NOISE CONTROL IN MECHANICAL SYSTEMS

Prof Sneha Singh

Department of Mechanical and Industrial Engineering

IIT ROORKEE

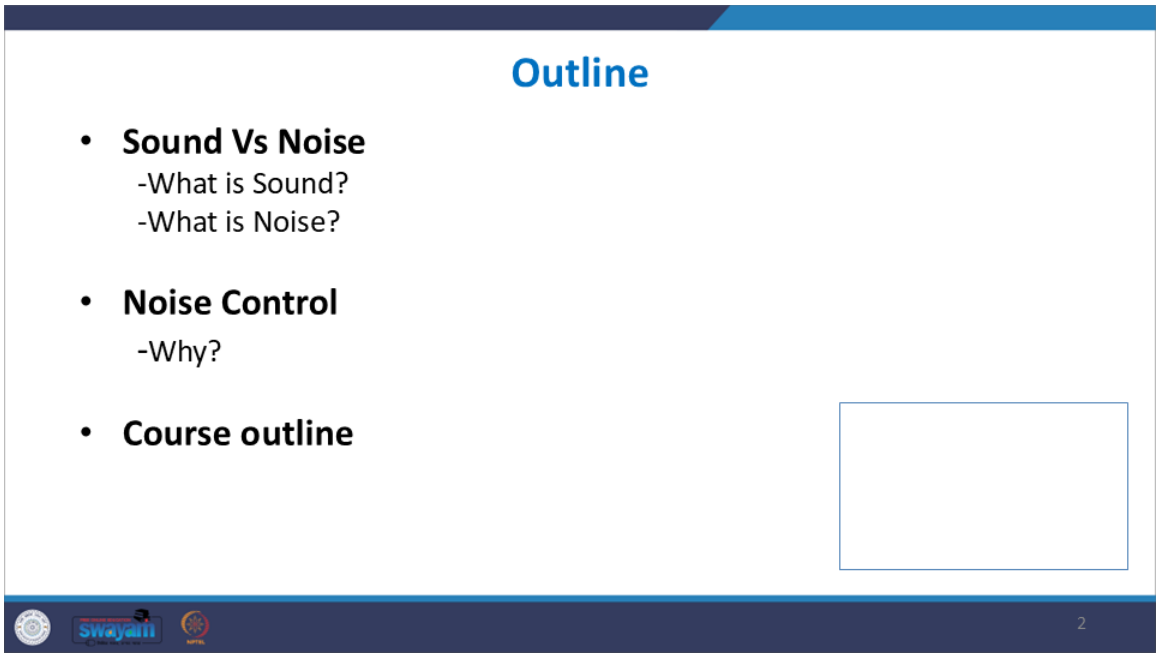
Week:1

Lecture:2

Lecture 02: Sound and Noise

Hello and welcome to lecture 2 in the series on noise control in mechanical systems. I am Professor Sneha Singh from the Department of Mechanical and Industrial Engineering at IIT Roorkee. And in the lecture number two, we will discuss about sound and noise. So, a brief outline, we will be discussing what is sound and what is noise and what form of subjectivity is there in the perception of the two. Then we will discuss about the noise control and what is the need for noise control.

And with that, we will outline our course and the topics that have to be covered in this course.

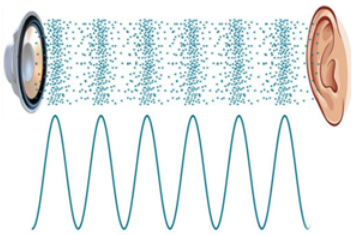


So, let us begin with this. So, what is sound? Obviously, we have covered that in the introductory lecture where we said that sound is a physical phenomenon which is a fluctuation over the atmospheric pressure which is varying with space and time and which is being perceived by our ear as the sound. So, there are various ways in which it is being generated such as the vibration of the objects, the air flow or any other means through which we can create a fluctuation in the instantaneous pressure and that too at a very high rate because typically the frequencies of the sound are quite high.

They are between 100 and 20,000 hertz typically. So, it transmits via the oscillation of the medium particles and very important to know here that this particular physical phenomenon of the sound wave, it is being perceived by our ear as the sound. So, here perception and sensing become very important.

