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Active Noise Control

Final Report

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Acknowledgements

As students of Novia University of Applied Sciences, we started the project of the European Project Semester (EPS) on the 3rd of September. This report has been prepared for Kaj Rintanen, our supervisor, Roger Nylund and for potential students in according to Active Noise Control (ANC).

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Enjoy reading,

Sannah van Duuren,
Emma Kleijn,
Marie Raynal,
Javier Valentin.

Vaasa, 14th December 2018.

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1. Introduction

The EPS project

The European Project Semester (EPS) is a program offered by eighteen European universities to students who have completed at least two years of study. EPS is a mixture of Project related courses and project organized/problem-based learning. It is to prepare engineering students with all the necessary skills to face the challenges of today's world economy. The students work in small international teams of 3-6 participants. During the project the host university organizes project related courses to support the project group with information about the project and teambuilding activities. (European Project Semester , 2018)

This semester, there are three different projects. The first project is about a 3D printed lawnmower, the second is about Active Noise Control and the third is about Transalgae. The subject from this report is the Active Noise Control.

In this first chapter, a brief introduction of Novia University of Applied Sciences and the team will be shown. Thereafter, the subject, goal, mission and vision of this project will be explained. Also, the build-up of the report will be shown in detail.

Novia University of Applied Sciences

Novia University of Applied Sciences is a University on the west coastline of Finland. It is situated in the Swedish speaking part of Finland. Novia is the largest Swedish speaking university of applied sciences in Finland with over 4000 students on four locations. The vision of Novia is state as "Novia UAS is an important developer of working life and industry near-by the campuses. In their strategic focus areas, they are among the top of the nation and internationally recognized." (Novia, 2018)

The team

We are four students from different nationality and studies around Europe. However, we chose to do a European Project Semester at Yrkeshögskolan Novia in Vaasa. During this semester, we must work together and realize a project.

Let's read the presentation of each people of the team:

I am Javier Valentín Colén and I am from Spain. I am studying Industrial Electronics and Automation Engineering at University of Lleida. I decided to go abroad to do the Erasmus course and specially the EPS not only to improve my English but also because I think that it would be a great opportunity acquire new skills and gain knowledge about a wide range of subjects that would help me not only in my future as engineer, but also in my daily life. I like to face challenges so, staying out from my comfort zone keeps me motivated.

Figure 1: Picture Javier

Figure 2: Picture Marie

My name is Marie Raynal. I am from Tarbes, a city located in the south of France. I study in a mechanical engineering school: ENIT (Ecole nationale d'ingénieurs de Tarbes). So, I'm studying mechanical engineering and manufacturing. I chose to do an EPS semester to improve my English level and discovering new cultures. This semester is for me the opportunity to participate in a multi-cultural and multi-disciplinary project. I chose this project to learn more about the new scientific knowledge available in our lives. Many of my friends have this technology on their headphones, in consequently, I would like to understand how its work. This project is, more or less, a research because the goal of this technology is to implement it in aeronautic. Finland is one of the most distant countries to France with a different culture and climate. My dream is to see Northern lights and cross the Arctic Circle.

Figure 3: Picture Sannah

My name is Sannah van Duuren. I am from Helmond a city located in the south of the Netherlands. I am an industrial engineering and management student at Avans University of Applied Sciences, it is situated in 's-Hertogenbosch. I am in my third year of my bachelor degree. The European Project Semester is my internship. I chose to go abroad for my internship to improve my English writing and communication skills and to work with different cultures together. The subject of the project is something new for me, that is why it is a little bit a challenge to understand everything but it is a great accomplishment if I understand everything after finishing the project.

Figure 4: Picture Emma

My name is Emma Kleijn. I am from the Netherlands and study in the south part of the country. I am an industrial engineering and management student at Avans University of Applied Sciences in 's-Hertogenbosch. I am now in my third year and the EPS (European project semester) is for me an interpretation of my internship period. I chose to go abroad for my internship to improve my English level in speaking and writing. It is an opportunity to develop myself on several levels. To work with different cultures together is new for me. The project that I have chosen is for me a new subject and I find it very interesting, that's why I want to take this challenge.

Subject

The subject of the project is Active Noise Control. ANC is a method to cancel or reduce noises. It is necessary to gather more information about the ANC and to find out what is possible and not.

The definition of the problem is a general lack of knowledge about Active Noise Cancelation. The mission statement is about what is intend to accomplish with the project. The mission of the project is project is to get more overall knowledge for people about ANC. The vision emerged from the mission. Namely, people can understand the principle of standing waves and have basic knowledge about ANC.

The objectives of the project are clearly formulated with the SMART model. This method is used when identifying specific marketing objectives, your long-term goals. When setting future objectives for marketing it is useful to look carefully at each measure and consider if it is essential. The SMART model helps as a test or filter which you can use to assess the quality of the project. (Smart in sights, 2018)

Specific
Give a demonstration to or for other students about standing waves in a tube and show the noise reduction in combination with the beat.

Measurable
Be able to observe the standing waves. One wave around the frequency of 100 Hz, two around 230 Hz and three waves around 340 Hz. Besides this, we need to be able to visualize the noise reduction. This is possible when the waves are gone.

Attainable
With the available equipment, it should be attainable.

Realistic
The Kundt's Tube experiment and ANC system already exists in the market (Headphones).

Figure 5: Smart model

Time limited
It must be finished before the 17th of December.

Project goal

The main goal of this report is to observe the standing wave and reduce the noise. For this project, it should be possible to make a demonstration of the standing waves to the other students and supervisors at the end of the project. Therefore, the team decided to show a wave in a tube, this experiment is called: Kundt's tube. In this case, the wave represents the noise. Then, the objective is to cancel the wave with another speaker if it is turned on. If the system works, standing waves and the destructive interference will be noticeable.

Risk Management

Certain precautions must be followed to avoid several problems during the project. That is why these risks have been studied and analysed. There are two different potential risks: the risks related to the team and those related to the project. The risks related to the team, are dependent on the behaviour of the team-members and the knowledge within the team. On the other hand, the risks related with the project are the consequences of time and experiments.

List of the risks

A list has been created to identify the risks of the project.

Risks related to the team:

- Lack of knowledge
- Low team motivation
- Sickness and traveling
- Languages problems
- Misunderstanding in the group
- Lacks responsibility

Table 1: Risks related to the team

Lack of knowledge	Not enough knowledge about all the subjects that is needed
Low team motivation	Someone is not interested by the project and does not work like the other team members
Sickness and traveling	The absence of a member can affect the progress of the project
Languages problems	Team members can have some difficulties to express themselves in English
Misunderstanding in the group	The work done is not understood by the team members
Lacks responsibility	Someone who does not take decisions

Risks related to the project

- Lack of time
- Availability of the supervisor
- Economics
- Scope is poorly defined
- Resource shortfalls
- Problems with the physical prototype

Table 2: Risks related to the project

Lack of time	If there is not enough time to achieve the desired result
Availability of the supervisor	Support and availability of the project by the supervisor is fundamental
Economics	Not enough money available to buy important materials
Scope is ill defined	The general risk of an error or omission in scope definition
Resource shortfalls	Inability to secure sufficient resources for the project
Problems with the physical prototype	Poorly structured prototype so it presents deficiencies

Probability and effect of the risks

To show the scale of the probability and effect of the risks, three words and colors will be used. The first, the green is the unlikely probability or effect. It corresponds to the word “low”, the risk is acceptable. The orange is the likely probability or effect. To avoid them, an investigation needs to be realized. Finally, the red is the very likely probability or effect. For these, it is necessary to review and investigate the case for removing or reducing the risk.

The probability of the risks and the impact of the risks will be explained by:

low	
medium	
high	

Table 3: Probabilities and impacts of the risks

Risks	Probability	Impact
Lack of knowledge		
Low team motivation		
Sickness and traveling		
Languages problems		
Misunderstanding in the group		
Lack of responsibility		
Lack of time		
Availability of the supervisor		
Economics		
Scope is poorly defined		
Resource shortfalls		
Problems with the physical prototype		

When risks are defined, a risk matrix is done to easily show which risks are the most dangerous for the project. This is the matrix:

Table 4: Risks matrix

Probability	High	Availability of the supervisor	Sickness and traveling	Scope is ill definied
		Lack of knowledge	Language problems Ressource shortfalls	Lack of time Economics Problems with the prototype
	Low	Lack of responsability		Low team motivation Misunderstanding in the group
		Low		High
		Impact		

Table 5: Risks matrix definition

	No risk
	Acceptable as a low risk
	Acceptable as a medium risk
	Acceptable as a high risk
	Completely unacceptable as an extern risk

As the matrix shows the most important risk is that the scope is poorly defined. The other important risks are sickness and traveling, lack of time, economics and problems with the prototype. These risks are in the case where the risk is high. So, the team decided to study the risks to reduce them.

Scope is poorly defined

As the project has been presented as a free alternative to reduce the noise, there are several possibilities from the team to get confused with the objective. The information that the group receives is brief. So, before to start the team make some research about the subject: ANC. The first goal is to reduce a noise in a room, but it is so complicated. With the tutor's agreement, the main goal will be to show standing waves and to cancel them. In each meeting, the secretary wrote a document to explain that the team and the tutor said. In this way, the tutor will be able to guide the team to the correct objectives. Anyway, everybody can contact the tutor or other member team with WhatsApp if something is not clear.

Sickness and traveling

At the beginning of the project, the team-contract has been written by the members of the team. A member of the team may be absent (within reasonable limits) if he/she informs the other members of the team. If one worker is too absent, he/she must inform Kaj and Roger.

Lack of time

The European project semester lasts 4 months, so 16 weeks. The project must be finished for this date. At the beginning of the semester, the team decided to name one person in charge of the planning: the planner. This person makes an agenda visible by the other workers. In fact, each task has a deadline and the team must make it before this expected date. To control that, a final editor was chosen. The team also has a milestone table to see the progress of the project.

Economics

The most important point is the budget. To control it, the team decided to study the project costs. The team will try to spend as little money as possible. The tools and raw materials that the school already has will be used in priority.

Problems with the prototype

If the prototype does not work, the team does not have an experiment to show to the other. The goal of the project is show standing wave for physical classes. To solve that, the team decided to test different ways like glass tube and plastic tube, long tube and short tube, flavour, Styrofoam balls and sand...

It is important to be aware about these risks because they can appear easily, so they need to be detected quickly to take corresponding measures.

Build-up of the report

To make the report as clear as possible to the reader the report is structured in a chronological order. The report consists four major parts with chapters dividing. First, the research and background information are described in five chapters. Chapter 2 is about the history of sound. Thereafter in Chapter 3 the different mechanical waves will be explained extensively. The theory of Kundt's tube will be discussed in Chapter 4. In chapter 5 the beat phenomenon is explained. In the last chapter of the research and background part the topic noise reduction is discussed in more detail, this can be found in Chapter 6.

The second part of the report is about the equipment. This part is divided in three chapters. Chapter 7 is about searching for the right substance. After that the accessories of the experiments will be discussed. In the last chapter of this part there is written about how to find the right tube, this can be found in Chapter 9.

In the third part of the report, the experiments will be explained. It is divided into two chapters. In chapter 10 there can be read about the Kundt's tube experiments. The last

chapter of the third part is Chapter 11. It is about the variants of Kundt's tube. In this chapter, the cancelation experiment and the results of the beat phenomenon will be discussed.

Project management and accountability report is in the fourth part of the report. In this chapter, the project management of the project will be described.

In chapter 12 is the conclusion. In the conclusion, there is a look back at the report. Besides that, the results of this project will be discussed. In the last part of the project is the critical reflection of the team and a personal reflection of the team members. This reflection is in Chapter 13.

Ⅰ Research and background information

In this main chapter of the report the research and background information is combined. This information is gathered during the project. It contains mostly theory about topics that have a connection with sound. The introduction of sound, mechanical waves, Kundt's tube, beat phenomenon and the noise reduction will be discussed.

2. Introduction of sound

In this chapter, the introduction of sound will be described. It will be an introduction for the subject sound. In the first part the unit of sound and how to study the diagrams of sound has been described. The second part of this chapter is about the history of sound cancellation.

Measure of sound

There are different types of sound measurements: dB, dB(A), dB(B), dB(C) … The decibel (dB) is used to measure sound level. It is connected to the intensity with the formula:

$$Number\ of\ decibels\ (dB) = 10\log(\frac{I}{I0})$$

I: Noise intensity studied

I_0: Reference noise (Hearing for a normal ear: about $2x10^{-5}$ Pa)

To measure the noise intensity in dB, it is necessary to put a microphone near to the studied sound and convert the noise in current. The dB logarithmic unit is used to describe a ratio. The ratio may be power, sound pressure (the measures that are used in this project), voltage or intensity. However, these decibels are not the reality (just the experiment measure) because, the human ears do not perceive the frequencies like a device. For example, a sound will be perceived differently, even if there is the same intensity but two different frequencies. This graphic shows that the ear sensibility is not the same according to the frequency.

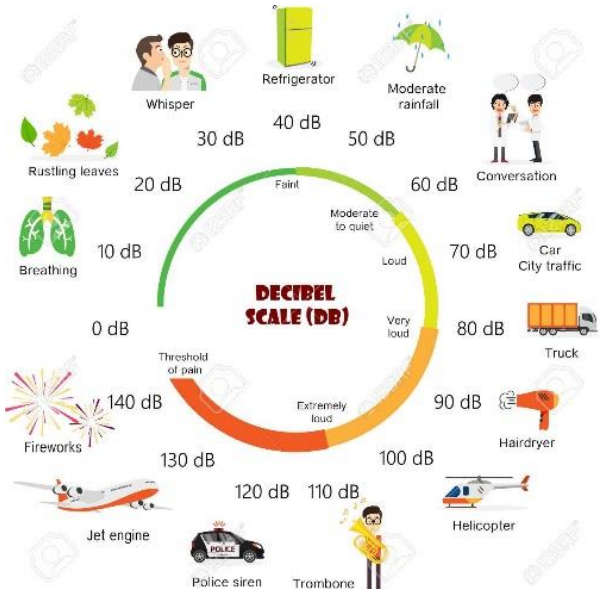


Figure 6: Decibel scale

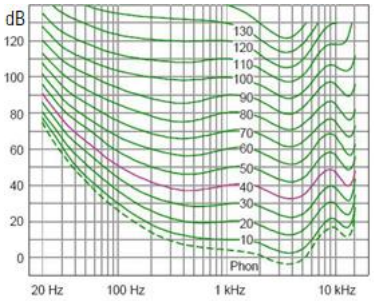


Figure 7: Equal-loudness contour

These curves are set to “phons”. By definition, the number of each curve (phons) is equal to the corresponding intensity in decibels at a frequency of 1000Hz. In fact, the higher the frequency, the higher is also the sound pressure.

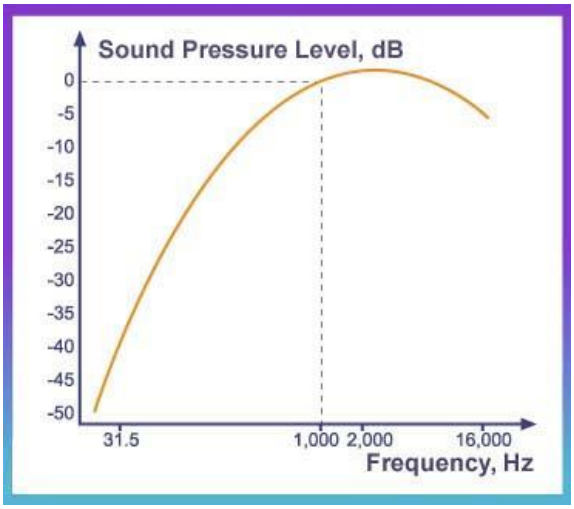


Figure 8: Frequency is plotting against sound pressure level

Therefore, the scientists have decided to create different varieties of dB to measure the sound intensity perceive by the human ear. The dB(A), dB(B), dB(C), (the most well-known) … are obtained when the scientists use a filter to simulate the human ear. But it is impossible with just one filter to reproduce the ear’s performance knowing that each person is different. To represent this, the weighting curves have been created.

The dB(A) is a filter which permit to reproduce the performance of ear for the 40dB at 1 kHz. This filter is best suited for this project, because the sound level is less sensitive to very high and very low frequencies. Therefore, it is the most used.

The graphic shows the performance of the different filters.

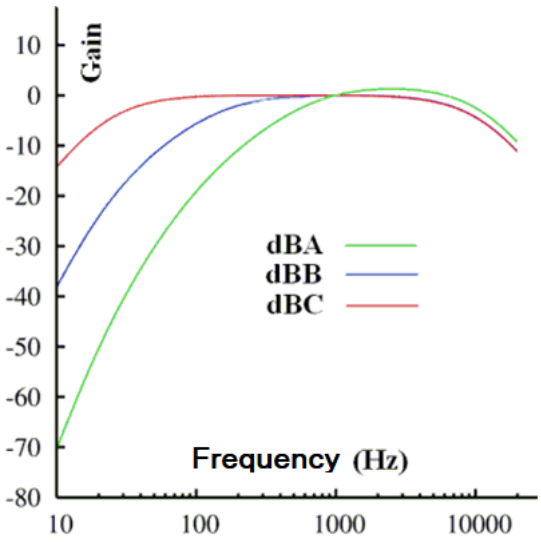


Figure 9: Frequency is plotting against gain

Table 6: Several filters

dB	dB(A)	dB(B)	dB(C)
Intensity	Low (< 55 dB)	Average (55-85 dB)	High (> 85 dB)

A normal human ear is able to hear sounds with frequencies from 20 Hz to 20.000 Hz. The range of 20 Hz to 20.000 Hz is called the audible frequency range.

