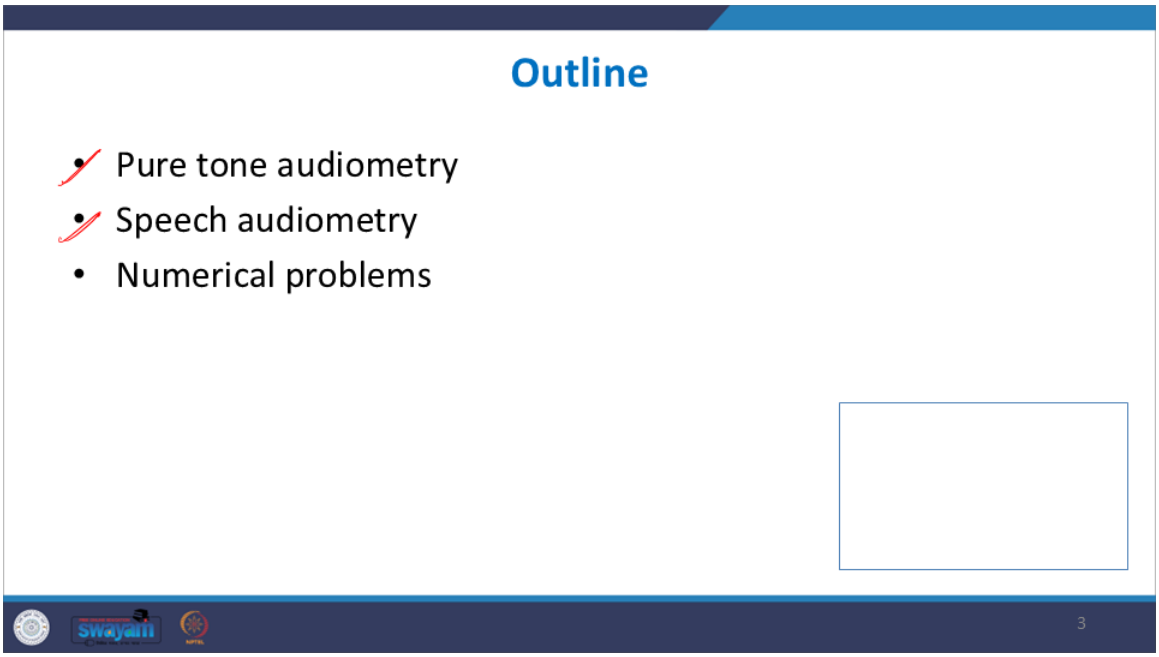
Lecture 21: Noise and human health: Numerical

Hello and welcome to Lecture 21 in this course on noise control in mechanical systems. And let's continue from our previous lecture on noise and human health. So here we'll continue the topics from the previous lecture and also solve some numerical problems based on that. So, to summarize, in the previous lecture, we studied the auditory and non-auditory effects of noise on human health. Then, noise-induced hearing loss was

introduced. This means the hearing loss that is caused due to noise exposure. So, here it is usually measured through audiometry, which is a standard clinical test to test somebody's hearing capacity, and we have pure tone audiometry and speech audiometry, and we had started the discussion on pure tone audiometry.

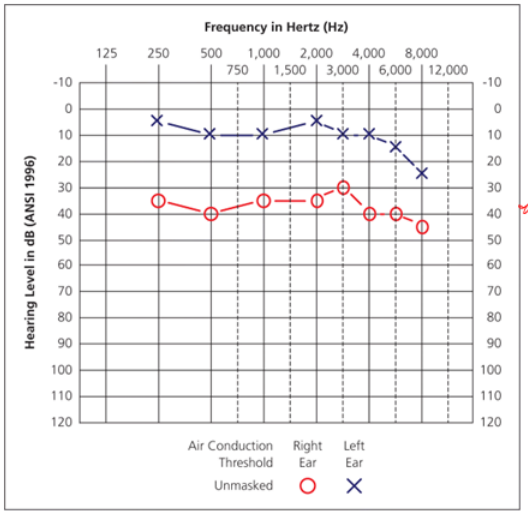


So, we will continue in this lecture with these discussions. We will see pure tone audiometry, speech audiometry, and solve the numerical problems based on that.



So, this is the pure tone audiogram that we just finished in the last lecture, that the result of testing the minimum levels at which somebody hears a pure tone at various frequencies is we get a graph of each ear where you know what is the minimum level at a particular pure tone frequency and where the sound is being heard. So, it looks like this; it is a decibel versus frequency graph. So let us solve what we do with this. Now we have obtained this audiogram, and we want to make an assessment or evaluate what is the extent of noise-induced hearing loss in a particular population. Let us say we are trying to assess in an occupational environment or some industrial setup. We want to assess how dangerous the noise exposure levels are, so we evaluate the NIHL, and how do we evaluate based on this audiogram data?

Pure tone Audiogram



Source: https://www.aafp.org/pubs/afp/issues/2013/0101/p41.html

There are two measures that can be used. One is finding out what is the grading of hearing impairment. The other one is the percentage hearing handicap, and both of them are calculated from the pure tone audiogram that is obtained.