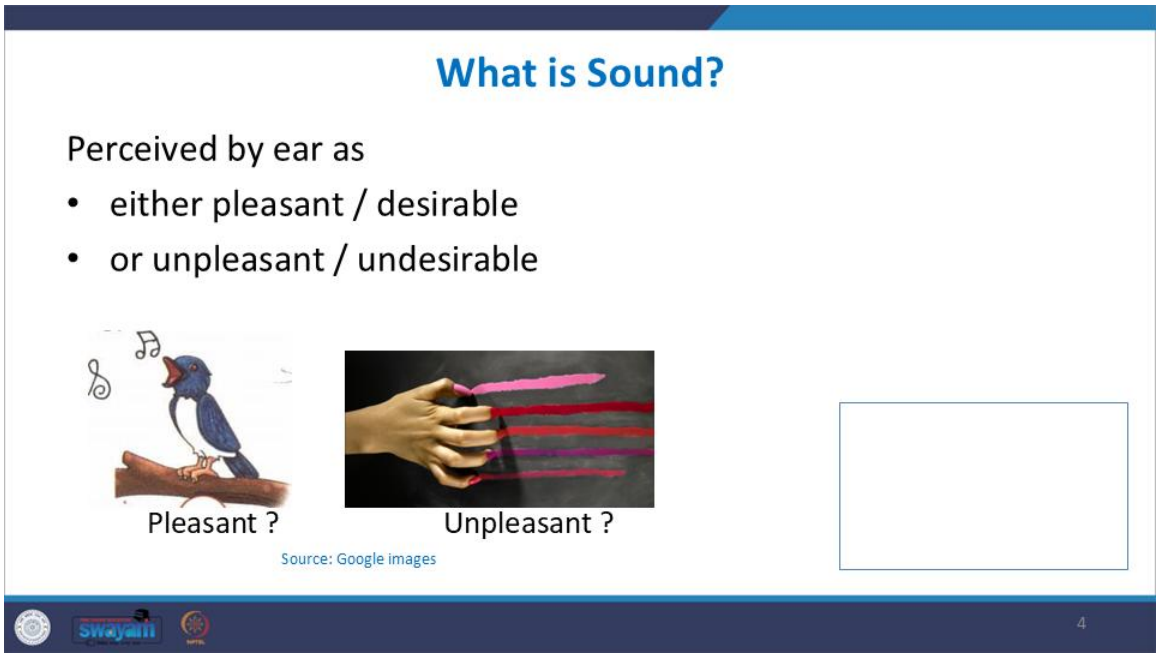
What is Sound?

- Generated by the vibration of objects
- Transmits from one place to another through oscillation of medium particles
- Represented in the form of waves of pressure fluctuation
- **Sensed** by the human **ear**



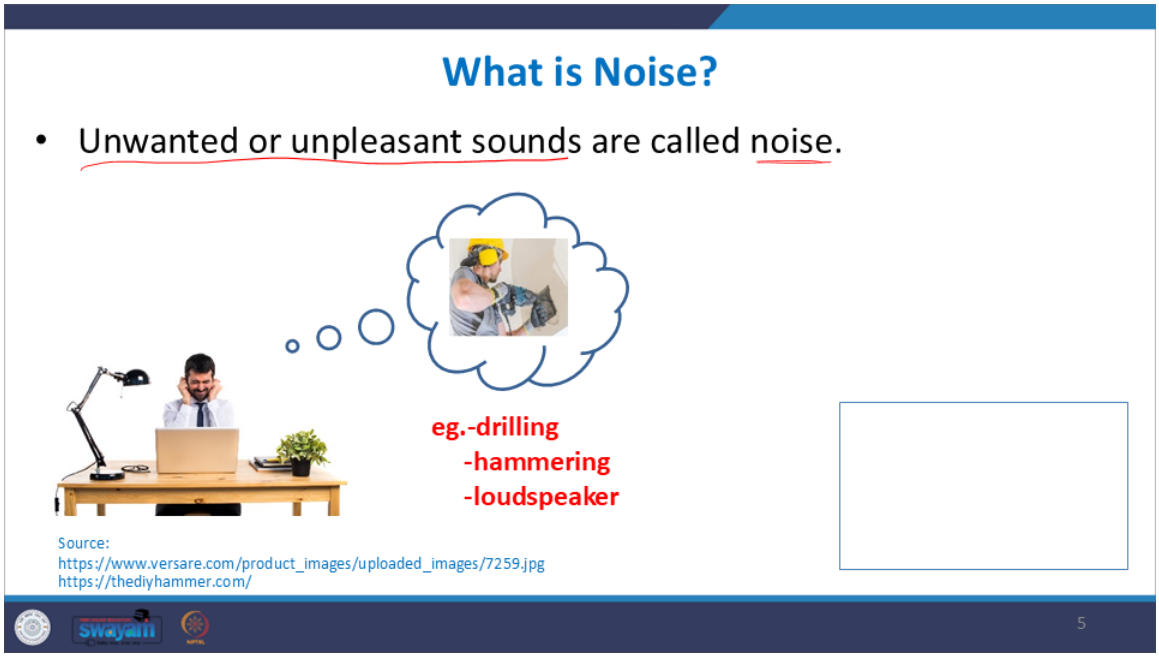
Source: https://warwick.ac.uk/newsandevents/knowledgecentre/science/maths-statistics/maths_and_music/

So, a human now we are receiving the signals of the sound. Now, it is for us to decide whether we like it or we do not like it, whether we find it very loud Whether we find it quiet, whether we find it interesting or we find it boring, whether we find it desirable or undesirable. So what are our response to the signals received by a brain from the ear? So that responses will actually indicate whether this is a pleasant sound, unpleasant sound, whether it is a noise. So, for example, let us see here a bird is tweeting and somebody is screeching on the board with the nails. They both are having the same decibels but still one can be perceived as pleasant whereas the others can be perceived as an unpleasant noise.