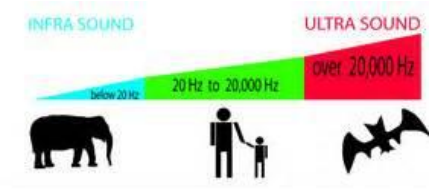


Figure 10: Frequency spectrum

The entire audible frequency range can be divided into 8 or 24 frequency bands known as octave bands or 1/3 octave bands respectively for analysis. A sound or noise can be seen to be having different strengths or sound pressure levels in the frequency bands, as illustrated by the following diagram.

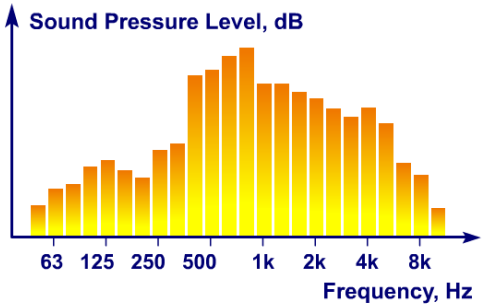


Figure 11: Sound pressure level is plotting against frequency

This form of diagram that is shown below is used to study and analyse the noise of the engine in this project.

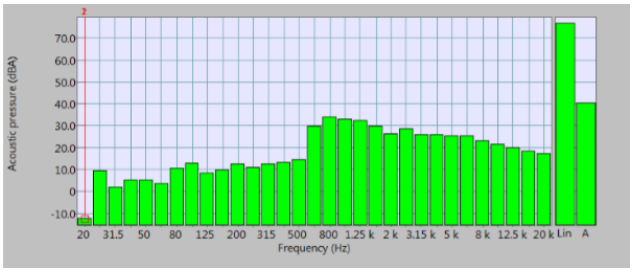


Figure 12: Sound pressure level is plotting against frequency experiment

Moreover, during the study, the team also analysed another graphic: the amplitude spectrum. This spectrum shows many aspects of the signal. An analyser display, like that of an oscilloscope has two axes. For the spectrum analyser, the vertical axis displays amplitude, whereas the horizontal axis displays frequency.

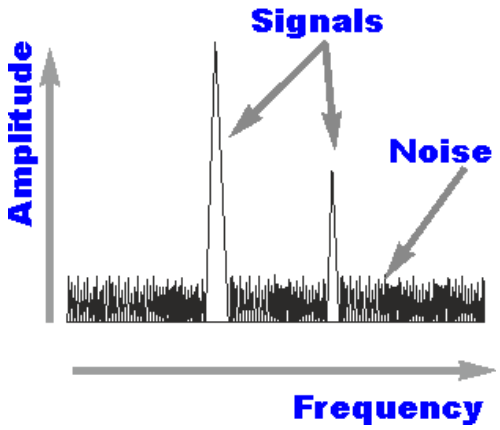


Figure 13: The amplitude spectrum

When this spectrum is used, and more than one peak can be displayed (so several frequencies), the sound is not pure, it is complex.

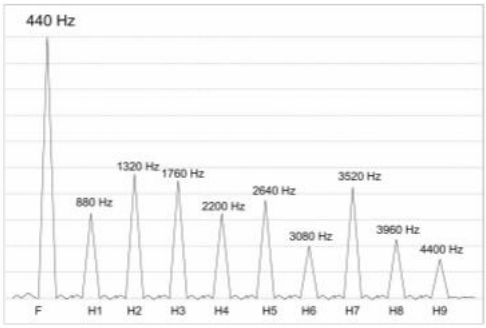


Figure 14: Example of complex sound

Thanks to the Fourier method, the complex sound can be broken down in several pure sounds.

The first peak, and the highest is named the fundamental frequency (in this case the 440 Hz) or the first harmonic frequency.

Then, the other peaks are the harmonic frequencies. They are multiples of the fundamental frequency. Indeed, the second harmonic frequency corresponds to 2x the fundamental frequency is 880 Hz. The third harmonic frequency corresponds to 3x the fundamental frequency is 1320 Hz. Etc.

The Fourier series corresponding to f(x) is defined by:

$$\frac{a_0}{2} + \sum_{n=1}^{\infty} \left(a_n \cos \frac{n\pi x}{L} + b_n \sin \frac{n\pi x}{L} \right)$$

$$\begin{aligned} a_n &= \frac{1}{L} \int_{-L}^{L} f(x) \cos \frac{n\pi x}{L} \mathrm{d}x \\ b_n &= \frac{1}{L} \int_{-L}^{L} f(x) \sin \frac{n\pi x}{L} \mathrm{d}x \end{aligned}$$

Where a_n and b_n are the Fourier coefficients

Note that the trigonometric functions cosinus and sinus are from period $\frac{2L}{n}$, so the frequencies are the multiples of $\frac{n}{2L}$.

$\frac{a_0}{2} = \frac{1}{2L} \int_{-L}^{L} f(x) \mathrm{d}x$ is the average of f(x) on a period

For a signal (like the sound), the function with the x variable and 2L period will used. With the signal theory, it is possible to use the temporary variable t and T for the period (T= 2L). The period is the inverse of the frequency, so: $f = \frac{1}{T}$. f is the fundamental frequency of the signal.

Then, $\frac{n\pi x}{L}$ become $\frac{2n\pi t}{T} = 2\pi n f t$ and $\frac{a_0}{2} = \frac{1}{T} \int_{-T/2}^{T/2} f(t) \mathrm{d}t$

a_0 is named the continue component.

$a_n \cos() + b_n \sin()$ are named the n^{th} harmonic.

History of sound cancellation

The first observation of sound cancellation was noted in 1878 by Thompson using two Bell telephones, however it was not until 1930 that the idea of sound cancellation by destructive interference was documented and patented. Over 20th century diverse scientists have built systems to achieve that goal, but due to limitations in availability of electronic control hardware and in control theory made that even the slightest change in the environment affecting the sound field conducted to the instability in the system. All those inconveniences prevented this technology from being commercialised. It was not until the 90s that was reported regular implementations outside the laboratory, as example systems to reduce helicopter and aircraft cabin noise. That transition from the laboratory to mass production has taken a long time, partly because of time needed to develop sufficiently powerful signal processing electronics, partly because the lack of understanding of physical principles involved and partly because the multi-disciplinary nature of the technology. (Hansen C. N., 2002)

Nowadays sound cancellation is used in a wide variety of applications like, active noise cancelation on headphones, industrial air handling systems and large office building air conditioning systems, gas turbine exhausts or diesel engine exhausts, control of plane wave sound propagation in air handling ducts or reduction of tonal noise in propeller driven aircraft using active engine mounts and vibration actuators mounted on the fuselage rings. (Hansen C. H., 2005)

Figure 15: Air-conditioning systems

Conclusion

In conclusion, there are many ways to measure and describe the sound. The Fourier series is more common in the field of mathematics and physics and shows the difference between the fundamental and the harmonics frequencies. For the sound cancellation, the team learned that this process exists since 1878, and the use of the technology increases. Indeed, in aeronautic, the engineers want to develop it (for example to reduce the engine noise).

3. Different mechanical waves

In this chapter, the mechanical waves will be explained. Thereafter, the two different mechanical waves, longitudinal and transverse waves, are being discussed. With longitudinal waves, a distinction is made between traveling and standing waves.

Figure 16: Mechanical wave

Mechanical waves are a fundamental physical aspect of the movement of physical objects, whether these objects are solids, liquids or gases. A mechanical wave is a disturbance traveling through a medium (solid, liquid or gas). A source of energy is needed to disturb matter and start a mechanical wave. Besides this, a carrier or a mid-substance is also needed for the wave because the energy can only travel through matter. Once the initial energy is added the wave travels through the medium until all its energy is transferred. The wave is caused by these vibrations. An example of this is a wave on the water surface or a wave in a rope. In this type of waves, the materials that integrate the medium do not move far from the initial point, energy is transported through the medium, however, the disturbance passes the material it returns to the initial state. The medium propagates faster in solids and liquids than in gases because of the proximity in the particles. The amplitudes of the mechanical waves are measured in an unusual way. Namely, displacement (v) divided by wavelength (λ).

There are two mechanical wave types that will be discussed: longitudinal waves and transverse waves. These will be discussed in the next paragraphs.

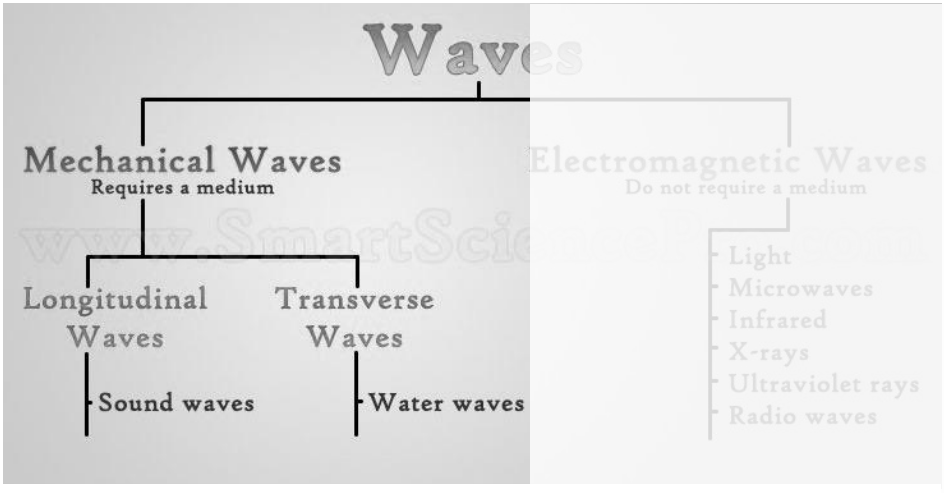


Figure 17: Different waves

Longitudinal waves

A longitudinal wave consisting of a periodic disturbance that takes place in the same direction as the advance of the wave. Each particle of matter vibrates about its normal rest position and along the axis of propagation, and all particles participating in the wave motion behave in the same manner. The combined motions result in the advance of alternating regions of compression and rarefaction in the direction of propagation. That's why, those are also called compressional or compression waves. Sound moving through air are compresses and rarefies the gas in the direction of travel of the sound wave as they vibrate back and forth.

With a coiled spring that is compressed at one end and then released experiences a wave of compression that travels its length, followed by a stretching then a point on a coil of the spring will move with the wave and return along the same path, go through the neutral position and reverse its movement.

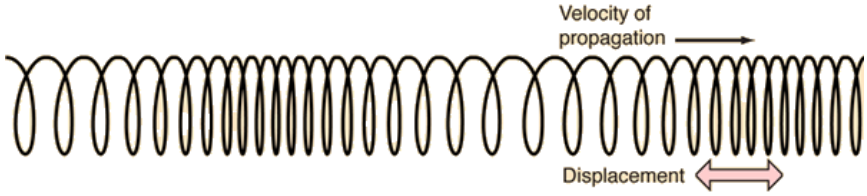


Figure 18: Longitudinal wave

Standing waves

A standing wave that is also known as a stationary wave. A stationary wave is a wave which oscillates in time but whose peak amplitude profile does not move space. This peak of the wave oscillations at any point in space is constant with time. The oscillations at different points throughout the wave are in phase. The points at which the amplitude is minimum are called nodes, the points where the amplitude is maximum are called antinodes. This can be occurred because the medium is moving in the opposite direction to the wave. It can also rise in a stationary medium because of interference between two waves who are traveling the opposite direction. The most common cause of standing waves is the resonance. Standing waves occur inside a resonator due to interference between waves reflected and forth at the resonant frequency.

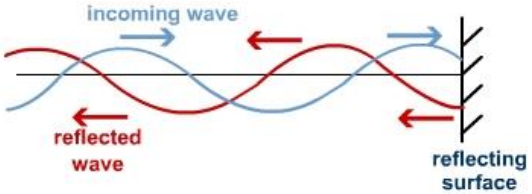


Figure 19: Standing wave

Travelling waves

A travelling wave is a temporary wave that creates a disturbance and moves along the transmission line at a constant speed. Consequently, it is a special type of spatiotemporal oscillation that is a periodic function of both space and time. This wave occurs for a short duration but induce a much disturbance in the line. The transient wave is set up in the transmission line. Travelling waves have a fundamental role in many mathematical equations.

Travelling waves are observed when a wave is not confined to a given space along the medium. The most common observed traveling wave is an ocean wave.

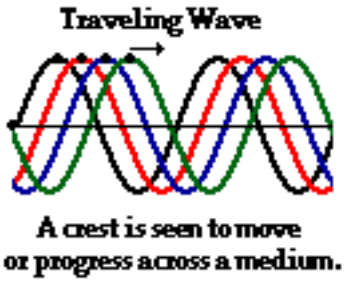


Figure 20: Travelling wave

Transversal waves

Transversal waves consist of waves that contain oscillations perpendicular to the direction of propagation. After a period in transversal waves can be observed that all particles pass by all states of vibration. The displacement of the medium is perpendicular to the direction of propagation of the wave. Here the formation of the crest and trough takes place. There are always two directions that are independent of each other that can be used as the direction of the wave. The typical example of a transverse wave is a wave that propagates in a rope. Transverse waves may occur on a rope, on the surface of a liquid, and throughout a solid. The waves cannot propagate in a gas or liquid because there are no mechanisms for driving motion perpendicular to the propagation of the wave.

If a point in the wave is observed during a period, it can be observed that all points in the same phase vibrate at the same time and are ranged at a wavelength. The wave motion itself has the shape of a sinus- of cosiness function, this is called a harmonic wave.

The biggest difference of the transversal and longitudinal waves is the propagation direction.

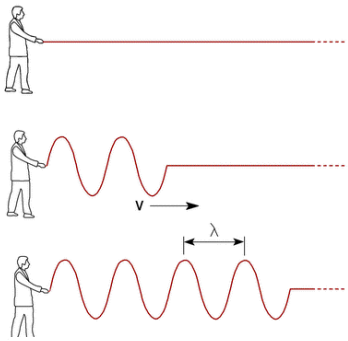


Figure 21: Transverse waves

Conclusion

In this chapter, it has become clear that there are two mechanical waves namely, longitudinal and transverse. The biggest difference between longitudinal and transverse waves is that with transverse waves the displacement of the medium is perpendicular to the direction of propagation of the wave. With longitudinal waves the displacement of the medium is parallel to the direction of propagation of the wave.

4. The Kundt's Tube experiment

The theory

Kundt's tube is an acoustical apparatus invented in 1866 by German physicist August Kundt. The goal is to measure the speed of sound and show the standing waves. This experience is used to demonstrate longitudinal standing waves, the wavelength and acoustical forces. (Wikipedia, 2018)

This method consists to create a standing wave in a circular tube, a pipe. The big tube permits to measure the low frequencies whereas the little tube measures high frequencies. The big diameter (100mm) measures between 90 Hz and 1900 Hz, the other between 800 Hz and 6500 Hz. The used pipe has a diameter of 100mm, so it is a big tube. This tube contains a fine powder. At the end of the tube, there is a loudspeaker which converts the sinusoidal signal in a sound wave. The loudspeaker is the sound source for this experience because it sends especially accurate frequencies, called resonance frequencies. Kundt's tube can be used two ways: opened or closed. The tube could be closed by a piston. It should be insert in the tube without touching it. The difference between opened and closed tube will be explained in the next part.

To calculate the resonance frequency, some corrections on the diameter will be used.

For a closed-closed or open-open tube: $\lambda_n = \frac{2}{n}(L + 0.8d), n = 1, 2, 3, \ldots$
where L is the length of the tube and d is the diameter.

For a closed-open tube or tube open on one side: $\lambda_n = \frac{4}{n}(L + 0.4d), n = 1, 3, 5, 7, \ldots$
where L is the length of the tube and d is the diameter.

A standing wave is present in a tube because there is one incident wave (send by the loudspeaker) and one reflexive wave. When the end of the tube is closed, the wave is reflexive by the piston. On the other hand, when the tube is opened, the reflection results in the different impedance. The acoustic impedance is the measure of the opposition that a system flow resulting of an acoustic pressure applied of the system. (Wikipedia, 2018)

So, in the opened tube there are 2 waves that spread: incident wave: $\Psi 1 = Ae^{i\phi 1}\, e^{i(\omega t + kx)}$ and reflexive wave $\Psi 2 = Are^{i\phi 2}\, e^{i(\omega t - kx)}$ (with A the amplitude, r the reflexion coefficient = 1, $\omega = 2\pi f$ and $k = \frac{n\pi}{L}$, L the length of the pipe.

$$\Psi(x,t) = \Psi 1 + \Psi 2 \; = A\, e^{i\phi 1} e^{i(\omega t + kx)} + Are^{i\phi 2}\, e^{i(\omega t - kx))}$$

$$\Psi(x,t) = \mathcal{A} e^{i\left(\omega t + \frac{\phi_1 + \phi_2}{2}\right)} \left(e^{i\left(-kx + \frac{\phi_1 - \phi_2}{2}\right)} + e^{i\left(kx + \frac{\phi_2 - \phi_1}{2}\right)}\right)$$
$$= 2\mathcal{A} e^{i\left(\omega t + \frac{\phi_1 + \phi_2}{2}\right)} \cos\left(kx + \frac{\phi_2 - \phi_1}{2}\right)$$

A relation between the wavelength exists, the frequency and the velocity of the sound.

$$\lambda = \frac{v}{f}$$

λ is the wavelength (m/s)
v is the velocity of the sound (340 m/s at 15°c) (Wikipedia, 2018)
f is the frequency (1/s or Hz)

Thanks to this relation, the frequency in the tube and the wavelength of the emitting wave are linked. In a certain case, when the tube is open, the wavelength is equal at the length of the tube. This phenomenon will be explained in the next part.