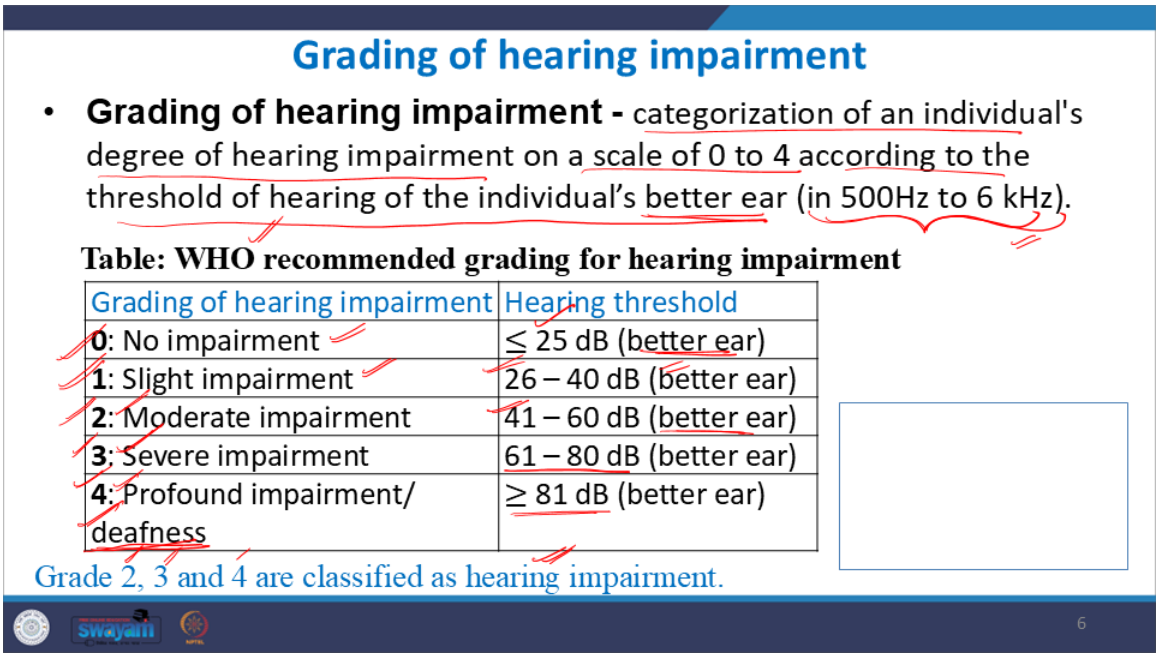
Measures for evaluating NIHL

- Noise Induced Hearing Loss can be measured in terms of
  - ✓ **Grading of hearing impairment**
  - ✓ **Percentage Hearing Handicap**

  - ✓ Both can be calculated from **pure tone audiogram**

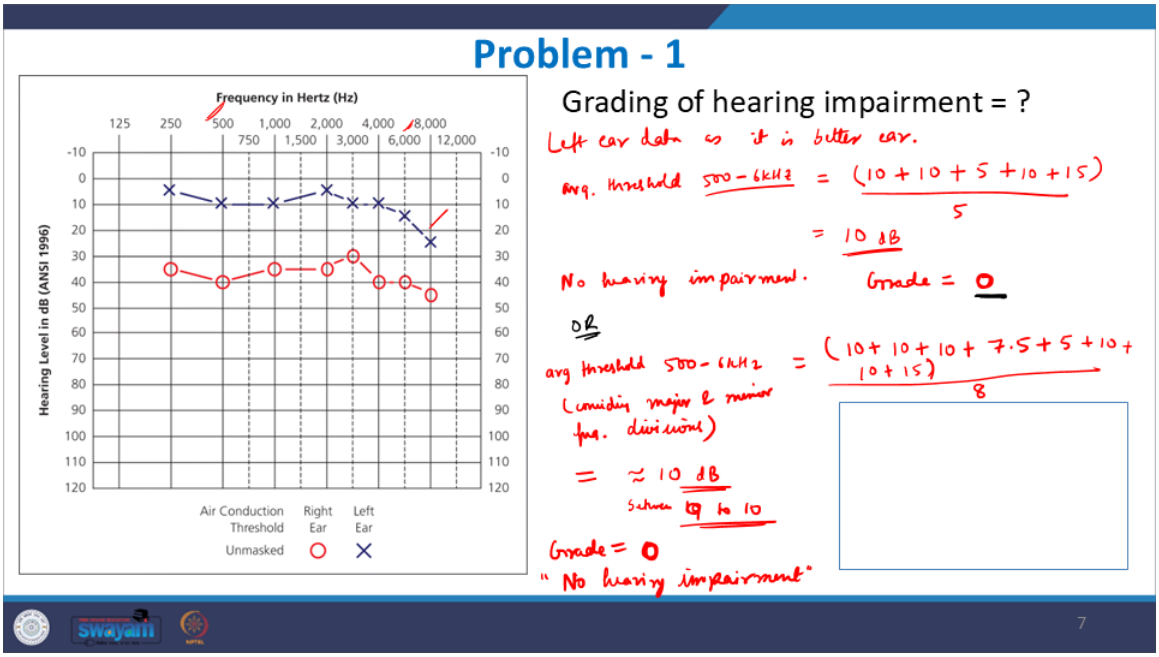
So, what is the first one? The grading of hearing impairment. It is the categorization of an individual's degree of hearing impairment on a scale of 0 to 4, according to the threshold of hearing of that individual's better ear in the more sensitive zone, which is 500 Hz to 6 kHz. Now, usually, this zone is selected because we know from the equal loudness contour that our hearing is the most sensitive in this region, and this is a region where the majority of noise sources generally found in nature are present. So, this zone has just been used as a reference zone to ease the calculation, and then within that zone, whatever the average threshold of hearing is found, based on the value obtained, some grading from 0 to 4 is given. So here, 0 means whenever the average hearing threshold in this particular region comes out to be less than or equal to 25 dB for the better ear, then we have zero as the grading, which means no impairment. Usually, what is found even for healthy human beings is that you don't actually hear the voice at zero decibels. Okay, any sound exactly at zero decibels is really hard to discern. Usually, people start hearing from 10 dB or 20 dB onwards, so anything less than or equal to 25 dB has been categorized as no impairment. Then, from 26 to 40 dB is the performance of the better ear that is given a grading of 1, which essentially means slight impairment. Then, 41 to 60 for the better ear becomes a grade 2, which means a moderate level of hearing impairment. 61 to 80 dB means there is severe hearing impairment and is given a grade 3, and greater than or equal to 81 dB essentially means the person has gone completely deaf, and we say it is a profound impairment or deafness has happened and is given a grade of 4. So, this table is something that can be remembered and is provided by WHO-recommended grading. So, usually, the way we see it is that anyone who is having a grading above 1.

So, is it grade 2, 3, or 4 that they are classified as having a hearing impairment, where 0 and 1 mean just mild things? So, they are not really classified as something that is cautionary and has to be prevented. So, it is grade 2, 3, and 4 onwards that are classified as a cautionary thing that has happened, and a hearing impairment has occurred in that individual.