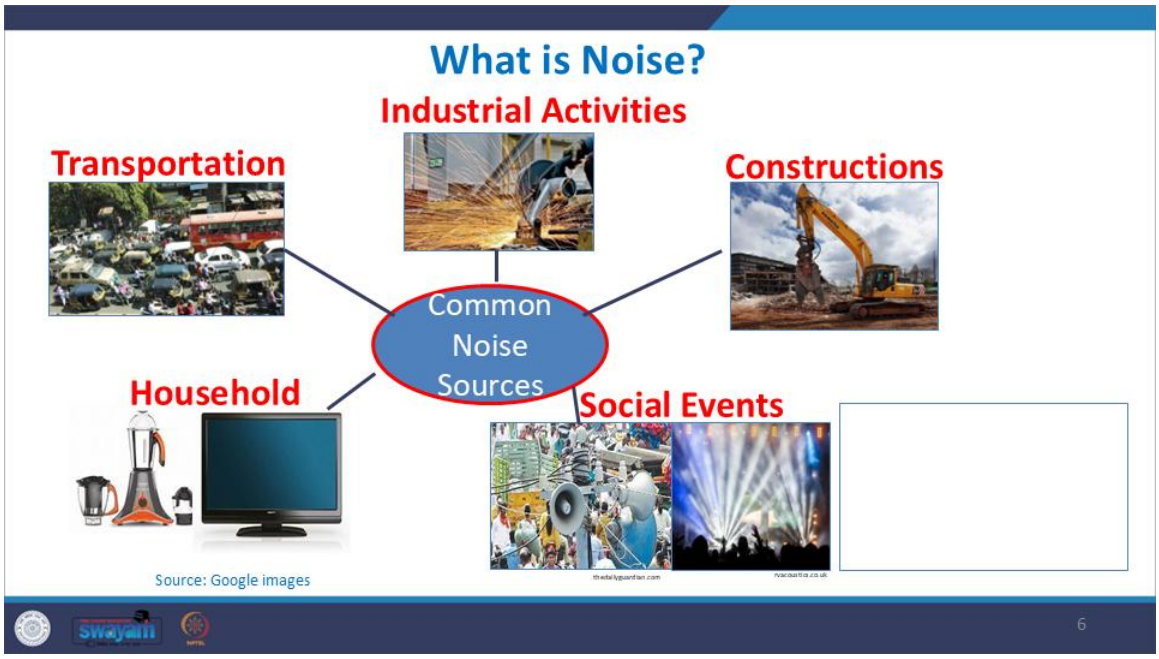
and that is what noise is. It is the unwanted or unpleasant sound which is called as the noise. So with this automatically one thing comes to mind is that it is unwanted or unpleasant. So, what do you mean by unwanted or unpleasant? Do we have some kind of mathematical measurement of that? It's dependent on the human that's receiving that sound. He or she is going to categorize that sound as pleasant or unpleasant. So for them it's noise or not. Now let us say some examples. Let us say I am again going back to a teacher delivering a lecture in a classroom. So, a teacher like me is delivering a lecture in a classroom and there is some construction noise going outside. So, for us because I want to deliver the lecture and the students they want to listen to this lecture. So, my sound I hope becomes desirable. and they want to listen to it, and the construction noise that is going on outside the building, which is interrupting from the listening, it becomes the noise for them, because it is unwanted for those students and for the teacher. So, that activity or that sound becomes noise, whereas things that are happening within the classroom, which are giving the information, such as the teacher delivering the lecture, is not a noise. Now, again in the same context let us say that somehow there is a room nearby where or let us say just next to this classroom is a small nursery of kids where the kids are sleeping. So, for us the construction sound was a noise. The delivering of the lecture was not. In the same context, if we see that the kids who are sleeping in a nursery, which is located very close to the classroom, even the teacher who's delivering the lecture, it's an unwanted sound for these kids. They just want to sleep. They don't want any disturbance. So both the construction

sound. and the sound of the teacher delivering a lecture in the classroom, both of these become a noise for those nursery kids. So, it depends on the context in which the sound is being perceived whether it becomes a noise or not. And for most of the cases when human is doing some activity or doing something.