The experiment

The protocol

To show the standing wave, the team decided to try the experiment of the Kundt's tube. To make this experiment work the following protocol is used:

- Take a pipe (in glass or Plexiglas) and put some powdered in it,
- Link the signal generator and the loudspeaker,
- Spread uniformly the powder inside the pipe,
- Fix the pipe,
- (Introduce the piston to the other end of the pipe),
- Generate signal with the signal generator,
- Move the piston in and out of the pipe till the resonance is obtained.

With this kind of wave some vibration would be observed. It is possible to see the resonance and the formation of the standing waves.

Figure 22: Wave in a tube

On the side of the loudspeaker, there is a node because the speaker's membrane vibrates and constitutes a region of maximum displacement. A node (in orange) is a point along a standing wave where the wave has a minimum amplitude (constant pressure). It is fixed. The opposite of the node is an anti-node (in green), a point where the amplitude of the standing wave is a maximum. This happens between two nodes.

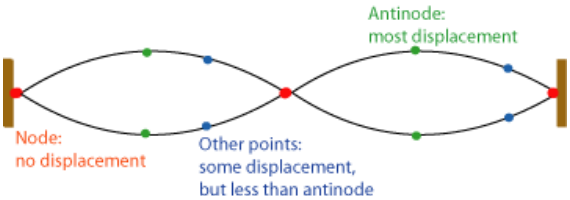


Figure 23: Node and antinode

Kundt's tube closed

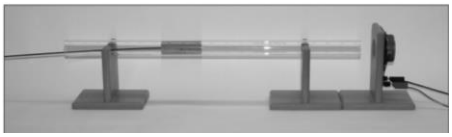


Figure 24: Kundt's tube closed

The tube is named "closed" if one of the two end is closed (figure 24). The loudspeaker is located at the open end. The resonance and the formation of the standing waves can be seen when one node was created in the close end and an anti-node was formed in the open end. When the tube is closed, the moving of the air is non-existent, an anti-node is created. If there is only one of each (one anti-node and one node), ¼ of one wave is observed.

In a particular case, when $L = \frac{\lambda}{4}$, one anti-node and one node is created.

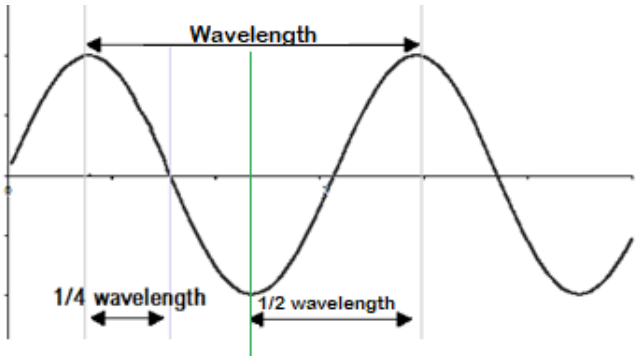
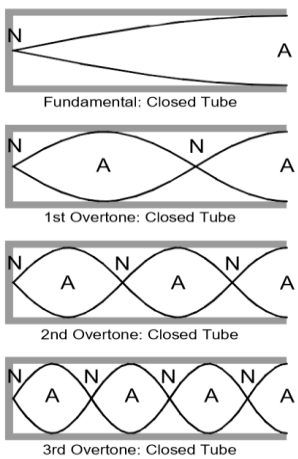


Figure 25: Wavelength

Then, there is a piston to change the distance between the end of the tube and the loudspeaker.

Table 7: Waves in a closed tube



¼ wavelength

¾ wavelength

5/4 wavelength

7/4 wavelength

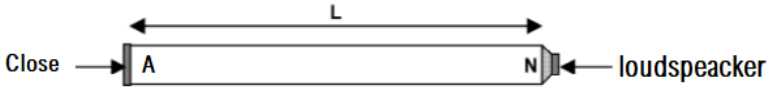


Figure 26: Closed tube L=λ/4

Kundt's tube open

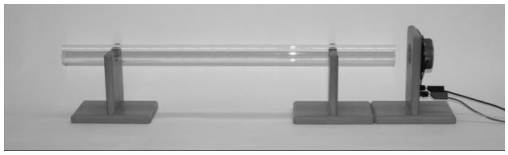
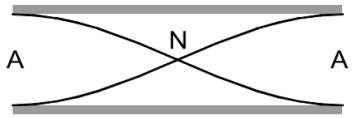
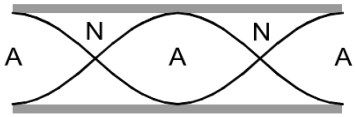
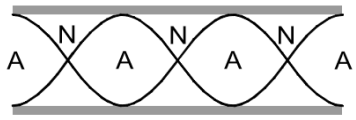
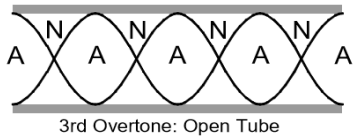


Figure 27: Kundt's tube opened

The tube is named "opened" if the two ends are open. The loudspeaker is located at one of the open ends. The resonance and the formation of the standing waves would be seen when two nodes were created at the two-open end. When the tube is open, the pressure is constant (atmospheric pressure), a node is created. The formation of the waves does not depend of the piston but the length of the tube.

Table 8: Waves in an opened tube

	½ wavelength	$L = \frac{\lambda}{2}$
	1 wavelength	$L = \lambda$
	3/2 wavelength	$L = \frac{3\lambda}{2}$
	2 wavelength	$L = 2\lambda$

In a particular case, when $L = \frac{\lambda}{2}$ one anti-node and two nodes are created.

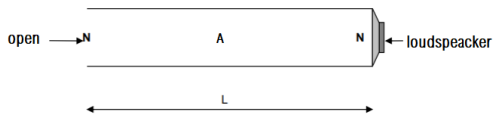


Figure 28: Opened tube L=λ/2

Conclusion

This experiment shows the standing wave in a tube with a substance. There are two different ways to try this experiment, opened or closed, the results are different. In the next part, the experiment will be implemented.

5. Beat phenomenon

During the experiment to cancel the noise, a phenomenon was perceived. The team members heard a strange periodic sound. That is why, some extra research was needed. In the next part, the theory about the beat will be explained.

Theory

After searching on internet, the observed phenomenon is the beat. In acoustic, a beat is an interference pattern between two sounds of slightly different frequencies, perceived as a periodic variation in volume whose rate is the difference of the two frequencies. (Wikipedia, 2018) The beat is the result of the superposition of two waves with the same amplitude and close frequencies. For instance, two waves of equal amplitude are travelling in the same direction. The two waves have different frequencies and wavelengths, but they both travel with the same wave speed. The below graphic shows the amplitude variation.

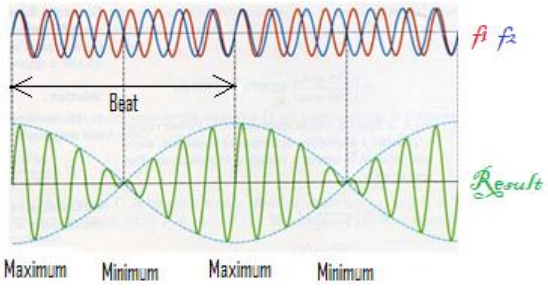


Figure 29: The beat phenomenon

In green is represented the addition of the two close frequencies. It is possible to see maximum and minimum point. The maximum point is a result of the superposition of the two amplitudes that are in the same point at the same time. The superposition is the addition of two sinusoidal standing waves amplitude. In this case: $Yt = y1 + y2$

On the other hand, the beat is the time between two maximum points. The period between two beats is described by the frequency. In fact, the frequency and the period are linked, because $f = \frac{1}{t}$ (f the frequency (Hz) and t the time (s)). The beat frequency can be calculated by: $fb = |f1 - f2|$ The beat frequency is the number of beat by second.

For example:

$$f1 = 240\ Hz$$

$$f2 = 241\ Hz$$

$$fb = |240 - 241| = 1$$

$$t = \frac{1}{1} = 1s$$

In this case, the beat phenomenon can be heard every second.

For example:

$$f1 = 240\ Hz$$

$$f2 = 243\ Hz$$

$$fb = |240 - 243| = 3$$

$$t = \frac{1}{3} = 0{,}33s$$

In this case, the beat phenomenon can be heard every 0,33 seconds.

Consequently, the beat phenomenon is a periodic modulation of a signal consisting of the superposition of two near frequency waves.

Simulation

To demonstrate the theory explained in the previous part a script has been designed (Annex 4). This script allows the user to learn what happens when two signals of different frequency are added. Also permits to change the phase of signal to determine how this change affect to the result obtained.

Results

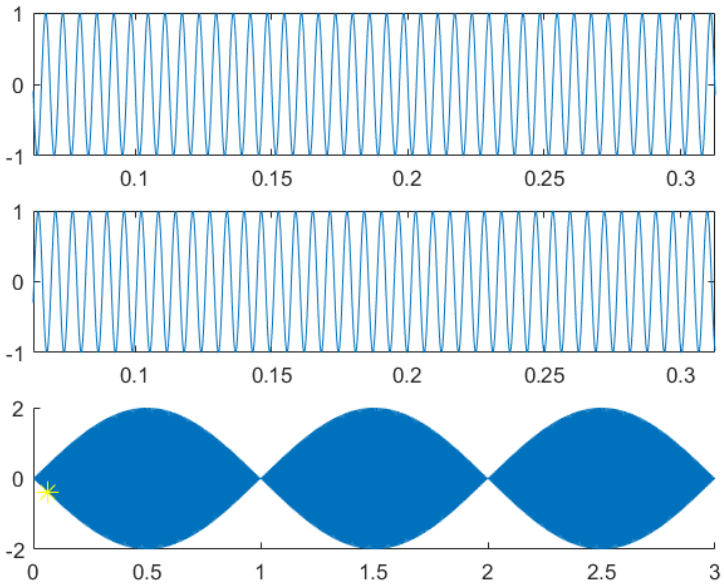


Figure 30 :Results for Ch1=160Hz, Ch2=159Hz

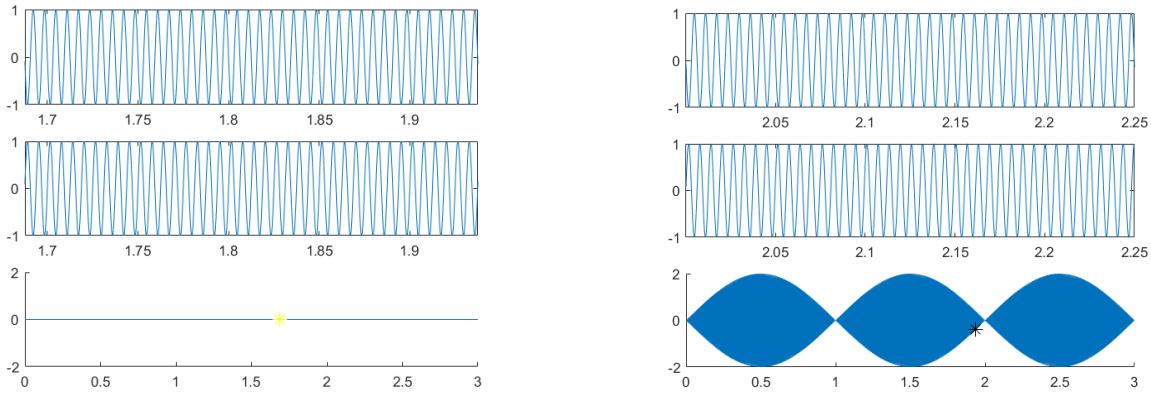


Figure 31: L: Results for Ch1=160Hz, Ch2=160Hz; R: Results for Ch1=160Hz, Ch2=161Hz

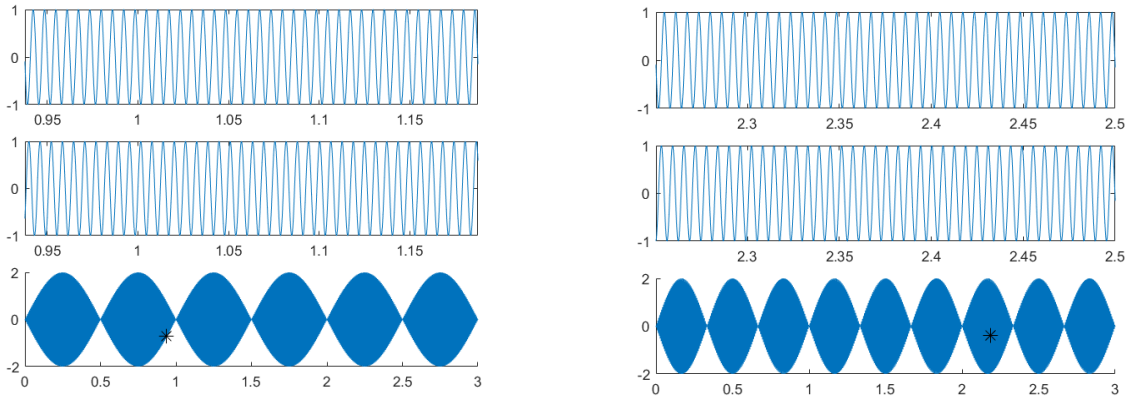


Figure 32: L: Results for Ch1=160Hz, Ch2=162Hz; R: Results for Ch1=160Hz, Ch2=163Hz

Conclusion

Results obtained for the simulation correlate completely with the results expected from theory. It is easily detectable that when the difference between two channels is 1Hz, then 1 beat is obtained in 1 second. The same happens for 2Hz, 2 beats are detectable in 1 second. This relation is linear. The most remarkable data is when the same frequencies are added, in that particular case signal obtained is zero, that means that cancelation has been produced.

6. Noise reduction

This chapter is about noise reduction. Noise reduction is a process of removing noise from a signal. The topics that will be treated are the three different noises, the Electronic control system and the Active Noise Control. Thereafter the companies who are active in this industry will be discussed.

Different noises

There are three different noises: the incidental noise, the passive noise and the active noise. These three methods can be implemented: creating a sound barrier between the source of noise and a listener, reducing the energy of noise near a listener and reducing the power of a noise at its source.

Passive Noise

The passive noise is the noise that can be reduced by noise-isolating materials. There are lot of materials to reduce the outside noise (and not cancel the noise) such as insulation, silencers, vibration mounts, damping, mufflers and sound-absorbing tiles. For example, on the headphone, the shape is very important. Indeed, this method is based on the shape of the headphone ear cups (to cover the ears) and how it fits over the head determines to a large degree how much noise the headphones can block out. The disadvantage of it is the bulk. The goal of the passive noise control is to prevent the spread of noise by converting acoustic energy into thermal energy. However, this method can often be limited to canceling frequencies above 1 kHz (high frequencies). (Learning about electronics, 2018)

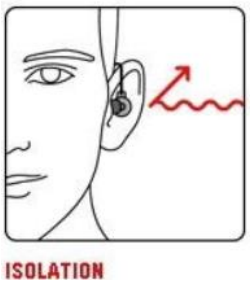


Figure 33: Passive noise

Active Noise

Many problems about the low frequencies are dominates, so the scientists decided to develop the active noise control. The active noise is the noise that it can reduce with a power source in emitting an opposite wave. The goal is to cancel the undesired noise whereas the other methods are to reduce the sound.

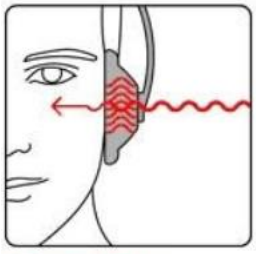


Figure 34: Active noise

This second wave emitting must have the same amplitude as the first, but with the opposite sign. This wave is created by an electronic circuitry and generated by a microphone. The principle of the active noise control is to cancel out the noise around user by emitting a second wave (destructive interference).

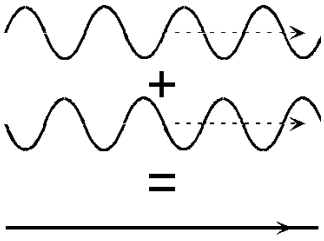


Figure 35: The destructive interference

The active noise control is described for the first time by Paul Lueg in a patent in United States in 1936. He decided to measure the waves travelling in a pipe with a microphone and then transmitting an appropriate signal to secondary loudspeaker so that the superposition of the both waves. He discovers the destructive interference. When two opposite sinusoidal waves add up, the result wave be as good as zero. It is the destructive interference. Two waves are called opposite when one point of one wave is at its maximum and the wave other at its minimum. (Phys-uconn, 2018)

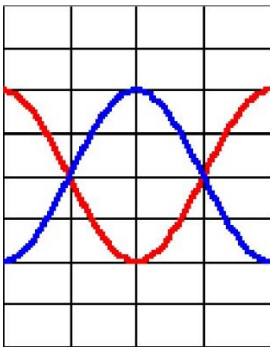


Figure 36: Opposite wave

Incidental Noise

The incidental noise cancellation is the most basic method to use headphones and earbuds. This method reduces the effect of the noise around user by introducing music or other sounds into the ears. This kind of method is the less expensive. (Dextroaudio, 2018)

Conclusion

The traditional approach to acoustic noise control uses another sound or passive techniques such as noise-isolating materials to attenuate the undesired noise. On the other hand, the active noise control system attenuates low-frequency noise here passive methods are ineffective or very expensive and bulky. The active noise control permits to block low frequency (the frequencies that are met in real life) below 1 KHz, for example, engine noise or noise from aircraft. This mainly led us to focus this project on the Active Noise Control.

Electronic Control System

In this section, the necessary parts to build the Electronic control system and the characteristics that shapes them will be discussed. The three major components to build an Electronic control system with ANC as an objective are: a digital filter, an adaptive algorithm and the design of a system to connect the previous two parts.