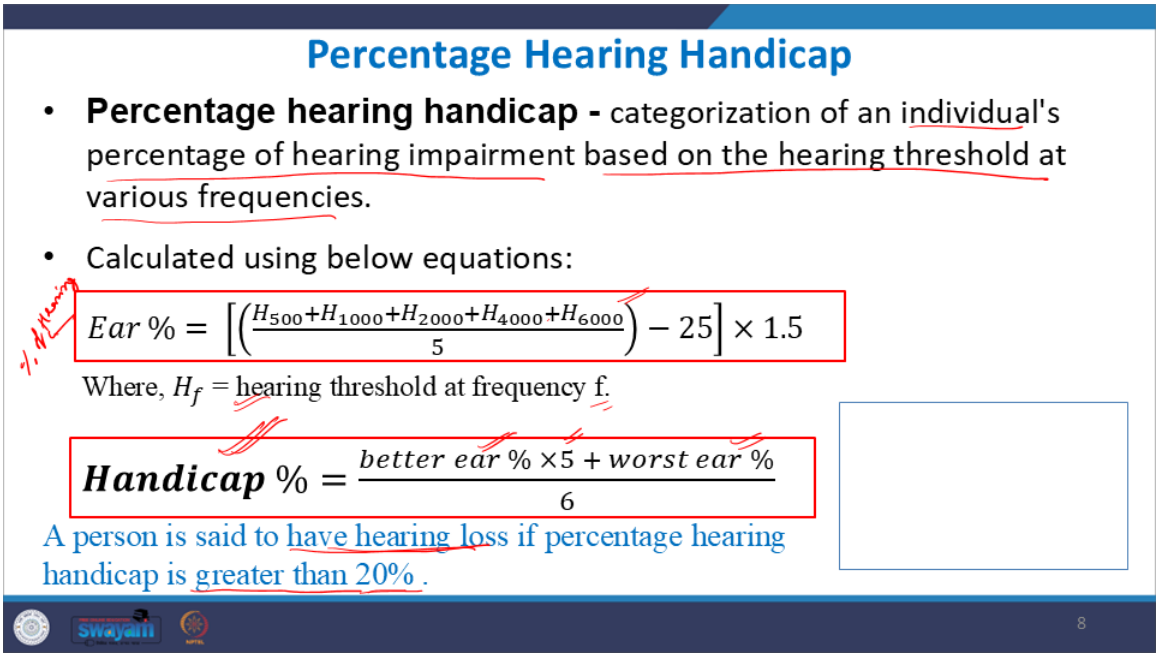
So, let us solve a problem based on this. So, let us say we have the same audiogram, and you have to find out what the grading of hearing impairment is. Now, you know that the grading is calculated for the human's better-performing ear. So, even if somebody is able to hear from one ear but has gone deaf in the other ear, that does not mean they are deaf; they can still hear sound from one ear. So, the better ear's performance is taken. So, here, as you can see clearly, the left ear is performing markedly better than the right ear at all the frequencies. So, we will take the left ear data, as it is the better ear. And then we will find out the average threshold in the region of 500 to 6 kilohertz. Now, there are two ways to do it: either you can take the major divisions and do it, or you can take all the minor divisions as well. If you just take the major divisions, then the average threshold in this region becomes If you see here, 500 is 10 dB, and 1000 is 10 dB, 2000 again is 5 dB, and then 4000 is going to be 10 dB, and then 6000 is going to be 15 dB. If you do this, what you find is 30 plus 20, 50 divided by 5. 10 dB becomes your average. So, if you look at this table, it is less than or equal to 25 dB. So, that means that, you know, no hearing impairment is the diagnosis. So, the grade that you give is 0, which becomes your answer: 0 grade, meaning no hearing impairment. There is another way to solve it. You can also, if you look at the, you know, minor divisions, okay. Then, the average threshold in this range here, considering major and minor frequency divisions,

So, here you start from 500, which is 10 dB. After that, you have 750 again at 10, 1000 is at 10, then your 1500 is between 10 and 15; it is a slope. So, you can say it is 12.5. Sorry, it is between 10 and 5. So, you can say it is 2 point, okay? Sorry, it is going to be 7.5, and then you have 5. Then, you have 10 for the 3000, then 10 for the 4000, and then for 6000, you have 15. And 8 divisions we have taken here, so the average, if you see, would be 30, 40. So, the average would again come close to, you know, 10. If you find out, it would still be approximately 10. It will be between 9 to 10 dB. So, if you solve it, you will see that again, the diagnosis is the same. The grade of hearing impairment is 0, which means no hearing impairment. That is the diagnosis based on the audiogram data. Now, in this particular measure, we only took, you know, the better-performing ear.