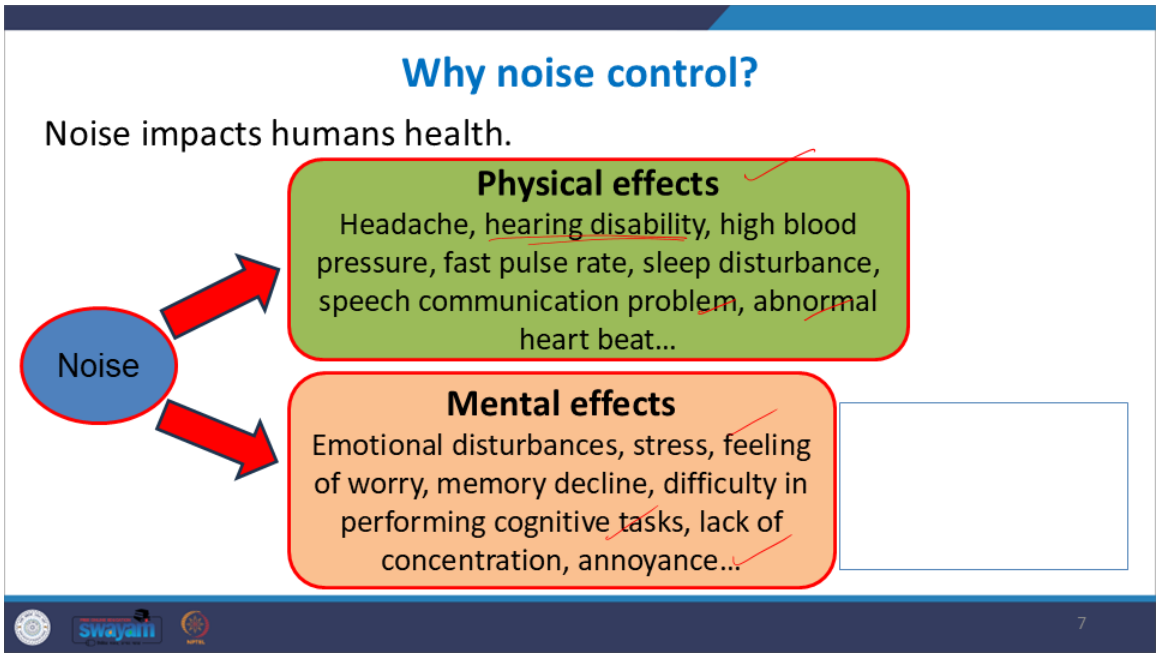


Anything that disturbs them becomes a noise. So, let us see some common noise sources. You have various industrial activities, drilling, construction, building activities. Then you have got the various social events, especially the events that are happening at night when you are trying to sleep. Then the household appliances can also create noise. And the transportation, especially if you are residing next to a busy street or a busy market area, then the transportation has a lot of noise which creates. So again, the context is important. Suppose there are residents who are living in their houses next to this busy road. For them, the traffic sound is a noise, right? But for the people who are in the road Whatever noise that particular vehicle is making is actually necessary because they get the information that the vehicle is arriving. So we cannot have a completely silent road. where the pedestrian is not able to hear the vehicles because that sound is also required there to provide the

information of the state of the vehicle and from where it is approaching. But to a person who is residing in the buildings next to a highway, that same traffic noise then becomes a nuisance. It becomes a noise for them.



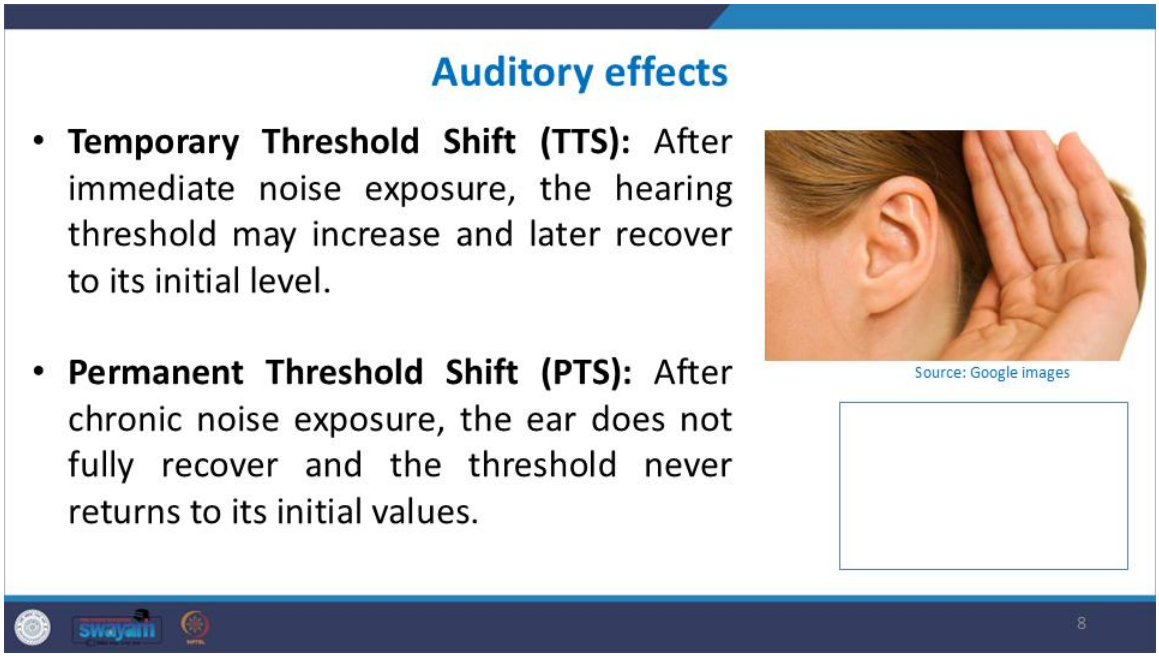
So why to do noise control? Now we are going to establish the context of why we are studying about noise control. Why do we need to control it? Because obviously, you know, noise is annoying, but it has various measurable impact on the human health. There are various physical effects, for example, headache, hearing disabilities, high blood pressure, then fast pulse rate, sleep disturbance. There are various speech communication problems, abnormal heartbeat, various kind of cardiovascular disorders. Then mental effect, you have emotional disturbance, stress, worry. memory decline, difficulty to perform cognitive task, lack of concentration, annoyance, various kind of mental effects as well. Okay, so let us study about some of the auditory effects within this. This is the most important one because obviously we are hearing the sound. So, the very first organ to get impacted should be the ear itself.