Adaptive control filters

Adaptive control filters are designed to generate a control signal output to the reference signal input. The control signal is fed to a control source that generates the cancelling sound. The control filter takes discrete samples of current and past reference inputs, multiplies them by a set of coefficients or weights, and adds the results to produce an output sample. The values

of the filter weights determine how the reference signal is modified by the control filter to produce the required control output. To drive the loudspeaker, consecutive output samples are converted to an analogic signal using a reconstruction filter.

The control filter may take several forms, the most common of which is the finite impulse response (FIR) filter. This will be described in the next section. (Hansen C. N., 2002)

Finite Impulse Response (FIR)

In this type of filter, the response to any finite length input also has finite duration, because it settles to zero in finite time, in the case of an impulse response (output in response to an Kronecker delta input) lasts exactly N+1 samples before it settles to zero.

The basic structure of a FIR filter:

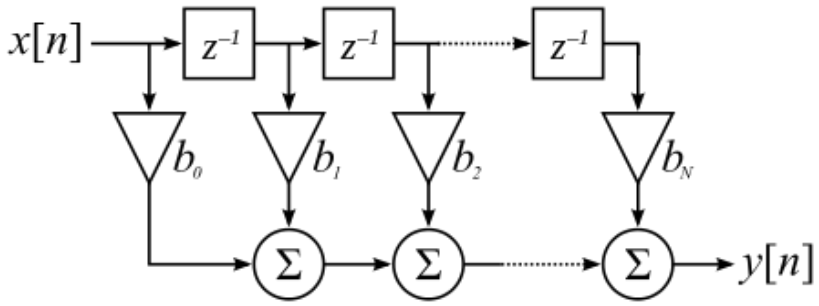


Figure 37: Basic structure of Nth-order discrete-time FIR Filter

Which is defined by the following equation:

$$y[n] = b_0 x[n] + b_1 x[n-1] + \cdots + b_N x[n-N] = \sum_{i=0}^{N} b_i \cdot x[n-i]$$

$x[n]$ is the input signal,

$y[n]$ is the output signal,

N is the filter order, an Nth-order filter has (N+1) terms on the right-hand side,

b_i is the value of the impulse response at the ith instant for $0 \leq i \leq N$ of an Nth-order FIR-filter.

Finally, the equation rewritten as the transfer function:

$$H(z) = \sum_{k=0}^{N-1} h_k z^{-k}$$

Some important properties that the FIR filters have are:

- They do not require feedback, that mean that rounding errors are not compounded by summed iterations.
- Very stable, since the output is a sum of a finite number of finite multiples of the input values, can be no greater than $\sum|b_i|$ times the larges value appearing in the input.
- The input signals and the output signals fulfil the linearity property. That mean that if the output represents the sum of two input signals then the same result is obtained from filtering the two signals separately and then sum the results.

(Wikipedia, Finite Impulse Response, 2018)

Infinite Impulse Response (IIR)

The main difference between IIR filters and FIR filters is that Infinite Impulse Response filters are recursive, depend on previous output values. In the case of an impulse after the initial instant it will not return to zero.

The basic structure of an IIR filter:

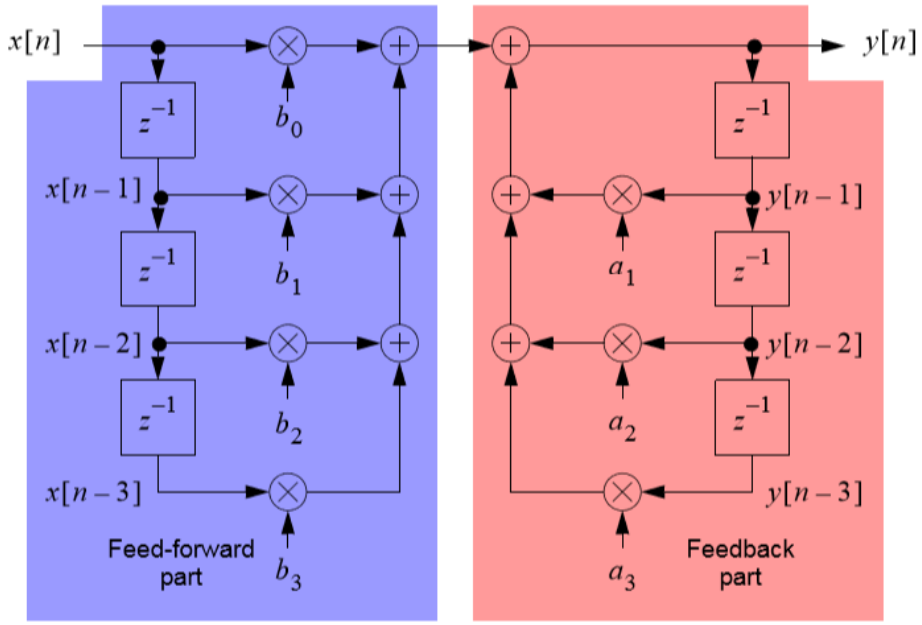


Figure 38: Basic structure of an Nth order IIR filter

Which is defined by the following equation:

$$y[n] = \frac{1}{a_0}\left(\sum_{i=0}^{P} b_i x[n-i] - \sum_{j=1}^{Q} a_j y[n-j]\right)$$

Which transfer function can be written as:

$$H(z) = \frac{\sum_{i=0}^{P} b_i z^{-1}}{\sum_{j=0}^{Q} a_j z^{-j}}$$

In most of the cases the coefficient a_0 will be considered as 1 so can be rewritten as:

$$H(z) = \frac{\sum_{i=0}^{P} b_i z^{-1}}{1 + \sum_{j=1}^{Q} a_j z^{-j}}$$

(Wikipedia, Infinite Impulse Response, 2018)

Difference between FIR and IIR filters

In this table below the differences between the FIR and the IIR filters are displayed.

Table 9: Difference between FIR and IIR

	FIR	IIR
Impulse response	Finite number of no zero values.	Infinite number of no zero values
Output	Depends only on the input	Depends on input and output
Recurrent	No	Yes
Computational needs	Higher	Lower
Stability	Cannot become unstable	Can become unstable
Efficiency	Less efficient	More efficient
Design	Easier	Harder

Adaptive Algorithms

The adaptation algorithm component of the controller is responsible for tuning the digital filter weights so that the resulting control signal minimises the error signal received by the controller. To achieve the task adaptive filters, require three inputs:

- The error signal corresponding to the sound level where the sound is to be minimised;
- The reference signal;
- The electroacoustic impulse response between the electrical input to the controller source and electrical output from the error sensor.

Adaptive algorithms used to optimise the FIR or IIR filter weights in active noise are derivations of algorithms used in systems such as telephone echo-cancellers and adaptive optics in telescopes. There are two types of algorithms that will be explained in the next sections.

Last mean square algorithm

It is based on a stochastic gradient descent method in that the filter is only adapted based on the error at the current time unlike descending gradient in which all samples must be processed before updating a parameter in the iteration, consequently is faster to use the stochastic gradient descent method.

The basic idea behind LMS filter is to approach the optimum filter weights, by updating the filter weights in a manner to converge to the optimum filter weight. The algorithms stats by assuming small weights and, at each step, by finding the gradient of the mean square error the weights are updated. That is, if the MSE-gradient is positive it implies, the error would keep increasing positively, if the same weight is used for further iterations, which means we need to reduce the weights. In the same way, if the gradient is negative, we need to increase the weights

This type of algorithm can be summarized as:

Parameters:

$p = filter\ order$

$\mu = step\ size$

Initialisation:

$\hat{h}(0) = zeros(p)$

Computational:

$For\ n = 0,1,2, \ldots$

$$x(n) = [x(n), x(n-1), \ldots, x(n-p+1)]^T$$

$$e(n) = d(n) - \hat{h}^H(n)x(n)$$

$$\hat{h}(n+1) = \hat{h}(n) + \mu e^*(n)x(n)$$

This algorithm never will achieve exact values of the coefficients, instead it will oscillate between optimal values. That is why it is required to choose an μ that fit the problem because if it is too big it will change the sign of the gradient on each iteration and produce a not optimal oscillation. On the other hand, if the steep size is too small the convergence time will be extensive. (Wikipedia, Wikipedia LMS, 2018) (Hansen C. N., 2002) (MSc. Fabián Jiménez López, s.f.)

Normalized LMS

Normalized last mean squares is a variant of the LMS algorithm that solves the problem of choosing a learning rate μ that guarantees stability by normalising with the power of the input.

This type of algorithm had the same equations as LMS but:

$$\hat{h}(n+1) = \hat{h}(n) + \frac{\mu e^*(n)x(n)}{x^H(n)x(n)}$$

Where the optimal learning rate is:

$$\mu_{opt} = \frac{E[|y(n) - \hat{y}(n)|^2]}{E[|e(n)|^2]}$$

ANC Algorithms

Standard adaptation algorithms cannot be used due to the existence of the secondary path. However, the influence of the secondary path on the performance of any standard adaptation algorithm can be compensated for if the reference signal is filtered using an estimate of the secondary path. This compensation mechanism results in a new range of adaptation algorithms referred as filtered-x adaptation algorithms. The basic of which is the Filtered-x Least Mean Square (FxLMS). (Ardekani & Abdulla, 2011)

Filtered-x Least Mean Square (FxLMS)

Filtered-x Least Mean Square is a gradient based algorithm which can be used for the identification of an unknown system at the presence of a secondary path. The system of the figure consist the ANC controller w and the FxLMS algorithm. Where $\hat{s}$ represents an estimate model of the secondary path. As can be seen, the reference signal is filtered by $\hat{s}$ before being used by the standard LMS algorithm. This is the only difference between the LMS and FxLMS algorithms, resulting the compensation for the secondary path.

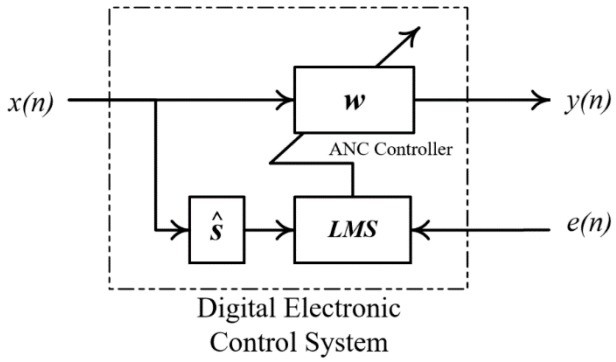


Figure 39: Digital electronic control system based on FxLMS

System can be modelled as:

$$y(n) = w^T(n)x(n)$$

$$x(n) = [x(n) \;\; x(n-1) \;\; \dots \;\; x(n-L+1)]^T$$

$$w(n) = [w_0(n) \;\; w_1(n) \;\; \dots \;\; w_{L-1}(n)]^T$$

$$w(n+1) = w(n) + \mu e(n) f(n)$$

$$f(n) = \sum_{q=0}^{Q-1} s_q x(n)$$

Where:

Control signal is $y(n)$
Tap reference vector is $x(n)$
Adaptive weight vector is defined by $w(n)$
$e(n)$ is the residual acoustic noise
Adaptation steep-size is μ
$f(n)$ is the filtered reference vector
s_q is the amplitude of the secondary path model impulse response at time index q

Conclusion

To end this research about this topic there must be emphasized that the choice of the right electronic control system is strongly linked to the speed and capacity of electronics required to build the ANC system. Because even the used algorithm is good enough to reach the optimum wide of the filter in fewer cycles is possible that the amount of calculations is not feasible in the required time.

Active Noise Control

Active Noise Control is a method for reducing unwanted sound by the addition of a second sound specially designed to cancel the first sound (Wikipedia, 2018). In this chapter, the three different methods of Active Noise Control will be discussed.

Feedforward

The first method, feedforward, is a method that works with a reference microphone, a controller and a speaker. This method is widely used to reduce the wide-band noise in different applications. An example of this method are the headphones. It is being used to reduce unwanted noise in busy environments.

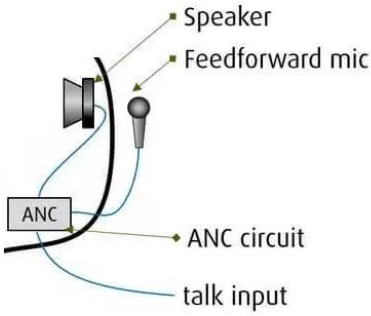


Figure 40: Feedforward method 1

First, the microphone picks up the ambient noise and transmit it to the ANC processor (the controller). Connected to the speaker, it sends the opposite secondary waveform generated by the controller. The specificity of this method is the use of the reference microphone. This method will be discussed (more specific than the feedback method and less expensive than the hybrid method).

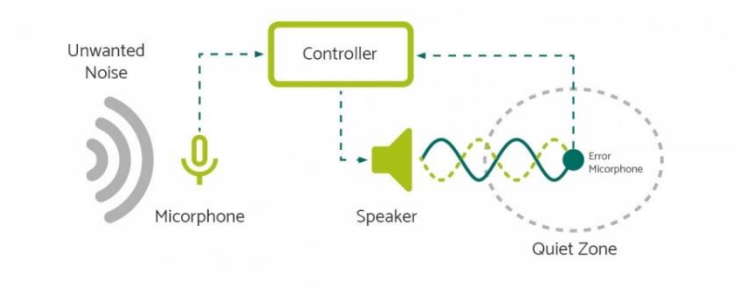


Figure 41: Feedforward method 2

Feedback

The feedback method works without reference microphone as used in the method before. Therefore, there is no reference signal, the controller relies only the information provided by the speaker to generate the control signals. To control the signals there has been used a microphone to monitor what the user hears. An example of this method is the use of an anti-noise to cancel the noise.

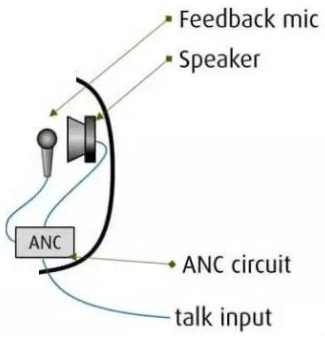


Figure 42: Feedback method

Feedback requires a microphone on the inside of the headset that monitors the sound going to the user's ear. The audio source is comparing with the sound in the user's ear, the feedback algorithm can identify the noise and create anti-noise to cancel the noise.

A challenge with the feedback method is that since the playback is being monitored, there is a risk that part of the playback signal will be considered as noise and cancelled.

Hybrid

The hybrid method is a combination between the feedforward and the feedback method. This method works with two microphones, a controller and a speaker. The use of two microphones is because there is one for the reference and one for monitoring what the user hears.

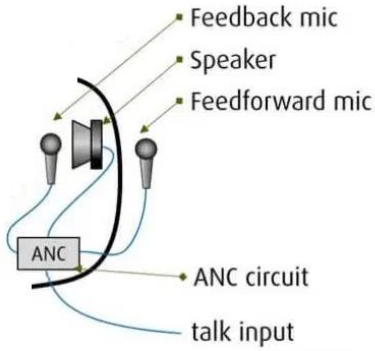


Figure 43: Hybrid method

Conclusion

To conclude the research of the different Active Noise Control methods there can be stated that the hybrid method is the most expensive method of the three. This is because of using two microphones instead of one microphone like the others.

Companies

In the research part of the project there were a couple of companies who are working with noise reduction on several ways. All the companies were contacted during the research phase and the responds are reproduced in the conclusion.

Silentium Ltd.

Silentium Ltd. is a high-tech company specializing in developing innovative noise reduction products and solutions for the automotive, home, industrial, medical and IT industries. They are situated in Israel. It is a World Leading company in the field of Active Noise Cancellation (ANC) for automobiles. The mission of Silentium Ltd. is to fight noise pollution in all its forms. Noise pollution from hardware causes undue stress, can impair hearing, judgement and communication. They have a range of ANC solutions for all kind of uses. The specialism of Silentium Ltd. is in the Quite Bubble technology and At-The-Source noise reduction. (Silentium, 2018)

Figure 44: Silentium Logo

Merford

Merford is a company that provides a wide and varied range of products and solutions to improve the environment. If it concerns the noise of factory machines, the uncomfortable positions a crane operator is forced to assume, the swinging beat form a discotheque or the audible burgeoning violin talent. They have a solution for any specific situation. They are situated in the Netherlands. The mission of Merford is to improve the climate of your living and working environment, by offering an all-inclusive concept. (Merford, 2018)

Figure 45: Merford Logo

Mentor Automotive

Mentor Automotive is a company that provides its customers with critical tools for solving the increasingly complicated problems of verifying that today's complex chip designs function as intended. They are situated in the United States of America. The mission of Mentor Automotive is to enable companies to develop better electronic products faster and more cost-effectively. The innovative products and solutions helps engineers conquer design challenges in the increasingly complex worlds of boarding and chip design. (Mentor, 2018)

Figure 46: Mentor logo

Signal Systems Corporation

Signal Systems Corporation is a small company with a strong capability in signal processing and active noise control. The specialism of Signal Systems Corporation is to distribute acoustic sensors for surveillance and reconnaissance. They are situated in the United States of America. (Signal Systems Corporation , 2018)

Figure 47: Signal Systems Corporation logo

AMS Technologies

AMS Technologies is a leading solution provider and distributor of high-tech, leading-edge components, systems and equipment, with more than 30 years of experience. They are Europe's leading solution provider and distributor for optical, power and thermal management technologies. The specialism of AMS Technologies is to create componentry and complete solutions for Optical technology, Thermal Management and Power technology fields, with access to and long standing relationships with the most advanced manufactures in each of those fields. They are situated in Germany. The mission of AMS Technologies is to facilitate innovative companies to convert these technologies into an asset for success. (AMS Technologies, 2018)

Figure 48: AMS Technologies logo

AcoustiControl

AcoustiControl is a company that makes a solution to prevent or solve noise and vibration related challenges in many different types of spaces. They can help you with mechanical noise and vibration control, noise and privacy criteria determination, indoor and outdoor environmental noise monitoring, outdoor noise pattern computer modeling and acoustical modeling of interior spaces. AcoustiControl is also the North American Representative for Silentium's unique "Silence in a Chip" Technology. (AcoustiControl, 2018)

Figure 49: AcoustiControl logo

Conclusion

After the research, there is a conclusion. The conclusion is that Silentium is a company with a bench mark in the Active Noise Control field. They also have a World Leading position in the field of Active Noise Cancellation (ANC) for automobiles. Besides this, the companies who were contacted refer to Silentium, because the lack of knowledge in these companies. So, Silentium is the company who can help with more information about Active Noise Control. On this moment, there is no response of Silentium yet. This means there is a little waiting time for that.