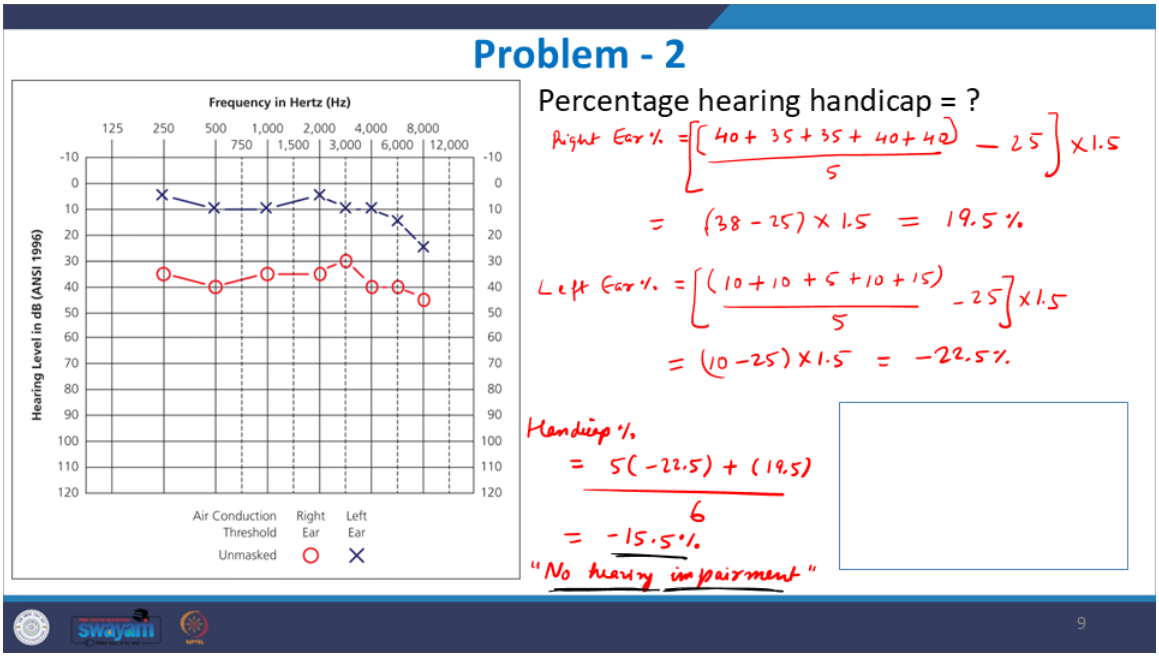
There is another measure, which is the percentage hearing handicap, where the data of both ears is taken into account, but the better ear is given a higher weightage. So, 5 times the data of the better ear plus 1 times the data of the worse ear, and then we take the average. So, how do you calculate this? This is the categorization of an individual.

Percentage of hearing impairment based on the hearing threshold at various frequencies. So, once again, the formula is that for each year, you first calculate the percentage of hearing in each ear. So, this is the percentage of hearing in every ear So, for each ear, you calculate the average of the threshold between 500, 1000, 2000, 4000, and 6000. The average threshold you calculate minus 25 because, up to 25, we are taking it as no impairment. So, you already subtracted 25, then you multiply by 1.5 here. And then what you do is here, all of this is the hearing threshold at these various frequencies. So, once you use the formulation and you find for both the better ear and the worse ear the percentage of hearing, you take five times the value of the better ear and one time the worse ear and find out another average, and you get the percentage hearing handicap. Usually, any person having it greater than 20 would be qualified as having hearing loss. So, less than 20 is not considered as hearing loss.

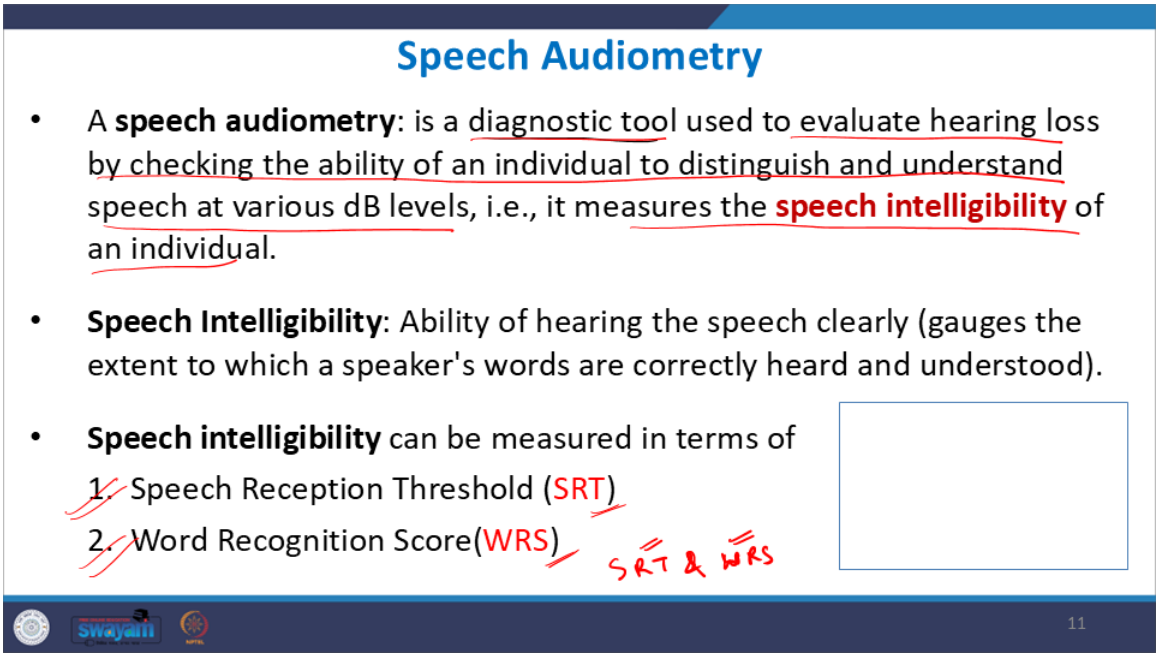


Let's see, let us find out what is the percentage hearing handicap for the same audiogram data. So, if you think about this, let's start with the right ear first. Let us find out the percentage of hearing in the right ear. So, you take the value, you take the average of 500,

1000, 2000, 4000, and 6000. So, the thresholds at these levels are taken. So, at 500, we have 40 dB. Then at 1000, we have got 35 dB. Then at 2000, again we have 35 dB. At 4000, we have 40 dB. At 6000, again we have 40. We're doing 5 times of that, then minus 25, multiplied by 1.5. So here, the average that you get is coming out to be 38. So, it is borderline; you can see that here, borderline, but we will use both the data for the poor ear and the better ear. So, let us now calculate the percentage of hearing in the left ear, and using the same formulation, let us first do the averaging of the various thresholds. So, this we have already done in the previous example. And we found it to be exactly 10. So, as you see here, the threshold is much lower than 25. So, you are getting a negative result here. Let us take it. It just means that it is going to be used in the equation. Now, the percentage handicap is going to be 5 times this. The value from the better ear and 1 times the value from the bad ear, and this, yeah, this is the one, and what you get once you solve this is again, so the diagnosis is the same; there is no hearing impairment because it is less than 20. So, usually, most of these measures in general give similar diagnoses. So, this is how you use the pure tone audiogram data to evaluate noise-induced hearing loss. You can either calculate the percentage of hearing handicap or you can calculate the grade of hearing impairment and make your assessment.