So, in the auditory effects, we have the threshold shift. We will discuss a lot in detail about this auditory effects and the threshold shift in our subsequent modules in this lecture series, but this is more of the introduction to the course. So, I will keep it short at this point. So, what it means is that

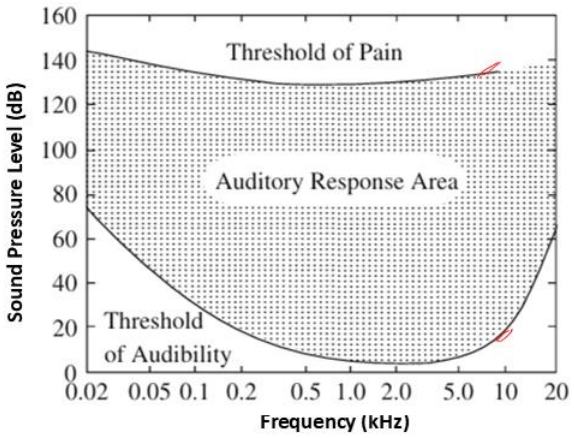
Threshold shift simply means that what is the minimum level of sound which a human ear can hear or sense. Suppose somebody is able to hear a sound as low as 10 decibels or zero. It's a healthy human ear. But if somebody is suffering from some hearing disability, they may not be able to hear quiet sounds. they would say that the person is not able to hear properly right so what is happening there the threshold is increasing for them that is they are not able to hear the sound below a certain level the ear is not functioning properly so that is called as the threshold shift which can happen because of the long-term exposure to noise and there could be temporary in nature or permanent now let me give you an example let's say suppose you went to some concert for a couple of hours and in the concert you know you know the band is playing you have these various the stadium the amplifiers are there and the music is playing really loud you enjoy the vibe etc but when you're coming out of it you will see the ringing in your ear and you may not be able to for a couple of hours or maybe for just 30 minutes or one hour not able to hear this very quiet sounds so you're having a temporary increase in your threshold and then it goes back your ear regains

its normalcy it's not like you went to one concert and you became deaf you would just it's a figure of expression that you're becoming deaf but you're just becoming like your threshold is increasing for a few hours and then it's regaining its original level and it's not causing any permanent damage but if suppose some worker was working in a noisy industry and that too for years and years For every day like 6 to 7 days a week. So, it's a continued long-term exposure and if such kind of continued long-term exposure is there that can lead to a permanent increase in the threshold. So, that will cause you a deafness.



Okay So, this figure illustrates and again the details of this figure we will discuss in our subsequent module where we discuss about human response to noise. So, for this particular lecture I am going to keep it short. So, this shows to you that this is the threshold at which we are able to hear and this is the threshold of pain. So, beyond a certain level we are going to experience pain in our ear.

Auditory effects



Source: Handbook of Noise and Vibration Control. Edited by Malcolm J. Crocker Copyright © 2007 John Wiley & Sons, Inc.

So, again all of this I will be discussing in our subsequent module where all of this is going to make more sense.