II The equipment

For the Kundt's tube experiment there are a few components needed. During the project to demonstrate the theory studied about Kundt's Tube, an amount of experiments has been designed and executed. As the name of the experiment says, a tube is necessary. Besides the tube, the following components are needed: a substance, a piston, a speaker, an electric circuit linking with a signal generator and a support. In this part, there is information about the components. To try to cancel the wave, another speaker and another signal generator will be added. All the demonstrations of the test were to research the right equipment to show the standing waves. The equipment that is described in this chapter will be used.

7. Substance

This chapter is about finding the right substance and know the quantity. To find the right substance and the quantity an amount of experiments has been designed and executed.

For the Kundt's tube experiment, it is necessary to have a substance with a low weight. This is because the substance needs to have to possibility to move in the tube by means of the sound waves. In the testing step, there is concluded that it is not possible to use all kind of substances. The first test that has been done was with flour. This was not working well, because the flour stacked into the tube. According to this the flower had not the possibility to move. The second substance that is tested were plastic balls. This was also not working, because the plastic balls were too heavy to move in the tube. The third substance is the Styrofoam. According to the tests it can be concluded that there can be a suitable or non-suitable substance to use in this experiment. The last substance is the cork dust. The cork dust is a light substance that can move easily in the tube.

Figure 51: L: Flour; R: Plastic balls

Figure 50: L: Styrofoam balls; R: Cork dust

Experiments with flour

This first part is about the test in which flour had been used. There have been two different tests. One with an opened tube and one with a closed tube. There was no difference in observation between the two.

Table 10: Open plastic tube with flour

Test:	Opened tube - Flour		
Materials used:	Plastic tube Flour Speaker Signal generator	Length of the tube:	200 cm
		Frequency:	340 Hz
Observations:	The substance used do not move, there are no signs of standing waves.		
Conclusions:	The stickiness of the flour may have caused an excessive need of energy to move the flour and the length of the tube.		

Table 11: Closed tube with flour

Test:	Closed tube - Flour		
Materials used:	Plastic tube Flour Speaker Signal generator Piston	Length of the tube:	45 cm
		Frequency:	755 Hz
Observations:	The substance used do not move, there are no signs of standing waves.		
Conclusions:	The stickiness of the flour may have caused an excessive need of energy to move the flour.		

Experiments with plastic balls

In this part, the plastic balls had been used as the substance. There have been three different test. One with an opened tube, one with a closed tube and one with a bottle. There was no difference between the observations of the three.

Table 12: Open plastic tube with plastic balls

Test:	Opened tube – Plastic balls		
Materials used:	Plastic tube Plastic balls Speaker Signal generator	Length of the tube:	200 cm
		Frequency:	340 Hz
Observations:	The substance used do not move, there are no signs of standing waves.		
Conclusions:	Due to the weight of the plastic balls may have caused that the energy produced by the speaker was not enough to move the plastic balls.		

Table 13: Closed tube with plastic balls

Test:	Closed tube – Plastic balls		
Materials used:	Plastic tube Plastic balls Speaker Signal generator Piston	Length of the tube:	45 cm
		Frequency:	755 Hz
Observations:	The substance used do not move, there are no signs of standing waves.		
Conclusions:	Due to the weight of the plastic balls may have caused that the energy produced by the speaker was not enough to move the plastic balls.		

Table 14: Bottle with plastic balls

Test:	Bottle – Plastic balls		
Materials used:	Glass bottle Plastic balls Speaker Signal generator	Length of the bottle:	25 cm
		Frequency:	1360 Hz
Observations:	The substance used do not move, there are no signs of standing waves.		
Conclusions:	Due to the weight of the plastic balls may have caused that the energy produced by the speaker was not enough to move the plastic balls.		

Experiments with Styrofoam balls

For the Kundt's tube experiment, it is necessary to have a substance with a low weight. This is because the substance need to have to possibility to move in the tube by means of the sound pressure. This material is mainly used as insulation material. There have been three different tests. One with an opened tube, one with a closed tube and one with a bottle. At the end, the team tested this substance in a glass tube to know the quantity to put in it. There was some difference between the observations. They are explained in the tables below.

Table 15: Open tube with Styrofoam balls

Test:	Opened tube – Styrofoam balls		
Materials used:	Plastic tube Styrofoam balls Speaker Signal generator	Length of the tube:	200 cm
		Frequency:	340 Hz
Observations:	The substance used do not move, there are no signs of standing waves.		
Conclusions:	The speaker does not produce enough energy to move the Styrofoam balls.		

Table 16: Closed tube with Styrofoam balls

Test:	Closed tube – Styrofoam balls		
Materials used:	Plastic tube Styrofoam balls Speaker Signal generator Piston	Length of the tube:	45 cm
		Frequency:	755 Hz
Observations:	The substance move slightly, but there are no signs of standing waves.		
Conclusions:	The speaker does not produce enough energy to move the Styrofoam balls.		

Table 17: Bottle with Styrofoam balls

Test:	Bottle – Styrofoam balls		
Materials used:	Glass bottle Styrofoam balls Speaker Signal generator	Length of the bottle:	25 cm
		Frequency:	1360 Hz
Observations:	The substance used do not move, there are no signs of standing waves.		
Conclusions:	The input of the recipient is not good enough to transmit the energy of waves inside the bottle		

In this part, the Styrofoam balls had been used as a substance. Styrofoam consists of 2% polystyrene and 98% gas. The material is therefore very light with a density of 15 to 40kg/m^3. Besides that, it is a relatively cheap material and available on the market. The goal of this part is to know the quantity of Styrofoam for the test works. Before to test it, a theory part is done. With the formula mentioned in the Kundt's tube part, the fundamental frequency is calculated for each coefficient. This calculate frequency, is the resonance frequency. With this frequency, the substances will have moved. The formula is: $\lambda = \frac{c}{f} \Rightarrow f = \frac{c}{\lambda}$

The length of the tube is the same in all experiments because the end is handled. The n is the coefficient to describe the length of the wave. This point is already explained before. For instance, 0,25 is equivalent to see ¼ of the wavelength.

Table 18: Closed tube theory

l (length of the tube)	n	c (speed of the air)	f (frequency)
0,35	0,25	340	242,8571429
0,35	0,75	340	728,5714286
0,35	1,25	340	1214,285714

As show the table, the spectrum frequency what we can see is included between 242Hz and 1215Hz. For the rest, the frequencies are named:

242 Hz	Low frequency
729 Hz	Medium frequency
1215 Hz	High frequency

After the theory part, the team tested the experiment. A matrix is done to compare what happens in relation with the frequencies and the quantity of the substance. To keep the same results on all experiments, the team will have followed this picture to know where is the wave.

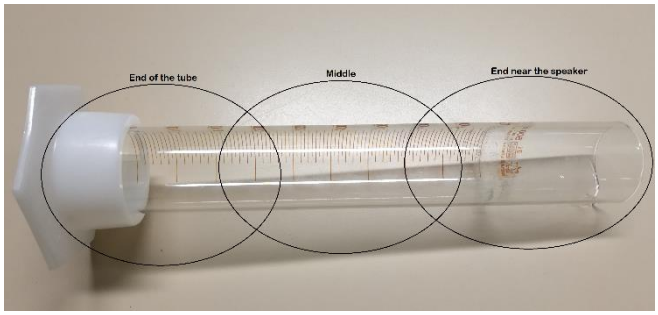


Figure 52: Glass tube with wave positions

As the picture shows, the tube is divided in graduation. To measure the quantity of substance in the tube, it will be written 50 in the report. This is an equivalent to “50 mL”. The team tried to measure the quantity for “50” to convert in grams but it is not representative as show the picture.

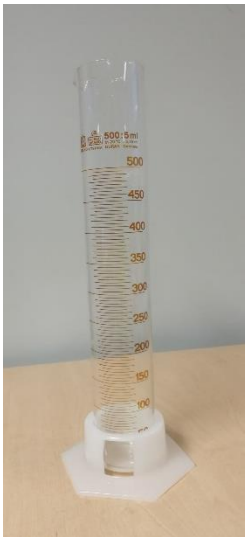


Figure 54: Glass tube

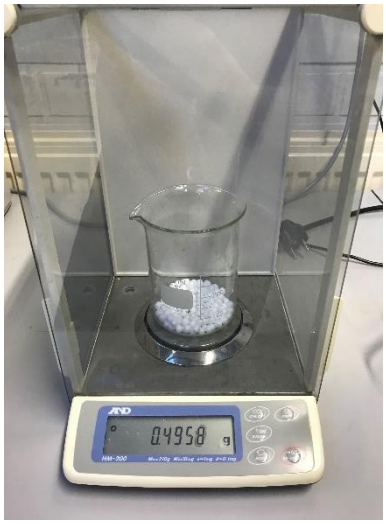


Figure 53: Weight of 50 styrofoam balls

Table 19: Glass closed tube results

Frequencies (Hz) / Substance (tube graduation)	50	100	150	200	250
230		1 wave at the end		1 wave at the end	1 wave at the end
250	1 wave at the end		1 wave in the middle		
450			1 wave in the middle		
540		1 wave in the middle		1 wave on the other end	
550	1 wave in the middle				1 wave in the middle
930					2 waves
970				2 waves	
1050	2 waves				

For 50-tube graduation of substance, a wave appears at 250 Hz. That can be called a low frequency. On the theory part for the medium frequency, two waves had to be created but not in this case. Thus, the 50-tube graduation of substance is not adapted for this experiment. The both next measurements of this substance are not analysed because the substance does not move for the high frequency. With more substance: 200 and 250-tube graduation, it shows instead of the 50-tube graduation, at least one wave for each frequency. For the low frequency at 230 Hz, one wave is perceived. For the medium frequencies (540 Hz for 200-tube graduation and 550 Hz for 250-tube graduation) only one wave is noticed. Finally, for the high frequency, two waves are discerned, as proved by the theory.

Below, the pictures are enjoined in the table to show the impact of the graduation tube substance on the frequency.

Table 20: Closed tube - low frequencies; Closed tube medium frequencies

For low frequencies (230 to 250 Hz)

Graduation tube	50	100	150	200	250
Frequency (Hz)	250	230	250	230	230
Picture					

For medium frequencies (450 to 550 Hz)

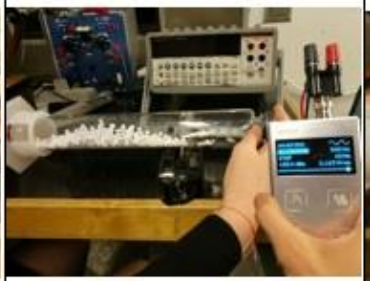
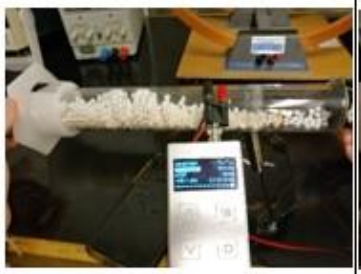
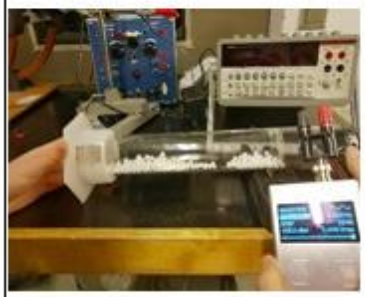
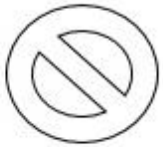
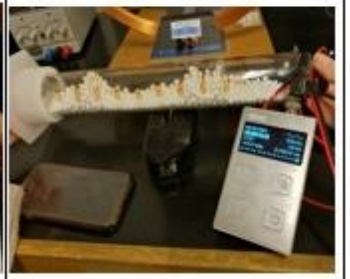
Graduation tube	50	100	150	200	250
Frequency (Hz)	550	540	450	540	550
Picture					

Table 21: Closed tube - high frequencies

For high frequencies (930 to 1050 Hz)

Graduation tube	50	100	150	200	250
Frequency (Hz)	1050			970	930
Picture					

Theory

Frequency (Hz)	243	729	1215
Picture			

There are several mistakes between the experiments done and the theory. To show the difference, a matrix is done. In this one, the tube graduation and the frequencies are compared with the theory. The goal is to identify the best tube graduation to use.

Table 22: Matrix for the glass closed tube

Length: 35cm

Diameter: 5cm

Glass closed tube

Tube graduation / Frequencies	50		100		150		200		250	
Low	1 peak	Speaker	1 peak	Speaker	1 peak	Speaker	1 peak	Speaker	1 peak	Speaker
Medium	1 peak	Middle	1 peak	End	1 peak	Middle	1 peak	End	1 peak (+1)	Middle (& Speaker)
High	2 peaks	Speaker & Middle	Nothing		Nothing		2 peaks	Speaker & End	2 peaks (+1)	Middle & End (&Speaker)

Theory

Frequencies	Peaks	Position
Low	1 peak	Near the speaker
Medium	2 peaks	Speaker & Middle
High	3 peaks	Speaker & Middle & End

Perfect
Acceptable
False

50 tube graduation:

Table 23: 50 tube graduation

Test:	Glass closed tube – 50 tube graduation		
Materials used:	Glass tube Styrofoam balls Speaker Signal generator Amplifier Support	Length of the tube:	35 cm
		Frequency:	250 Hz 550 Hz 1050 Hz
Observations:	The substance used move, there are waves but not like the theory		
Conclusions:	Not adapted, for the next experiment will used more substances in the tube		

For the low frequency, the wave is observed at the end of the tube next to the speaker. For the medium wave, a wave is created in the middle of the tube. In theory, two waves should have formed. Thus, the 50-tube graduation of substance is not adapted for this experiment. The 100 and 150-tube graduation are not studied is this part because they are not accommodated.

Table 24: 200 tube graduation

Test:	Glass closed tube – 200 tube graduation		
Materials used:	Glass tube Styrofoam balls Speaker Signal generator Amplifier Support	Length of the tube:	35 cm
		Frequency:	230 Hz 540 Hz 970 Hz
Observations:	The substance used move, there are waves but not like the theory		
Conclusions:	Not adapted, for the next experiment will used more substances in the tube		

For the first frequency, the wave is situated near to the speaker. For the second tested frequency, the wave is at the end of the tube, where the tube is closed. Thus, the 200-tube graduation of substance is not accurate for this experiment.

Table 25: 250 tube graduation

Test:	Glass closed tube – 250 tube graduation		
Materials used:	Glass tube Styrofoam balls Speaker Signal generator Amplifier Support	Length of the tube:	35 cm
		Frequency:	230 Hz 550 Hz 930 Hz
Observations:	The substance used move, there are waves and it is closer to the theory		
Conclusions:	More adapted		

For this measurement, the wave is near the speaker when the low frequency is sent. For the medium frequency, one wave is also located at the middle of the tube, but a “peak” can be guessed next to the speaker. This peak is not mentioned in the first matrix during the experiment because it was too small. For the high frequency, two waves are observed and one can be again guessed.

Therefore, the best tube graduation to use is the 250-tube graduation because this is the closer to the theory.

In conclusion, the quantity of the substance is the tube influence the experiment results. The team decided to endeavour to choose the best quantity for the experiment will not fail. In this part, the best tube graduation is the 250-tube graduation for the experiment.

Conclusion

After the tests with the open tube it is notable that with a long tube the necessary energy to move the substance and generate the standing waves is too high. Consequently, a reduction of the length of the tube is necessary to achieve the goal of generating the standing waves. The length of the tube will be explained in another chapter. About the experiments with the closed tube it can be observed that the reduction of the tube achieved a slightly movement in some substances, but not enough to generate the standing waves. With the bottle experiments can be deduced that the way that the sound is transmitted it is an important point to keep in mind during the designing of the experiments and influences directly in the results.

In conclusion, it is necessary to have a substance with a low weight. After these tests, there is decided to work with Styrofoam balls. The material is therefore very light, this is the main reason why there is chosen for Styrofoam balls. Like the probe the last tests, in the glass closed tube, the best tube graduation is the 250-tube graduation for the experiment.

8. Accessories

Speakers

During this project, we used three different speakers. The characteristics of these different speakers are visual in the table below:

Table 26: Different speakers

Speaker	The first one	The smaller	The bigger
Resistance (Ω)	8 Ω	8 Ω	4 Ω
Rated Power (W)	-	5 W	30 W
Maximum Power (W)	2 W	8 W	50 W
Frequency response (Hz)	Between 200 Hz and 10.000 Hz	Between 150 Hz and 20.000 Hz	Between 100 Hz and 20.000 Hz
Magnet size (mm)	Ø45 mm	Ø45 mm	Ø60 mm
Voice coil (mm)	Ø14.4 mm	Ø50,5 mm	Ø71 mm

Figure 55: L: Smaller speaker; R: Bigger speaker

In the beginning of the project, the first speaker has been tried. When the team started the first experiment the speaker was not able to work in the right way for this experiment. The power of this speaker was not strong enough. After adding the amplifier and the transformer, the substance in the tube moved. Many frequencies have been tested, and the first speaker heated. This speaker is made from iron coil. With the heat, the iron melted and make a short-circuit. Then, two others speaker (one smaller and one bigger) are used in the experiment. For the next experiments the smaller speaker will be used for the glass closed tube and the bigger speaker for the Plexiglas tube. With these two speakers, the substance moves. In addition, with the new speakers, an amplifier would be added to improve the power.