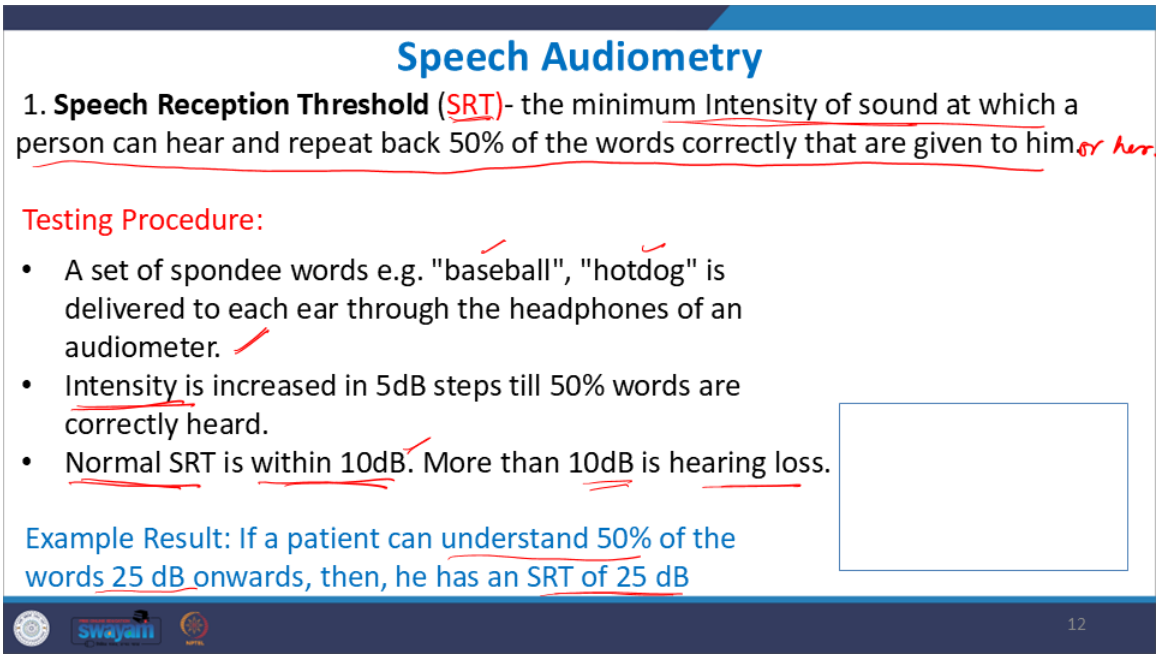


Now, let's see the second type of audiometry, which is called speech audiometry. Now, what is happening here is that in the tone, you are simply giving a single frequency tone, and people are able to just detect that sound. But speech means you are giving them some words or speech, and they have to identify what that word is. So, speech audiometry is again a diagnostic tool. It is used to evaluate hearing loss by checking the ability of an individual to distinguish and understand speech at various dB levels, i.e. What does it do? It measures the speech intelligibility of an individual. So, what is speech intelligibility? It is the ability to hear speech clearly. Which means that it gauges the extent to which a speaker's words are correctly heard and understood. So now, speech intelligibility is harder than just hearing sound because you don't just have to detect the presence of a sound stimulus, but you also have to understand what it means, as in you have to understand what that particular stimulus is. Okay, so it is used to assess the hearing of speech and the extent to which a speaker's words can be correctly heard as well as understood. So detection plus being able to understand what exactly it is. So, it can be measured in terms of the speech reception threshold and the word recognition score, SRT and WRS.