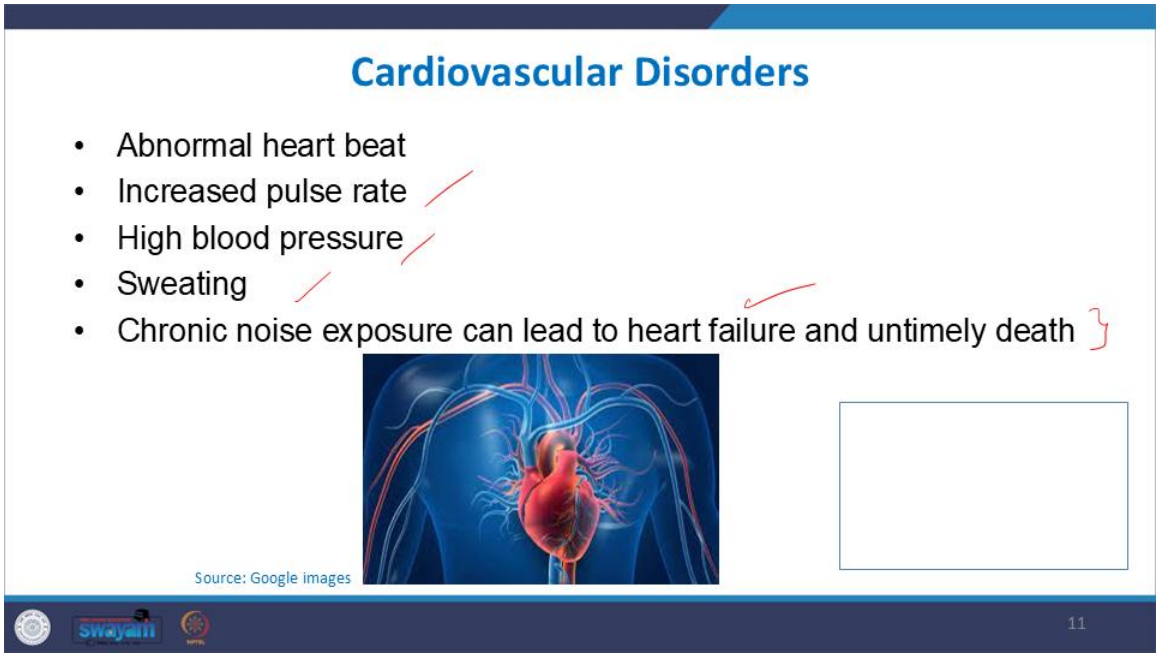
Auditory effects

A-weighted SPL in dB (re 20μPa)		Sound pressure in Pa
Upper threshold for hearing	140	200
Pneumatic chipper at 1.5m	120	20
Textile looms	100	2
Diesel truck 70 km/hr at 15m	80	0.2
Window AC unit at 1.5 m	60	0.02
Whispered speech	40	0.002
Quiet room		
Snowy rural area, no wind, no insects	20	0.0002
Threshold of hearing at 1000Hz	0	0.00002

Rock and Roll band

Lawn mover at operator's ear

Okay, let us come to the cardiovascular disorders. So, other than the auditory disorders which is deafness or increase in the threshold, one of the most common effects of continued exposure to sound or even just immediate exposure to loud noise. could be that it has various cardiovascular disorders such as abnormal heartbeat, increased pulse rate, pressure, sweating and a chronic exposure may also lead to heart failure and an untimely death. Obviously, this probability is very low, but a continued exposure has a chance of doing that to you.



Obviously, people living in the noisy environments, there are various studies which show that they have a much higher blood pressure compared to the people who live in calm and quiet environments. And if this continues, they can lead to stroke, untimely death.

Blood Pressure

- People who live in noisy environments have a greater risk of hypertension comparison to a calm environment.
- High blood pressure consequence can lead to stroke and unexpected death.

So other than the physical effects and obviously, you know, the sleep disorders are also there, which also causes the same, you know, increased blood pressure, headache and various kind of other. physical effects on you the mental effects also are there of chronic exposure to noise you have stress anxiety then annoyance emotional disturbance and depression these can all come with the exposure to you know some or other unwanted sound which is noise.

Mental Effects

- Stress
- Anxiety
- Sleep disturbances
- Annoyance
- Emotional disturbances
- Depression

physical

Source: Google images

Then cognitive effects so again If somebody is involved in some kind of cognitive task and which means that a task where you have to focus and use your brain, a task where you need more mental resources or more attentional resources. Let us say, for example, somebody who's solving a tough mathematical problem. somebody who's attending a tough lecture on physics and solving some brain puzzles or something like that. So, in these kind of cognitive tasks, you need to engage your brain much more on an average than other activities. So, in that case, noise becomes a serious problem. I mean, even slightest of sound can create disturbance the more you need focus the more you need attention the less sound you need in order to focus on that cognitive task and long-term exposure can also have something like impaired learning memory and reading comprehensions decreased concentrations and problem skill also goes down academic performance can go down so obviously in classroom specially you know whenever the architects they are designing these buildings classrooms and these they are paying special attention to the acoustics of the building because all of this need the students to be involved in cognitive task. And as I told as I am going to repeat again that you know a person who is involved in such task needs is more sensitive to outside noise. So, somebody let us say is playing in the playground just playing and having fun in the playground. The small nitty gritties and the small sounds will not affect them so much. But somebody who is solving some tough problem in maths, physics or doing something in the university, writing a book or something, for them even the slightest of noise becomes a problem. So, especially in these areas such as the research centers and the universities, take a special care in the classroom acoustics and make the outside noise dim down.

Cognitive Effects

- Impaired learning, memory and reading comprehension
- Decreased concentration, problem solving skills, and academic performance.
- Reduced cognition performance that leads to decrease human performance, and work productivity.