Electric circuit

After the experiments to finding the right substance, there is concluded that there is other equipment needed to complete the experiment in a good way and in different tubes. Besides this, there was also concluded that it was necessary to have more power from the speaker. For this problem, the team decided to buy new components. These components permit to create and improve the frequency and to operate the experiment.

The electric circuit is a circuit with several components. For this project, the electric circuit is composed of: one transformer, one amplifier, one speaker and one signal generator. To connect the components, electric wires are used and each component is soldered with the wires. In each case, the red corresponds to the plus and the black to the minus or the ground. Before to connect the transformer and the wall outlet, it is necessary to link the speaker and the signal generator with the amplifier. This circuit permits to create and to generate a frequency.

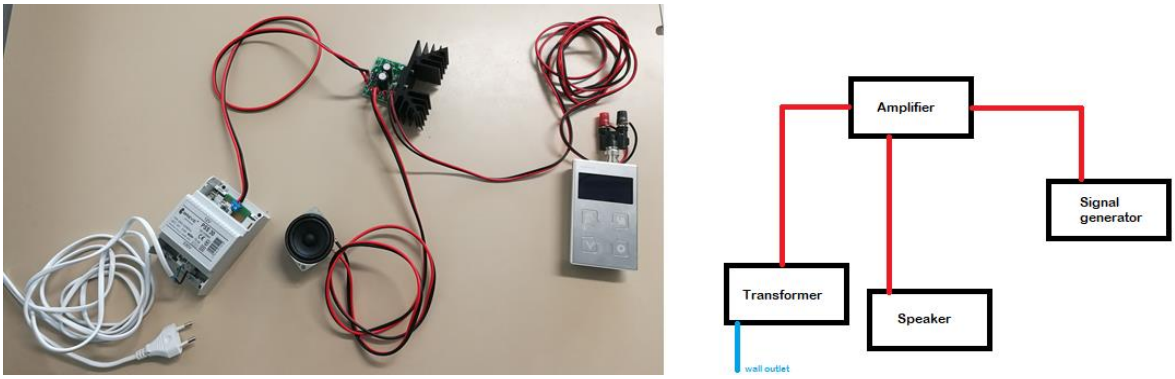


Figure 56: The circuit for the experiment Kundt's tube

Signal generator

A signal generator is piece of test equipment that produces an electrical signal in the form of a wave. When looking at what a signal generator is, it will be seen that they come in many forms - there are many signal generator types, each one being used to provide a different

form of signal. Signal generators have been used for many years, but today it exists many signal generator types:

- Arbitrary waveform generator (waveforms specified by the user)
- Audio signal generator (audio application delivered frequencies between 20Hz and 20KHz)
- Function generator (produced waveforms such as sine waves, saw tooth waveforms, square and triangular waveforms)
- Pulse generator (created pulses)
- RF signal generator (Radio frequency signal)

(Electronics-notes, 2018)

It exists several generator types:

- PLL (Phase Locked Loops)
- DAC (Digital analogue converter)
- DDS (Direct digital synthesis)

The phase locked loops (PLL) is a control system that generates an output signal whose phase is related to the phase on an input signal. (Wikipedia, 2018)

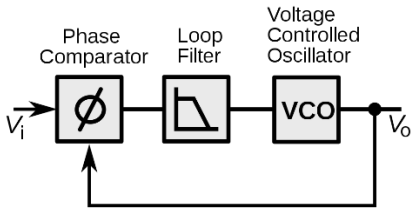


Figure 57: Phase Locked Loops (PLL)

The digital analogue to converter (DAC) is a system that converts a digital signal (discrete-time signal) into an analogue signal (continuous signal). The inverse is ADC. (Wikipedia, 2018)

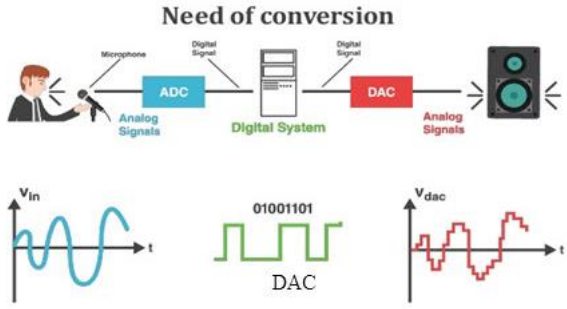


Figure 58: DAC & ADC

The direct digital synthesis (DDS) is a method employed by frequency synthesizers used for creating arbitrary waveforms from a single, fixed-frequency reference clock. (Wikipedia, 2018)

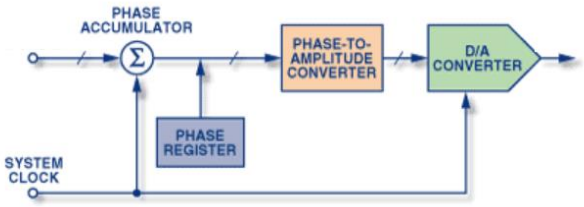


Figure 59: Direct digital synthesis (DDS)

The direct digital synthesis is a method of producing analogue waveform (usually and in our case: sine wave) by generating a time. Many possibilities for frequency generation are open to a designer, ranging from phase-locked-loop (PLL) (based techniques for very high-frequency synthesis), to dynamic programming of digital to analogue converter (DAC) outputs to generate arbitrary waveforms at lower frequencies. But the DDS technique is the less expensive and a compromise between price and quality. (analog, 2018)

	Phase-Locked Loops	DAC	DDS
Spectral Performance	High	Medium-high	Medium
System Power Requirements	High	High	Low
Digital Frequency Tuning	No	Yes	Yes
Tuning Response Time	High	Low	Low
Solution Size/Footprint	Medium	High	Low
Waveform Flexibility	Low	Medium	High
Cost	Medium	High	Low
Design Reuse	Medium	Low	High
Implementation Complexity	Medium	High	Low

Figure 60: Table of comparison generator type

We decided to use this signal generator:

INFO

Features:

- DDS type generator (Direct Digital Synthesis)
- sweep function with bi-direction option
- OLED screen
- operates on 4 x 1.5V AAA batteries (not included)
- signature white back casing

Specifications:

- DAC resolutions: 10 bits
- frequency range: from 1 Hz to 1.000.000 Hz (± 0.01 %)
- frequency steps: 1 Hz, 10 Hz, 100 Hz, 1 kHz and 10 kHz
- waveforms: sine, square and triangle
- output voltage: max. 8 Vpp
- real output level measurement: dBm / Vrms or Vpp readout (± 3 %)
- typical sine wave distortion (THD): < 0.1% @ 1 kHz / 0dB / 600 Ohm
- square wave rise/fall time: typ. 0.2 µs
- output impedance: 50 Ohm
- dimensions: 114 x 68 x 22mm / 4.48 x 2.67 x 0.86"
- power consumption: 70 mA max
- battery life: about 15 hours on quality alkaline batteries

For the last step, when the team will try to cancel the noise, another similar signal generator available in the lab will be used.

Amplifier

The amplifier is an electronic device which is used to increase the magnitude of the signal applied to its input. To connect it, it is necessary to link the input, the output and the source. The input is the signal generator, the output is the speaker and the source is the transformer.

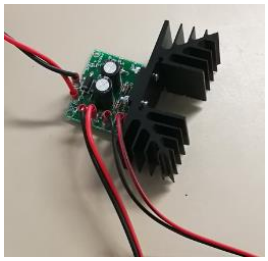


Figure 61: The amplifier

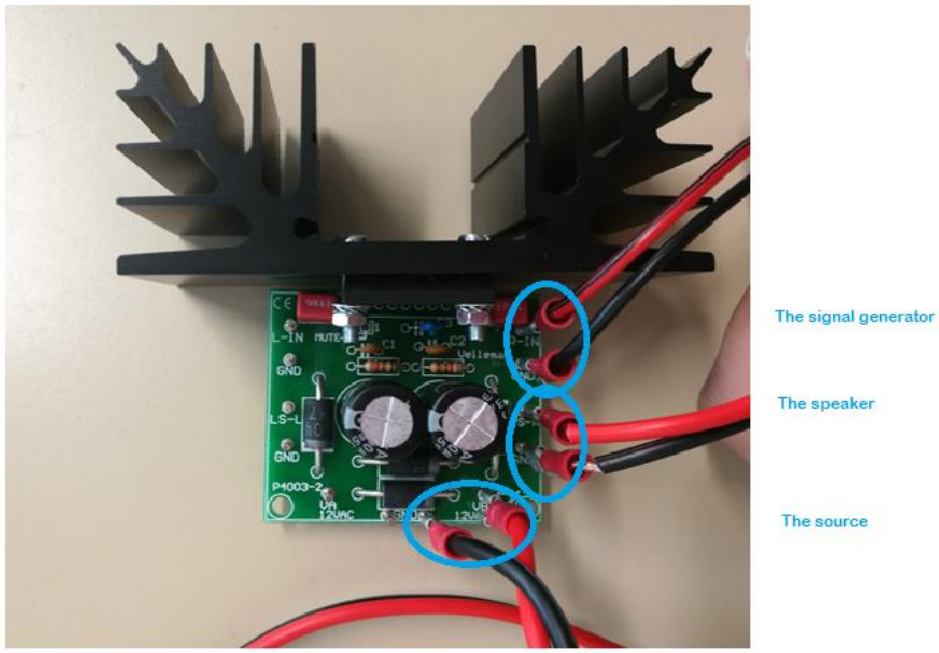


Figure 62: How to connect the amplifier

Power supply

DC power supplies use AC mains electricity as an energy source. Such power supplies will employ a transformer to convert the input voltage to a higher or lower AC voltage. Output voltage is passed through an electronic filter to convert it to an unregulated DC voltage. The filter removes most, but not all the AC voltage variations; the remaining AC voltage is known as ripple. The electric load's tolerance of ripple dictates the minimum amount of filtering that must be provided by a power supply. In our case, the 230V is replaced by 12V. This device has a fuse. This device permit to cut the current if the intensity is too high.

Figure 63: The Power supply

Piston

With the possibility to change the length of the tube by modifying the distance between the speaker and the end of the tube a piston is used. In this project, the piston had been made by the project team itself. The piston is used when the tube is closed. The consequences are explained in the part of Kundt's tube.

To realize the piston, a process to remove material from a workpiece is needed.

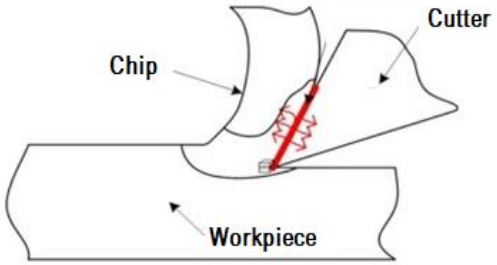


Figure 64: Chip formation

The milling machine is the machining process of using rotary cutters to remove material from a workpiece by advancing in a direction at an angle with the axis tool (Quora, 2018). On the other hand, it also exists a wood-turning machine. In this process, it is the piece that turns, and not the cutter.

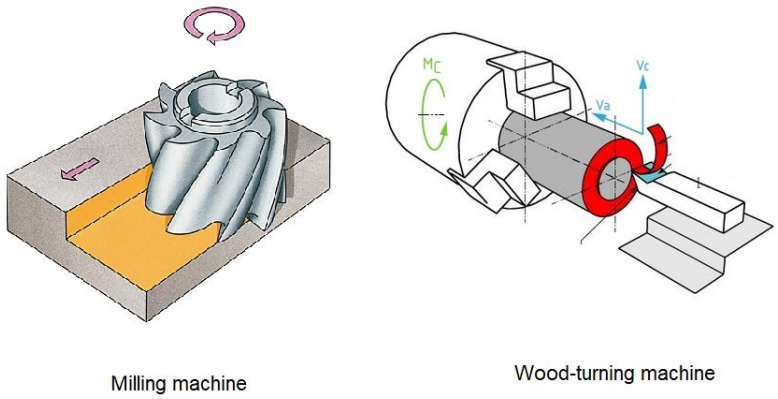


Figure 65: Milling machine and wood-turning machine

Aluminium has been used to make the piston. Aluminium is a silvery-white, soft, nonmagnetic, corrosion resistant and ductile metal. Aluminium is the world's most abundant metal and is the third most common element comprising 8% of the earth's crust. The versatility of aluminium makes it the most widely used metal after steel. Aluminium is one of the lightest engineering metals, having a strength to weight ratio superior to steel. Aluminium is not able to absorb sound waves. In contrast, it reflects the waves back. Aluminium is compared to steel three times more expensive. In comparing to copper it is cheap.

The milling machine

To design the piston, the vertical milling machine, available in a Technobotnia lab, is used. The designs are often CAD directed, and many milling machines are CNC-operated, although manually milling devices are also common. The CNC (Computer Numerical Control) is the automated control of machining tools by means a computer. For this project, this method has been used. (Wikipedia, 2018)

Figure 66: L: Manually milling machine; R: CNC milling machine

Often automated, milling machines can be positioned vertically or horizontally.

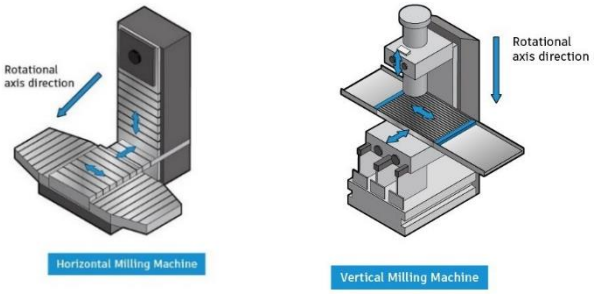


Figure 67: L: Horizontal milling machine; R: Vertical milling machine

The orthonormal coordinate system can be represented by three finger of the right hand. The axis of the spindle (the axis Z) represents the orientation of the machine.

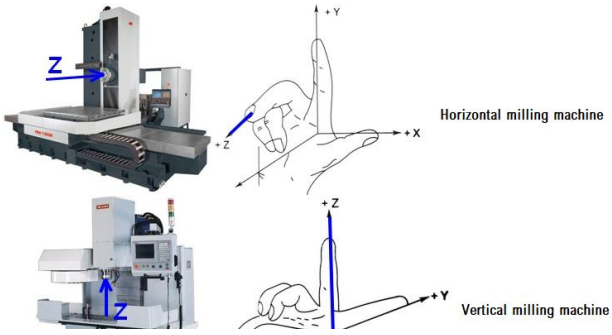


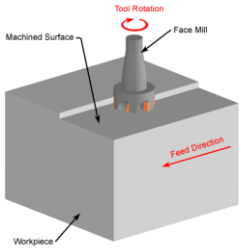
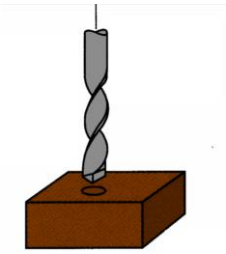
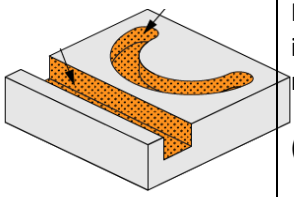
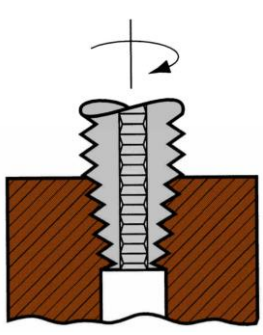
Figure 68: Horizontal and vertical axis

The acronym CAD signifies Computer Aided Design. It is a software used by engineers to create precision drawings or technical illustrations. For this project, CATIA Solidworks, a software to create three-dimensional (3D) models is used. (Wikipedia, 2018)

Figure 69: CATIA logo

There are different ways to remove materials from a workpiece. The methods used during the project are explained in the table below.

Table 27: Different ways to remove material

Name of the method	**Cutter (Tool)**	**Picture**	**The goal**
Surfacing			Is used to produce a smooth finish on flat surfaces (Wikipedia, 2018)
Drilling			Is a cutting process that used a drill bit to cut a hole of circular cross-section in solid materials (Wikipedia, 2018)
Grooving			Is a long and narrow indentation built into a material (Wikipedia, 2018)
Tapping			Used to provide internal screw threads on an existing hole

The program

We chose to use a CN-operated milling machine. To work, this machine had to be programmed. This program was written directly on the machine.

The program is composed lines of code which are numbered, and begin by N in order to the number of the line like this:

Example CNC Program

```
N5 G90 G20
N10 M06 T3
N15 M03 S1250
N20 G00 X1 Y1
N25 Z0.1
N30 G01 Z-0.125 F5
N35 X3 Y2 F10
N40 G00 Z1
N45 X0 Y0
N50 M05
N55 M30
```

Figure 70: Example CNC program

Before beginning, the most important is to notice the 0 point on the piece (for us the bottom left corner).