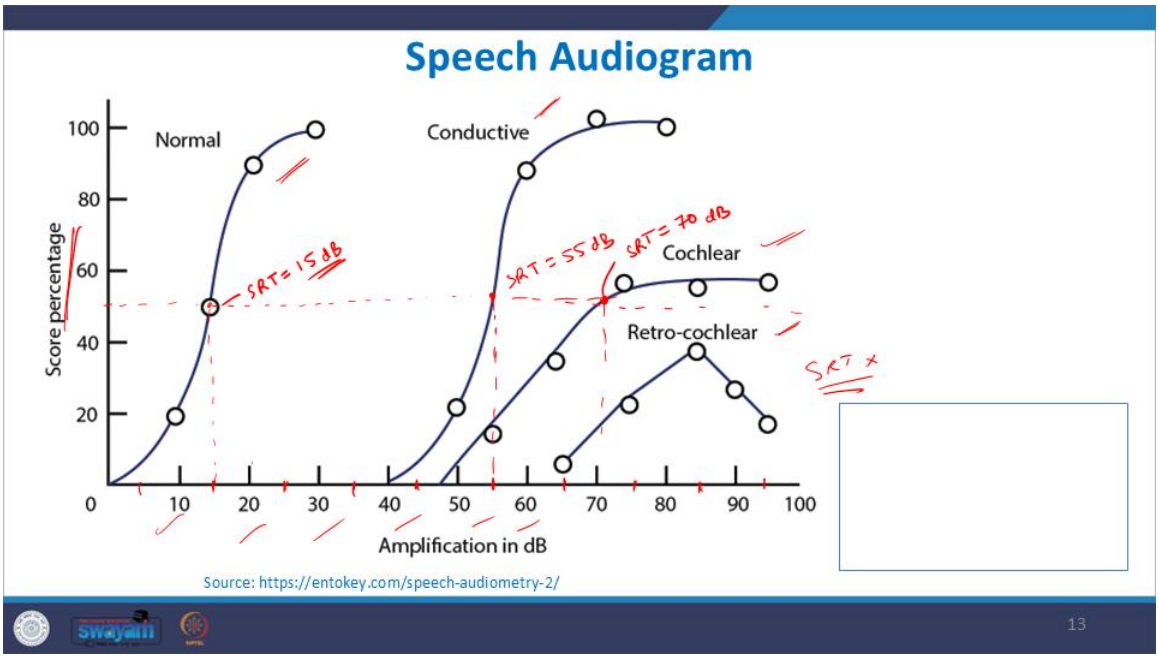
So, the very first measure for measuring speech intelligibility is through speech audiometry, which is the speech recognition threshold, or SRT. That's the first measure. So what is this SRT? It is the minimum intensity of sound at which a person can hear and repeat back 50% of the words that are correctly given to them. So how it happens is that, you know, a set of spondee words are given to you. So spondee words are the words with two different syllables. Such as, you know, baseball, hot dog, and so on, benchmark, etc., etc. So, these kinds of a set of standard spondee words are prepared. Typically, the list could be 50 words in general. So, a list of standard words is available at the clinical procedures, and these words are delivered through the ear or the headphones of an audiometer, and the person listens to these words and one by one, and has to repeat back the words that the person has listened to. So, the way it starts is that, you know, it starts from 0 dB, and slowly the intensity is increased in steps of 5 dB. So, first, all the words would be delivered to the person one by one at 0 dB, at 5 dB, 0 dB, and the person will have to respond back what they have just heard, and then the number of words heard correctly would be marked. Then again, the same set of words would be repeated at 5 decibels. The person hears them one by one and has to repeat back what words they have just heard. And then again, the same list of words will be presented to the person at 10 decibels, and they have to once again hear the words one by one and repeat back what they have just heard, and then again the same list will be repeated at 15 decibels, and the process will continue, so 0 decibels, 5 decibels, then 10 decibels, 15 decibels, 20 decibels, 25 decibels, and so on, in steps of 5 decibels, and each time the person repeats back the word that they have heard And the number of words that they are repeating correctly is noted down. So, the decibel level at which 50% of the words start to be heard correctly, that level is noted down. So, it is the level at which 50% of the words which are given to the person, so at least the person is able to correctly repeat them back. So, this means that the minimum level at which the person starts to hear at least half of the words in the list correctly. So, that level is noted down, and that becomes the speech recognition threshold for the person. And what happens here? Suppose a person's pure tone. So, usually what happens is that the pure tone audiometry is done first, and that is followed by the speech audiometry. So, suppose the pure tone audiometry has already been done, and the pure tone threshold of the person has been noted down. Let us say some person A had a pure tone threshold of, let us say, 20 dB. Now, we do with the same person A speech audiometry, and we note down the minimum level at which person A starts to hear at least 50% of the words in the list correctly. And let us say the speech audiometry threshold comes out to be somewhere around 30 dB. Okay, so whenever this speech, the speech audiometry threshold or the speech recognition threshold, this SRT. is coming out

as 30 dB, so whenever this SRT is within the 10 dB of the person's average pure tone threshold, so if it is within plus or minus 10 dB of its pure tone threshold, in this person, let us say the pure tone threshold was 20 dB, and the speech recognition threshold is coming out to be 30 dB, which means that the person has got normal speech intelligibility, so this will be considered as a normal SRT value, but in case The speech recognition threshold, let us say, came out to be 35 dB, which was more than 10 dB of its pure tone threshold. And this would start to be known as some kind of deficiency in the speech intelligibility and so on. So, let us say some person is able to repeat, you know, 50 percent of the words correctly from 25 dB onwards, then he has an SRT of 25 dB, and suppose the pure tone threshold was 15 dB, then again this would be considered as a normal SRT score. and so on.

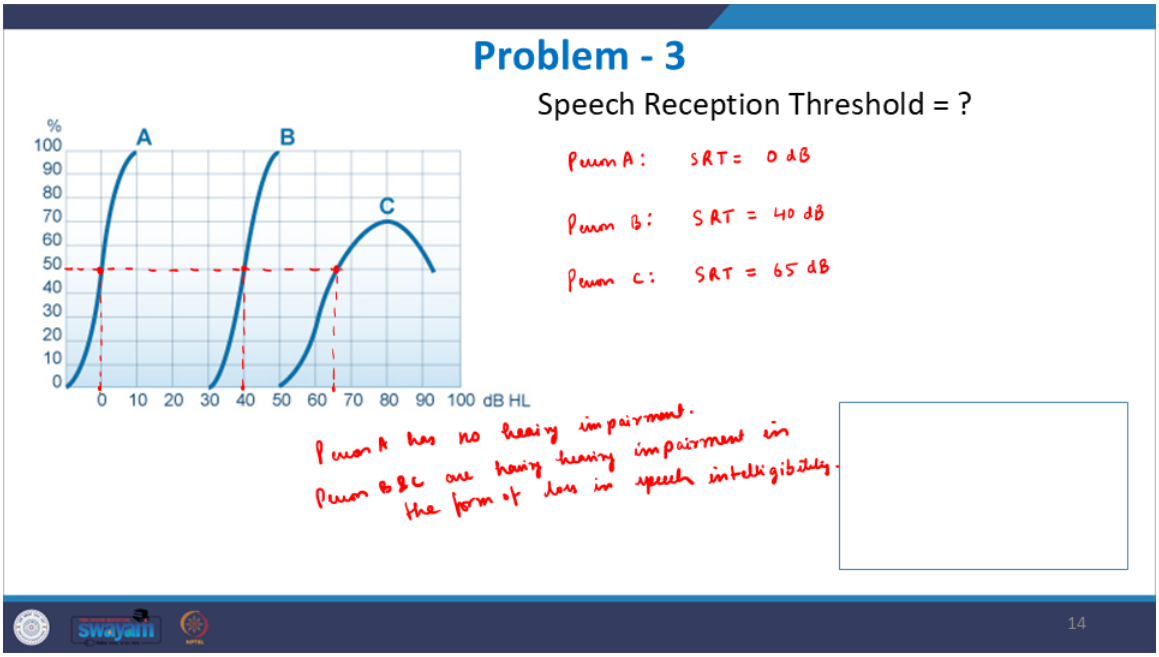


This shows the typical speech audiogram. So, here what you have is the same standard list of words which you will be playing at different levels. So, you have levels at which the same list is being played. Here, 5 dB steps are there; they are not shown just for