Source: Google images

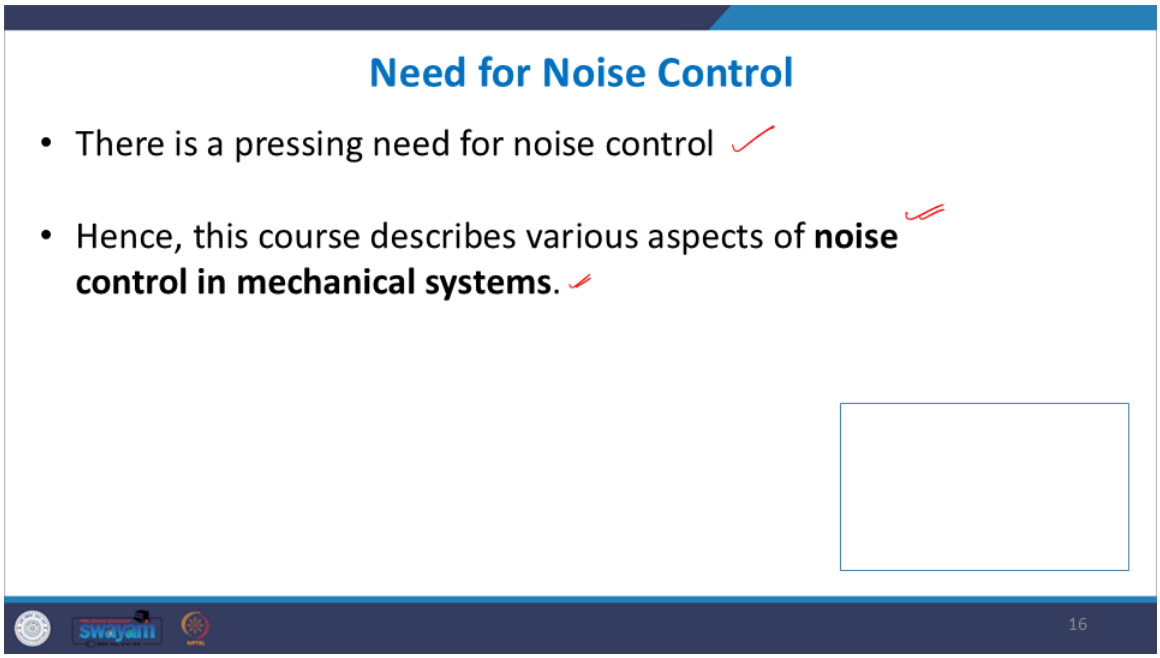
Then the human productivity in such situation will also go down because obviously noise is nothing but a disturbance in their mental and physical tasks. More chances of human error and accidents at the workplace can happen and productivity can overall go down. There could be a decline in the motivation.

Human Productivity

- Speech communication issues and job delays.
- Decline in motivation, reduced performance.
- More human error and accident at work place.
- Lower labor productivity.

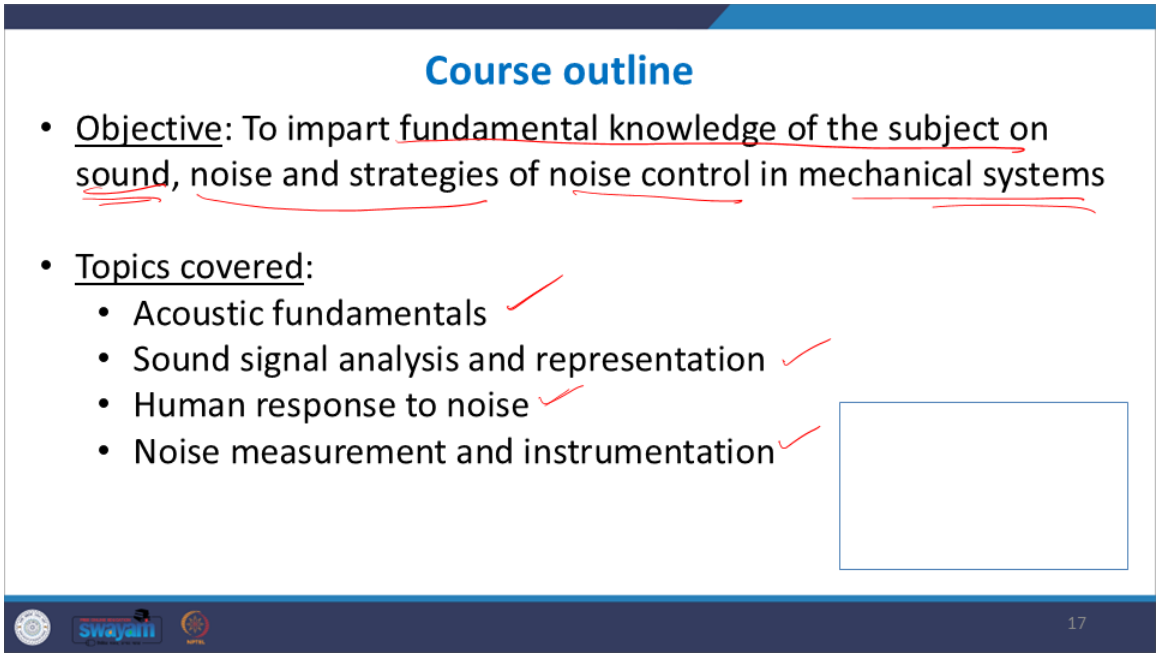
Source: Google images

And all of this then justifies and sets the premise for why do we need a noise control because of all these reasons that are there. So there is a pressing need for noise control and when you Google search, let's say you go and you search on the web of science, you go to the Google Scholar, you see that the number of articles on noise control is increasing tremendously over the kids and especially as the population has risen. There is lot of traffic, there is lot of industries, lot of people, lot of hustle-bustle. So man-made sources of sound have increased and hence the problem of noise pollution has also gone up and all of this justifies and sets the premise for having a course on noise control in mechanical systems and that is what this course is about.