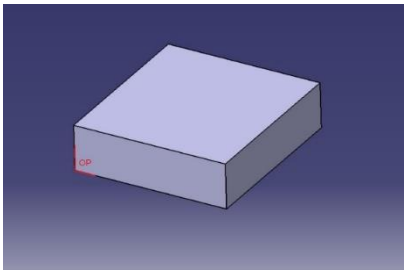
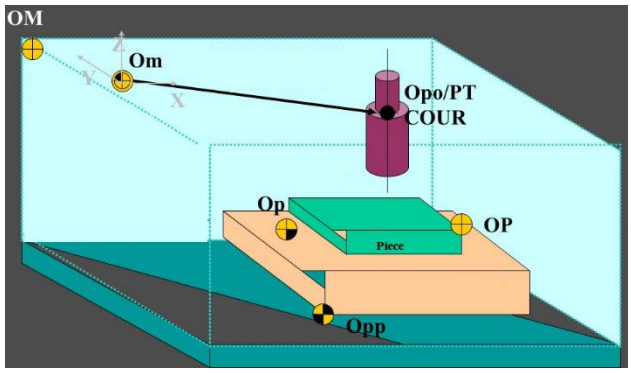


Figure 71: Program's origin

This point is the “program’s origin”. It exists different origin.

Table 28: Origins

	OM	Machine’s origin	Manufacturer data
	Om	Measure’s origin	Starting point for all dimensions
	OP	**Program’s origin**	**Starting point for all dimensions in absolute code**
	Op	Piece’s origin	

A center finder will be used to notice the O point, the program's origin.

Figure 72: Center finder (notice the 0)

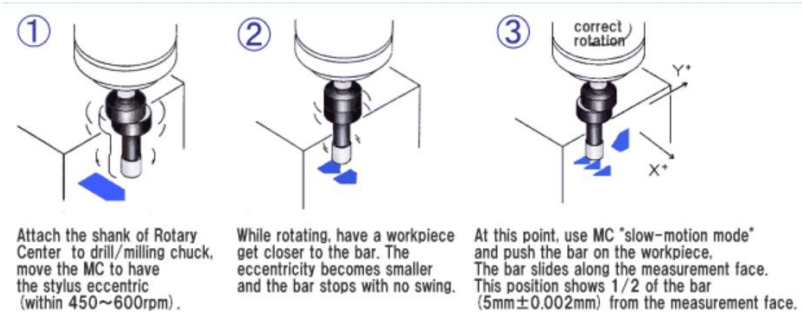
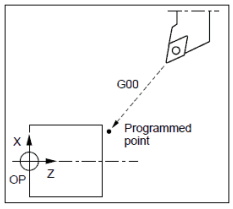
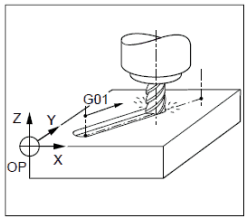
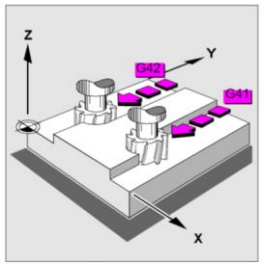
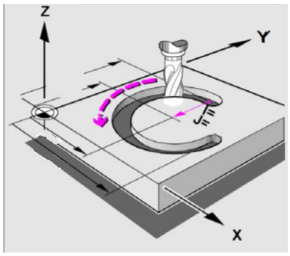
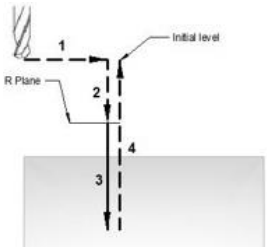


Figure 73: Explication to notice the 0

There is chosen to use different function to remove materials from our workpiece. It exists several kinds of functions but the G and M are used. The G are the preparatory functions and the M the auxiliary functions. These functions can be seen in the following table.

Table 29: Functions CNC

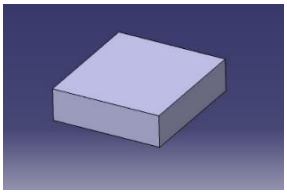
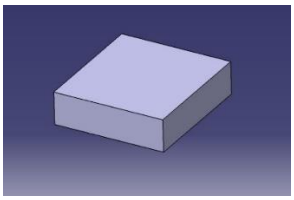
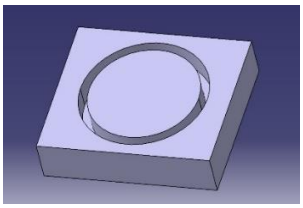
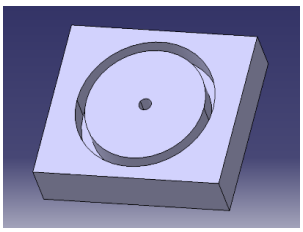
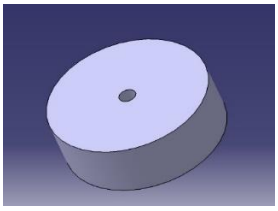
Functions	Explanations	Drawing
G00	Rapid positioning	
G01	Linear interpolation	
G90	Absolute programming reference	Measured from the program zero: Program's origin

G91	Incremental programming reference	Measured from the current position
G42	Tool radius compensation right	
G40	Tool radius compensation off	
G03	Circular interpolation (counter clockwise)	
G81	Simple drilling cycle	
M06	Automatic tool change	
M13	Spindle on (clockwise rotation) and coolant on (flood)	
M02	End of program	

Machining

The piece of the piston is designed in the software CATIA. In the table below, is presented the different steps to make it. In the right column, there are the drawings of the piece at each step.

Table 30: Machining piece

Untreated		
Step 1	Surfacing	
Step 2	Grooving	
Step 3	Drilling	
Step 4	Tapping	
Final	Grooving	

Support

To make a good support for the big plastic tube we chose to use wood. It is a relatively cheap material. There are hundreds of different species of wood.

Physically, wood is strong and stiff. It is also light and flexible. Wood is comparing to many different other materials anisotropic. This means a lump of wood has different properties in different directions. Dry wood produces a great deal of heat energy when burned. Although wood can absorb sound very effectively, wooden object can also be designed to transmit and amplify sounds. It conducts sound because it is easy to move but it also absorbs like a sponge blocking sound (Woodford, sd). Thereafter wood is suitable to contribute to a good sound insulation (Characteristics of wood, 2013). The average absorption coefficient of wood is 0,05 – 0,90. It depends on the quality of the wood. This applies to frequencies between 500 and 2000 Hz (Table with absorbing materials, sd).

One wooden board is made to close the tube at the beginning. The speaker is processed in this wooden plate. This board stays vertical on a horizontal wooden plank. On this wooden plank, the electric circuit is attached. On the other side of the tube there is a wooden stand to hold the tube straight. This wooden support is important so there is now loss of sound. Besides that, the plastic tube is off the surface to protect for losing waves. Last, in this support there is no need to hold the plastic tube.

Figure 74: L: Support speaker 1; R: Support speaker 2

Figure 75: L: Support back side; R: Total wooden support

9. Tube

The tube is one of the main objects in this experiment. The tube is needed to keep the sound waves and the substance in a certain space. There are several factors which are required to choose a tube. These factors are the material, the length of the tube, the costs and the availability. In this chapter, these factors will be discussed.

Material

First, the material of the tube is a really important factor to keep in mind during the decision. The available materials were glass or plastic. Glass a reflecting material and is very acoustically reflective because it is flat and rigid. But the problem with glass is that it depends on the thickness. The average absorption coefficient of glass is < 0,05. This applies to frequencies between 500 and 2000 Hz (Table with absorbing materials, sd). On the other hand, Plastic is not a good reflecting material. It has an acceptable acoustic insulation (Characteristics and properties of plastic, sd). Plastics can absorb mechanical energy by transforming it into heat. For a good absorb material plastic is not the best option. However, it cannot be used for desorption.

The closed tube matrix is to know the best diameter and material for a length of 35 cm. The glass tube has a diameter of 5 cm whereas the plastic tube has 11 cm. The resonance frequencies are different between the both tubes that is why the frequencies will be studied as: low, medium and high frequencies.

Table 31: Matric glass tube and plastic tube 35cm

Closed tubes

Length: 35cm

Diameter: 5cm (glass) & 11cm (plastic)

Frequencies / Diameter	230			392			550			785			930			1177		
	1 peak	2 peaks	3peaks	1 peak	2 peaks	3peaks	1 peak	2 peaks	3peaks	1 peak	2 peaks	3peaks	1 peak	2 peaks	3peaks	1 peak	2 peaks	3peaks
5 cm		x	x		x	x	x		x	x		x	x	x		x	x	
11 cm		x	x		x	x	x		x	x		x	x	x		x	x	

x impossible

Visible
Acceptable (some vibrations)
Not visible

Theory

	Frequencies for the glass tube	Frequencies for the plastic tube
Low frequencies	230	392
Medium frequencies	550	785
High frequencies	930	1177

As shown in the matrix, the best diameter is 5 cm. For each frequency, the substance moves in the glass tube. In the plastic tube (11 cm), using theses frequencies, the Styrofoam moved but did not create a wave.

This matrix shows that the materials and the diameter have an influence on the Kundt's tube experiment. The best tube for this experiment is the glass tube with a length of 35 cm.

Length

Second factor is the length of the tube. The length of the tube to produce standing waves has been determined with the following formula: $= v/f$. This formula has been used to calculate the useful lengths of the tube for different frequencies. In this formula, the λ, which is the symbol for Lambda, is used to indicate the wavelength of any wave (Wikipedia, 2018). The v is the symbol for Velocity and is used to indicate the rate of change of its position with respect to a frame of reference and is a function of time (Wikipedia, 2018). The f is the symbol for Frequency and is used to indicate the number of occurrences of a repeating event per unit of time (Wikipedia, 2018). When looking at the formula, it can be concluded that when the frequency is higher, the length of the tube must be shorter. This can also be read from the table shown below. In the formula, the number of 340 m/s is used to represent the velocity of the air. There is a spectrum used between 230 Hz and 580 Hz.

Table 32: Frequency combined with wavelength

Frequency (Hz)	Wave length (m)
230	1,47826087
240	1,416666667
250	1,36
260	1,307692308
270	1,259259259
280	1,214285714
290	1,172413793
300	1,133333333
310	1,096774194
320	1,0625
330	1,03030303
340	1
350	0,971428571
360	0,944444444
370	0,918918919
380	0,894736842
390	0,871794872
400	0,85
410	0,829268293
420	0,80952381
430	0,790697674
440	0,772727273
450	0,755555556
460	0,739130435

470	0,723404255
480	0,708333333
490	0,693877551
500	0,68
510	0,666666667
520	0,653846154

530	0,641509434
540	0,62962963
550	0,618181818
560	0,607142857
570	0,596491228
580	0,586206897

Concluded to the calculation the decision is made to use a piston to have the possibility to change the length of the tube, with this improvement it is added flexibility to the experimentation part making available different tests with the same equipment.

Costs

Plastics are organic substances formed by macro cells called polymers. Due to its macro production plastics have a low production cost. Glass is a relative expensive material especially if it is not standard shapes, for this case for a tube of the dimensions needed for the proper view of the experiment the cost it is exorbitant compared with the plastic production cost.

Availability

It was a defining factor to make the final choice because it was available one Plexiglas tube at the University and one small glass tube. In this case, the tube was available, and the project team wanted to make it work.

Glass tube 35 cm

This test tube repurposed to a closed pipe to test the standing waves is made from glass. It has an inner diameter of 5 and length of 35 cm. This test is to probe if it is possible to create standing waves inside the glass tube, and see which problems affect directly to the creation of those. Due to the rigidity of the glass this tube it shouldn't be problems with loss of energy caused by the material so the test can be focused on detecting other sources of loss of energy.

Table 33: Experiment glass tube 35 cm

<table>
<tr><td>Test:</td><td colspan="3">Glass tube 35 cm</td></tr>
<tr><td rowspan="2">Materials used:</td><td rowspan="2">Glass tube
Styrofoam balls
Speaker (small)
Signal generator
Amplifier</td><td>Length of the tube:</td><td>35 cm</td></tr>
<tr><td>Frequency:</td><td>392 Hz
785 Hz
1177 Hz</td></tr>
<tr><td>Observations:</td><td colspan="3">The Styrofoam balls were highly affected by the waves produced it was visible the towers created by it. At certain moments of the test balls agglomerate in some places and produce strange events. Standing waves were clearly visible.</td></tr>
<tr><td>Conclusions:</td><td colspan="3">This kind of tube almost do not vibrate, by this reason it seems to translate more energy to Styrofoam. To improve this test should be reduced the amount of Styrofoam inside the pipe.</td></tr>
</table>

Plastic tube 35 cm

To have a comparison the plastic tube had the same length as the glass tube, 35 cm. However, the diameter is 10,4 cm. The challenge is to observe the standing waves in the plastic tube. By starting the test phase, the same frequencies had been used as in the test phase with the glass tube.

In the following table the summary of the experiment can be seen. With the most important date obtained.

Table 34: Experiment plastic tube 35 cm

<table>
<tr><td>Test:</td><td colspan="3">Plastic tube 35 cm</td></tr>
<tr><td rowspan="2">Materials used:</td><td rowspan="2">Plastic tube 35 cm
Styrofoam balls
Speaker (Big)
Signal generator
Amplifier</td><td>Length of the tube:</td><td>35 cm</td></tr>
<tr><td>Frequency:</td><td>392 Hz
785 Hz
1177 Hz</td></tr>
<tr><td>Observations:</td><td colspan="3">The plastic tube vibrates. The Styrofoam balls had a little vibration on the frequency points, but it was not close to observe the standing waves.</td></tr>
<tr><td>Conclusions:</td><td colspan="3">The tube takes a lot of energy from the sound and the power of the speaker is not enough. It is also possible that the tube is not long enough to have the same ratio between the diameter and the length of the tube as in the glass tube. Poor sealing.</td></tr>
</table>

Concluding the test, the whole distribution takes too much energy from the sound and the power of the speaker is not high enough to mitigate this fact. As it is known by the previous research, plastic tube takes a lot of energy from the sound. This is can be seen in the plastic tube vibration. It is also possible that the tube is not long enough to have the same ratio between the diameter and the length of the tube as in the previous test. Good sealing may be also a critical problem for this loss of energy. For all these reasons is why it is still a challenge to observe the standing waves in this plastic tube.

Plastic tube 165 cm

Made from Plexiglas, with an inner diameter of 10,4 cm and an outer diameter of 11 cm and length of 165 cm. An advantage of this tube is that it can be divided in smaller lengths. With this experiments the idea is to test if the dumping by vibration of the long tube is high enough to ruin the experiments and how the length of the tube affects the movement of the Styrofoam.

Table 35: Experiment plastic tube 100 cm

<table>
<tr><td>Test:</td><td colspan="3">Plastic tube 100 cm</td></tr>
<tr><td rowspan="2">Materials used:</td><td rowspan="2">Plastic tube 100 cm

Styrofoam balls

Speaker (big)

Signal generator

Amplifier

Support

Piston</td><td>Length of the tube:</td><td>100 cm</td></tr>
<tr><td>Frequency:</td><td>156 Hz

313 Hz

470 Hz</td></tr>
<tr><td>Observations:</td><td colspan="3">The Styrofoam balls were affected by the waves produced by the speaker. Even the tube absorbed some energy of the waves that was transformed to a vibration of the tube. It was possible to see clearly the standing waves at frequencies tested.</td></tr>
<tr><td>Conclusions:</td><td colspan="3">The length of the tube taken to do this test is good enough to see clearly the standing waves which mean that the equipment is well proportioned.</td></tr>
</table>

Table 36: Experiment plastic tube 150 cm

<table>
<tr><td>Test:</td><td colspan="3">Plastic tube 150 cm</td></tr>
<tr><td rowspan="2">Materials used:</td><td rowspan="2">Plastic tube 150 cm

Styrofoam balls

Speaker (big)

Signal generator

Amplifier

Support

Piston</td><td>Length of the tube:</td><td>150 cm</td></tr>
<tr><td>Frequency:</td><td>107 Hz

214 Hz

322 Hz</td></tr>
<tr><td>Observations:</td><td colspan="3">The Styrofoam balls were affected by the waves produced by the speaker. Even the tube absorbed some energy of the waves that was transformed to a vibration of the tube. It was possible to see clearly the standing waves at low frequencies, on the higher frequencies it was less visible.</td></tr>
<tr><td>Conclusions:</td><td colspan="3">The length of the tube taken to do this test is good enough to see clearly the standing waves which mean that the equipment is well proportioned.</td></tr>
</table>

After the experiments this tube has shown to be more proportioned to produce standing waves. It is also more practical due that you can vary the length of the zone with Styrofoam letting more space inside to create the “towers” and create a more optimum environment to produce the waves. The importance of good sealing of the tube with the support it has been also probed.

III Experiment

After finding the working equipment in the previous chapter it is possible to make the Kundt's tube experiment. The goal of this experiment is to observe the standing waves. After observing the standing waves experiments were done to cancel the waves. During these experiments the beat phenomenon was observed. After this observation, more experiments for the beat were performed. In this chapter, the results of these experiments will be discussed.

10. Kundt's Tube

In this chapter, the experiments of Kundt's tube will be explained. The testing is done with the plastic tube in different lengths. It is tested with a closed pipe and with an open tube. The experiment is also tested with one side open and one side closed. This happened in each way. The first chapter is about the closed tube on both sides.

Experiment closed – closed

For this experiment the long plastic tube had been used. This tube is adjusted on three lengths, the first is 1500 mm, 1000 mm and the last 500 mm. With these lengths is the closed tube tested. When the tube was 500 mm no waves were detected.

The theory to calculate the frequency in addition to the wave length is used. This theory is for the closed-closed and opened-opened tube. This will be calculated with the following formula: $\lambda=(2/n) *(L+0,8d)$ n= 1,2, 3... Here is L the length of the tube and d the diameter. After this step, the frequency can be calculated with the formula: $f = c/\lambda$. This formula is extended explained in paragraph of the glass tube.