clarity, but you definitely have 5 dB steps. And then you are plotting the number of correct responses. So, if suppose it is out of 50, then this is the score in percentage or the percentage of words heard correctly at that particular level. So, the percentage of words heard correctly versus the dB at which these words are played, and as soon as the 50 is reached. The level at which the 50 is reached becomes the SRT. So, this would be what? This would correspond to an SRT of 50, sorry, SRT of 15 decibels. So, this is the minimum level at which the score reaches 50 percent or higher, and so on. You know the 50 dB in the same way; for the 50 dB value, each of these curves can be recorded. Here you can see this corresponds to an SRT of 55 dB So, only at 55 decibels is that person scoring at least 50 percent, able to understand or hear at least 50 percent of the words correctly, and in the same way for this graph, I do a straight line; this becomes an SRT of 70 dB, and in the same way over here, the SRT is obviously not found. So, you know, different curves give you different patterns of hearing loss that has happened. This is a normal curve, a normal hearing curve. This becomes conductive hearing loss, cochlear hearing loss, retro cochlear, and these are some of the clinical terms which actually define, you know, what is the cause behind the hearing loss and what kind of damage has actually happened to the hearing. Okay, so we just saw that, you know, this is the speech audiogram and what it means and what kind of hearing we have.

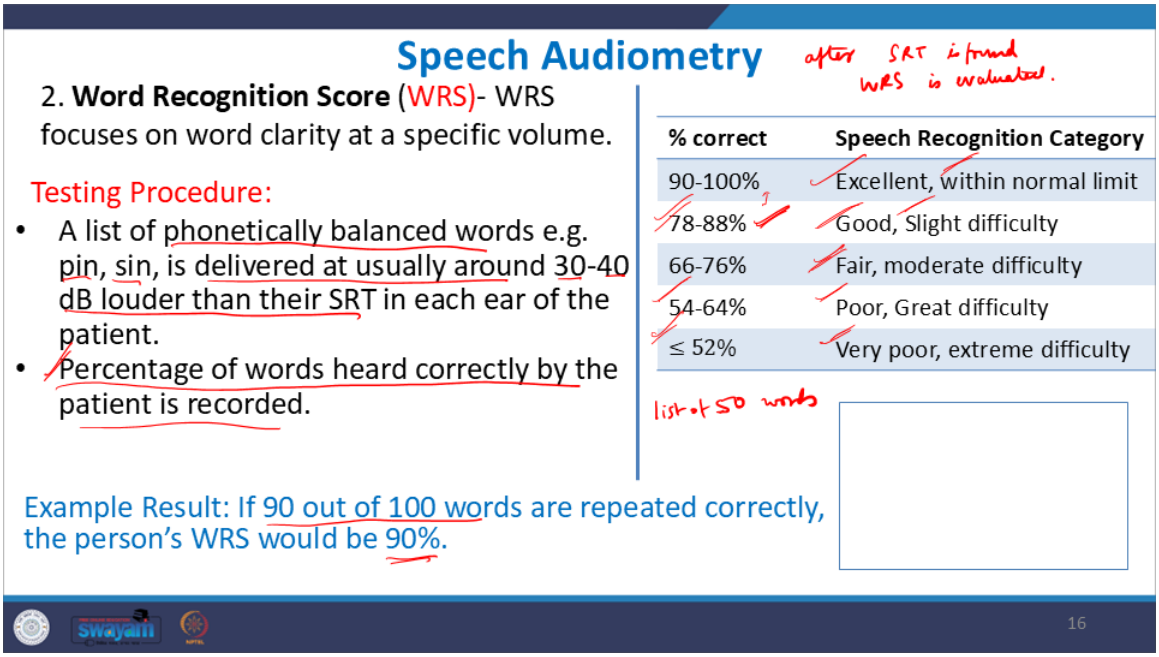


So, let us solve a problem based on this, you know. Let us see, we are given the speech audiogram data of three persons, A, B, and C, and we have to find out what is the speech reception threshold for each of them. So, by definition, it is what? It is the minimum level at which the person is able to understand at least 50 percent of the words correctly. So, how do you find it? You simply draw the line of 50 percent and see where it intersects these curves and see that at what level this 50 percent is reached. So, what you see is that for a normal curve or the person A, the SRT is coming out at 0 dB, for the person B, this SRT is coming out at 40 dB, and for the person C, the SRT is coming out at 65 dB. And what you can deduce from this is that, you know, person A has no hearing impairment, the speech intelligibility is perfectly fine, and person B and C are having hearing impairment. Because anything above 10 dB would be counted as a hearing impairment here. So, B and C are having hearing impairment in the form of loss in speech intelligibility. So, this is the form of their impairment. What is happening? It is loss in the speech intelligibility. Okay, so if you see here, this curve also corresponds to the normal curve, B is the conductive hearing loss, and C is the sensory neural hearing loss curve.