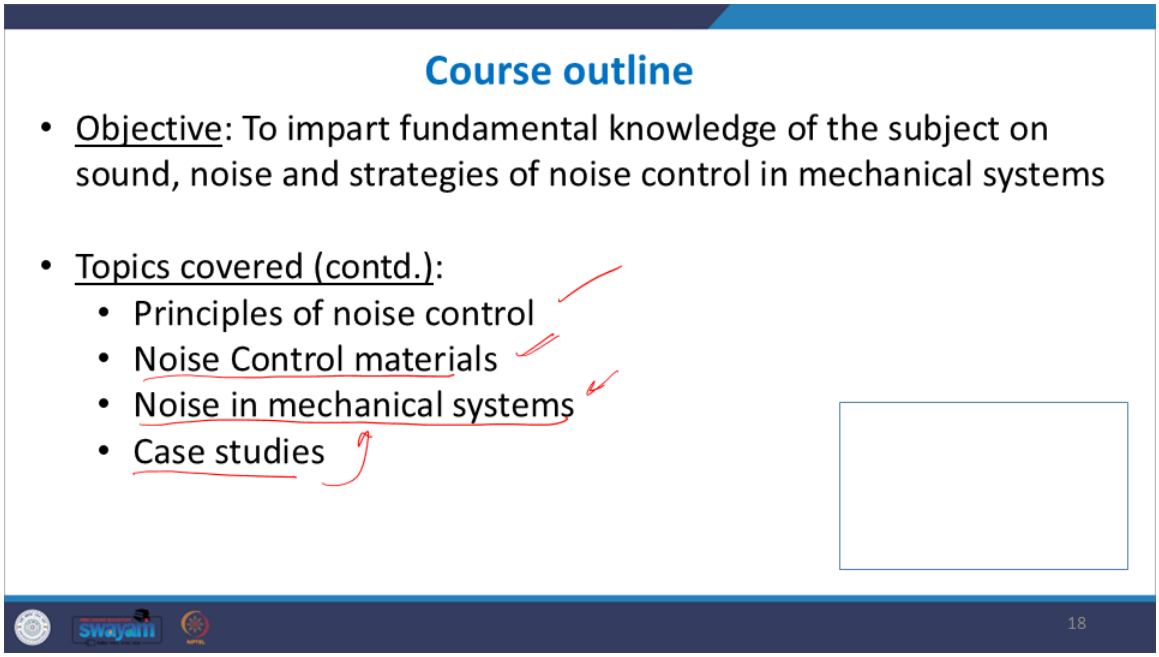
So, the objective of this course will definitely be to impart fundamental knowledge on the subject of sound. how it propagates, what is sound as a physical phenomenon and how it propagates, how it transmits through various surfaces, how it deflects back from the various surfaces and because that knowledge is very important to understand how to control that particular sound. So, the fundamentals of sound propagation will be discussed and various noise and strategies for controlling the noise in the mechanical systems will be done. So, we will begin with the acoustic fundamentals post this lecture and in the fundamentals we will discuss about all the important topics such as transmission, reflection, propagation, the

equations will lot of numerical problems will be solving based on sound wave propagation because as I said again this knowledge is primary so that we understand how to control it. We need to understand the phenomenon so that we know how to control or manipulate it to bring the noise down. So, post this, we will do some sound signal analysis and representation part, where we will see that the same sound, how it is captured and represented in the form of a signal, what kind of time domain, frequency domain analysis is usually done, especially in the industries and by the noise control engineers. Then the human response to noise will also be discussed, where we discuss about You know, what do you mean by loudness, pitch of a sound, then how a human ear perceives the sound, what is the need for having the filters and then what's the need for having noise regulations in India and everything related to the human aspect would be discussed here. Then how the same sound is measured, what kind of instrumentation you need and what are the good measurement practices will be discussed.



Then we will go ahead once all the fundamentals related to noise and sound is clear, we will go ahead and establish the general principles for noise control and we will discuss about the various classifications of the strategies such as active noise control and passive noise control and because I am a passive noise control researcher, so we will go in depth into the passive noise control strategies. So, here we will discuss about the passive noise

control involves the use of materials to control the noise. So, we will discuss about these various noise control materials. We will have a rather elaborate discussion on that and then we will do that what are the sources of noise in the mechanical systems and then some case studies on how to control that very same sources of noise in the mechanical system. So, I hope in all the subsequent lectures you will be able to gain interest in this field and be able to apply this knowledge in the real life as well.



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