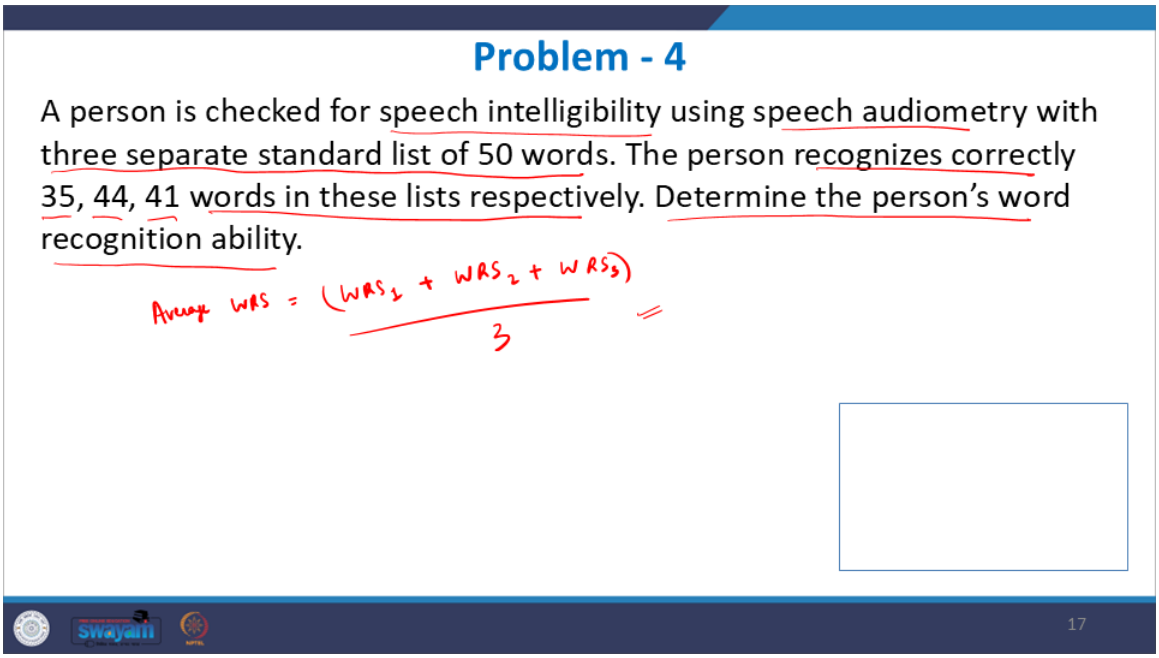
So, there were two kinds of measures. If we saw here in the speech audiometry, if we have to find out what is the speech intelligibility and assess it, we can use a speech reception threshold and, followed by that, we use the word recognition score. So, SRT and WRS are used together. In the case of pure tone audiometry, you know, grading of hearing impairment and percentage hearing handicap, they are complementary, which means that you can either use the grading of hearing impairment or you can use the percentage handicap, whichever measure suits you. But in the case of assessing the speech intelligibility, you need to assess first what is the SRT and then follow that up with WRS. So both of these have to come together to assess the speech intelligibility. So, now that when the SRT has been calculated for the person using this particular procedure and some value has been ascertained, you go ahead and find out what is the word recognition score. So, this happens after SRT is found; WRS is evaluated. So here, what we do is that now we focus on the word clarity at a specific volume. So, in the SRT, you get the data in the decibel levels. Now you will see that at one particular level, how many words they are actually able to repeat back correctly. So, how it is done again in the same setup of audiometry in a darkened and quiet room, the headphones are placed on the person, and using the audiometer again, a standard list of words are played to them, and now we are giving phonetically balanced words having single syllables like pin, sin, etc. and they are delivered usually at a level of 30 to 40 dB louder than their SRT. So, once we have already ascertained what is the minimum threshold at which 50 percent of the words are able to be guessed correctly, these two-syllable words, then now we place a different single-syllable word and Which are more difficult to distinguish, and they are played at a level of 30 dB above the SRT or 40 dB in case their hearing loss or their SRT curve is quite sloped in nature. If it is a normal SRT curve, we give it at 30 dB above the SRT, and then how many words they are able to guess correctly and repeat back, that percentage is recorded, which becomes their word recognition score in percentage. So, suppose we are playing to somebody at SRT plus 30 dB, a list of words, and out of that, 90 out of 100 words they are repeating correctly, then the score is 90%. What is the clinical diagnosis for that? If it is between 90 to 100, it means your speech recognition is excellent within the normal limit. For 78 to 88 percent, it is good, only with slight difficulty. From 66 to 76, it is fair or moderate difficulty. And from 54 to 64, it is poor, which means great difficulty in speech recognition. And less than or equal to 52, it is very poor or an extreme level of difficulty. Now, you see here that there is a gap between these numbers, from 90 to 88, suddenly from 88 to 78 to 76.

So, usually, the word recognition comes as an even number. Why? Because the standard list of 50 words is given. So, 50 words are given to you. So, whatever percentage is, whatever the number of words multiplied by 2 will give you the percentage. So, you are getting an even number. So, WRS is coming out to be an even number, and hence you are able to guess that word. So, WRS becomes even.



So, let's see the problem again, and this is the last problem of this lecture. So let's say a person is being checked for their speech intelligibility using speech audiometry, and three separate standard lists of 50 words are given. So sometimes, to ascertain, you repeat the process again and again, and then you find out what the average score is. You know, just to make the scoring more reliable in nature. So here, the speech audiometry is done, and three separate standard lists of 50 words are given and repeated. So the person recognizes correctly 35, 44, and 41 words in these lists respectively, and you have to find out what the person's word recognition ability is. So here, the WRS test is being repeated three times using a list of 50 words. So, you know, the average WRS would be what? It should

be the average of the scores, you know, the WRS found in the first test, second test, and third test, and the average of them, okay.



So, let us solve it again here. So, the average WRS for that person is going to be The WRS for the first test would be 35 by 50 into 100. So, that gives the percentage of correct words. I am taking 100 as common for the second one, or let us write it like this. Then, for the second test, the WRS score comes out to be 44 out of 50. Then, 41 out of 50 for the third test. Okay, and this data, and then we are doing one-third of that, summing it up to get the average, so this data becomes in percentage. So, let us see, we can directly write it like this also. If we take this as common, then effectively what it becomes is that you are simply doing the average of their scores in the three tests, and then you are finding out the WRS of that. Once you do this, the answer that you get is 80 percent once you solve this. So, what does it mean? What is the diagnosis? It falls in this range: 80 percent. It means that good speech recognition is happening, with only slight difficulty. So, the diagnosis is that, you know, this is their WRS score, and it means good speech recognition ability with only slight difficulty in recognizing words. So, that becomes the diagnosis.

Solution - 4

$$\text{Avg. WRS} = \frac{1}{3}\left[\frac{35}{50} \times 100 + \frac{44}{50} \times 100 + \frac{41}{50} \times 100\right] \%$$

$$= \frac{35+44+41}{3} \times \frac{1}{50} \times 100 \%$$

$$\text{WRS} = 80\%$$

"good speech recognition ability" with only slight difficulty in recognizing words.

So, with this, I would like to close this lecture. Thank you for listening.

Thank You