In the following tables, there can be seen the wavelengths in addition to the frequencies in theory. In the last column of the table is the result of the experiment given. If the wave was visible in the tube the cube is green and the frequency is being given.

Table 37: Frequencies closed - closed 0,5 m

n	L	d	λ=(2/n) *(L+0,8d)	c	f = c/λ	Wave visible (Hz)
1	0,5	0,104	1,1664	340	291,4951989	No
2	0,5	0,104	0,5832	340	582,9903978	No
3	0,5	0,104	0,3888	340	874,4855967	No

Table 38: Frequencies closed - closed 1,0 m

n	L	d	λ=(2/n) *(L+0,8d)	c	f = c/λ	Wave visible (Hz)
1	1	0,104	2,1664	340	156,9423929	170
2	1	0,104	1,0832	340	313,8847858	340
3	1	0,104	0,722133333	340	470,8271787	510

Table 39: Frequencies closed - closed 1,5 m

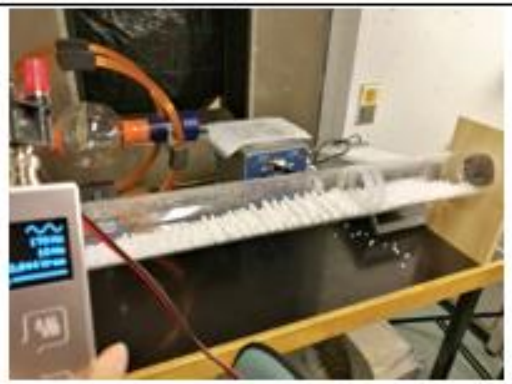
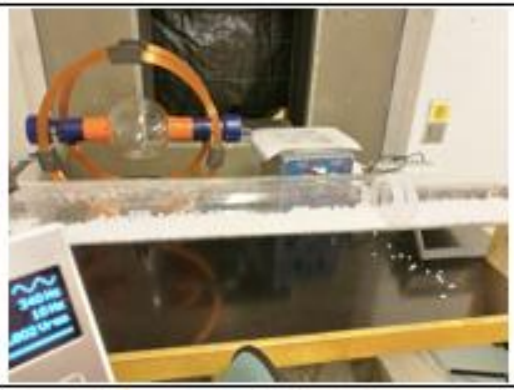
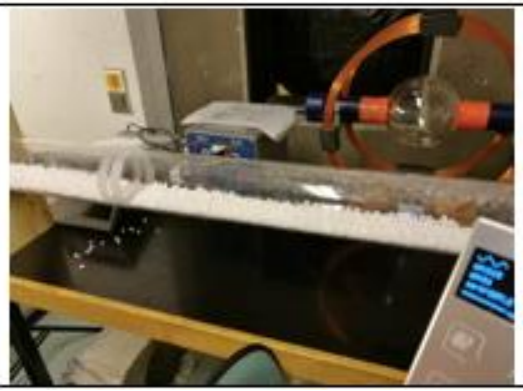
n	L	d	λ=(2/n) *(L+0,8d)	c	f = c/λ	Wave visible (Hz)
1	1,5	0,104	3,1664	340	107,3774634	100
2	1,5	0,104	1,5832	340	214,7549267	230
3	1,5	0,104	1,055466667	340	322,1323901	340

There can be concluded that the frequencies with the tube of 1000 mm and 1500 mm are not exact the same as in the theory but the reality comes very close.

In the tube of 50 mm there were no waves visible. When the tube was 1 meter there were waves visible at 170, 340 and 510 Hz. In the tube of 1,5 meter the waves were also visible at three frequencies namely, 100, 230 and 340 Hz.

In the following table the pictures of the experiments are shown. Here are the waves with the particular frequency of the two longest tubes.

Table 40: Closed - Closed 1 meter; Closed – Closed 1,5 meter

Frequency (Hz)	170	340	510
Picture			

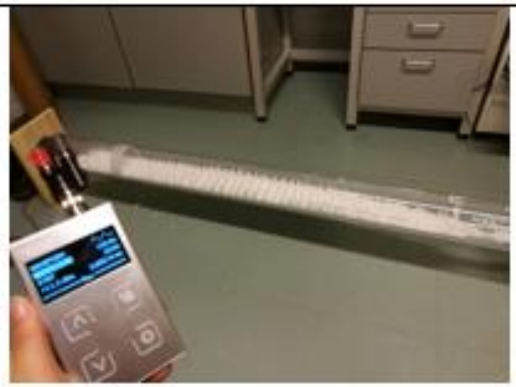
Frequency (Hz)	100	230	340
Picture			

Table 41: Experiment closed tube 0,5 m

Experiment	Closed tube 0,5 m		
Materials used:	Plastic tube Styrofoam balls Speaker (30 - 50 W) Signal generator Amplifier Support Piston	Length of the tube:	50 cm
		Frequency:	292 Hz 583 Hz 875 Hz
Observations:	The Styrofoam balls had no vibration on the frequency points.		
Conclusions:	The tube takes a lot of energy from the sound and the power of the speaker is maybe not enough. It is also possible that the tube is not long enough to have the same relationship between the diameter and the length of the tube.		

Table 42: Experiment closed tube 1,0 m

Experiment:	Closed tube 1 m		
Materials used:	Plastic tube Styrofoam balls Speaker (30 - 50 W) Signal generator Amplifier Support Piston	Length of the tube:	100 cm
		Frequency:	170 Hz 340 Hz 510 Hz
Observations:	The Styrofoam balls had vibration on the frequency points. It was possible to see the standing waves.		
Conclusions:	On the low frequency, the waves are the best visible. However, on all the 3 frequencies the waves were visible.		

Table 43: Experiment closed tube 1,5 m

Experiment:	Closed tube 1,5m		
Materials used:	Plastic tube Styrofoam balls Speaker (30 - 50 W) Signal generator Amplifier Support Piston	Length of the tube: Frequency:	150 cm 100 Hz 230 Hz 340 Hz
Observations:	The Styrofoam balls had vibration on the frequency points. It was possible to see the standing waves.		
Conclusions:	On the low frequency, the waves are the best visible. However, on all the 3 frequencies the waves were visible.		

In conclusion, the length of the tube has an influence in the experiment results. In the next part the opened – opened tube is discussed.

Experiment opened – opened

There is worked with an open plastic tube in these experiments. On both sides the tube is not closed with support. This means that there will be ½ wave. This is the same for the closed-closed tube but now there will be two anti-nodes, at the end and the beginning of the tube. In the experiment were 3 frequencies where the waves were visible. However, the waves were not visible enough. The Styrofoam balls were a little vibrating. The balls were not vibrating enough to show the experiment with an open tube to an audience.

For this experiment, the same theory as in the closed – closed experiment is used. In this part, the formula is further explained. In the last column of the table is the result of the experiment given. If the wave was visible in the tube the cube is green and the frequency is being given.

Table 44: Frequencies open-open 1,64 m

n	L	d	λ=(2/n) *(L+0,8d)	c	f = c/λ	Waves visible (Hz)
1	1,64	0,104	3,4464	340	98,6536676	100
2	1,64	0,104	1,7232	340	197,3073352	190
3	1,64	0,104	1,1488	340	295,9610028	No
4	1,64	0,104	0,8616	340	394,6146704	390
5	1,64	0,104	0,68928	340	493,268338	No

Table 45: Experiment opened tube 1,64 m

Experiment:	Opened tube – 1,64m		
Materials used:	Plastic tube Styrofoam balls Speaker (30 - 50 W) Signal generator Amplifier Support	Length of the tube: Frequency:	164 cm 100 Hz 190 Hz 390 Hz
Observations:	The Styrofoam balls had a little vibration on the frequency points, but it was not close to observe the standing waves.		
Conclusions:	The power of the speaker is maybe not enough. It is also possible that the tube is too long to have the same relationship between the diameter and the length of the tube.		

Experiment opened – closed

This experiment consists on fixing the piston to a length of 1.5 meters and the speaker 1 cm from the entrance of the pipe. After that put some Styrofoam balls inside the tube. As shown in the sketch. Finally, with the signal generator a sinusoidal wave it is added inside the tube to certain frequencies calculated with the following formula in addition with a correction for the diameter of the pipe:

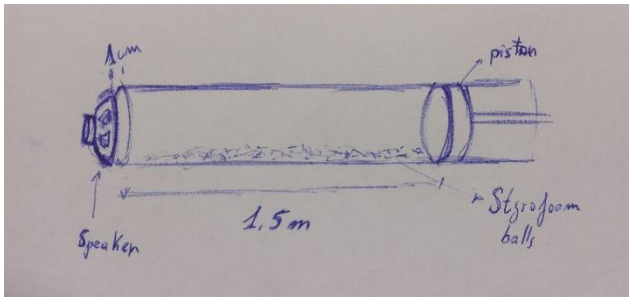


Figure 76: Sketch of the Open-Closed tube

$$\lambda = \frac{(L + 0{,}4 \cdot D) \cdot 4}{n}$$

Table 46: Calculations of frequencies for Open-Close Pipe

n	L	D	C	λ_1=L*4/n	f_1=c/λ_1		λ_2=(L+0,4D) *4/n	f_2=c/λ_2	Error	Wave visible(Hz)
1	1,5	0,104	340	6,00	56,67		6,17	55,14	1,53	No
3	1,5	0,104	340	2,00	170,00		2,06	165,41	4,59	No
5	1,5	0,104	340	1,20	283,33		1,23	275,69	7,65	No
7	1,5	0,104	340	0,86	396,67		0,88	385,96	10,70	No
9	1,5	0,104	340	0,67	510,00		0,69	496,24	13,76	No

It can be observed that the differences between the calculations with correction of diameter and the calculations without correction increase at the same time with n (number of ¼ of wavelength). This means that when n is higher (more waves inside the pipe), bigger will be the error associated to the diameter.

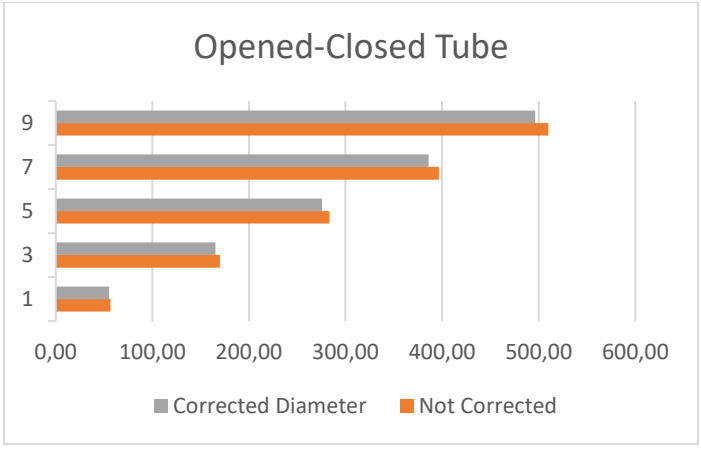


Figure 77: Error between corrected and uncorrected pipe

On frequencies tested the most similar look to the phenomenon of standing waves was seen on the lower frequencies. When frequency is risen to higher overtones the effect of standing waves become too small to be noticed.

After the experimentation, there are no signs of standing waves on the frequencies calculated, it is observable movement on top of the Styrofoam, but not enough to create the desired phenomenon. Although some corrections have been made to reduce errors and to make more visible the waves, it can be concluded that there is too much damping in certain factors as loss of pressure at the entrance of the tube and vibration of the tube.

Table 47: Experiment Opened-closed tube 1,50m

<table>
<tr><td>Experiment:</td><td colspan="3">Opened- closed tube – 1,50m</td></tr>
<tr><td rowspan="2">Materials used:</td><td rowspan="2">Plastic tube
Styrofoam balls
Speaker (30 - 50 W)
Signal generator
Amplifier
Support
Piston</td><td>Length of the tube:</td><td>150 cm</td></tr>
<tr><td>Frequency:</td><td>55Hz
165Hz
276Hz</td></tr>
<tr><td>Observations:</td><td colspan="3">The Styrofoam balls had no vibration on the frequency points.</td></tr>
<tr><td>Conclusions:</td><td colspan="3">The power of the speaker is maybe not enough. The speaker losses a lot of sound because the speaker is one centimeter from the tube. On the sides of the speaker the sound escapes.</td></tr>
</table>

Experiment closed – opened

This experiment consists on a signal generator that create a sinusoidal wave, that wave is transformed to pressure waves by a speaker situated on the support in attached to the tube inside of the piston as it is shown in the figure, this construction is inside of the pipe 1,5 meters from the tube outlet, which is opened, in the tube there are also Styrofoam balls which will show the standing waves.

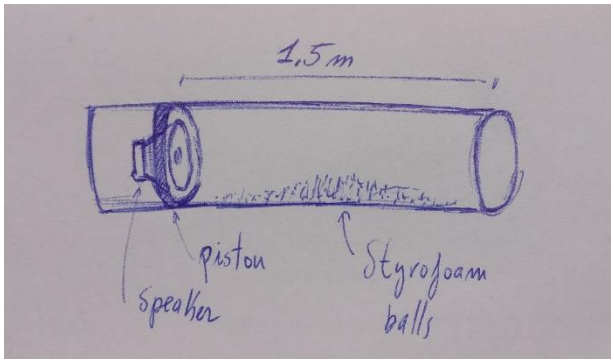


Figure 78: Sketch of the Closed- opened tube

The frequency is calculated using the same equations used in the Open-Closed tube, as a result the same frequencies are obtained.

First, the experiment has been tried without the wood support. The tube was just in front of a wood sheet. At 60 Hz, it was some movement on top of the Styrofoam, but not enough to achieve the desired result. At 170 Hz in the pipe was less movement than in the 60 Hz and when you rise the frequency to upper frequencies with possibility of standing waves it was less movement on each frequency. After that team concluded that the piston was not the best choice to recreate this Close-Opened distribution.

After that, the team implements a wood support. The experiment was retried with the wood support. Waves are created. For the first frequency 50 Hz, one peak can be observed until the end of the pipe (like the probe the theory part). For the second frequency 160 Hz, two peaks are showed and three peaks for the third 26 0Hz. After these frequencies, no other wave cannot be observed.

Table 48: Closed-opened tube 1,64m

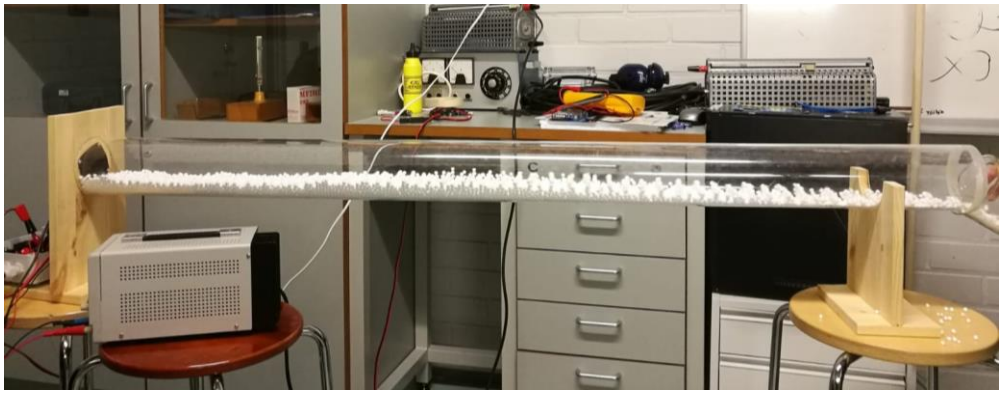
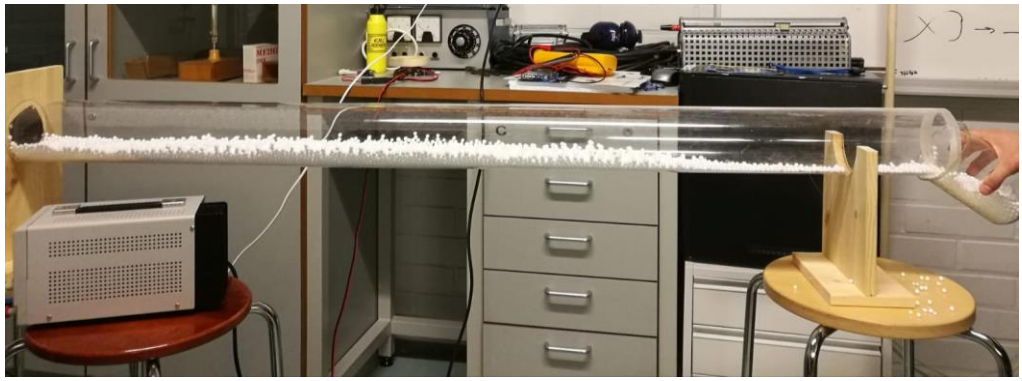
Frequencies	Pictures
50 Hz	
160 Hz	
260 Hz	

Table 49: Experiment Closed-opened tube 1,64m

Experiment:	Closed- opened tube – 1,64m		
Materials used:	Plastic tube Styrofoam balls Speaker (30 - 50 W) Signal generator Amplifier Support	Length of the tube:	150cm
		Frequency:	50Hz 160Hz 260Hz
Observations:	The Styrofoam balls made the standing waves on the three frequencies with the wooden support.		
Conclusions:	The tube needs to be very closed at one side to be able to show the standing waves.		

Conclusion

In conclusion, there can be seen that the waves are not always visible when according to the theory they should be. In practice this does not always appear to be the case. The waves are the best visible in the closed tube. They can be seen with the tube from 1 m and 1.5 m. The open tube let see a little vibration at 3 frequencies with a tube of 1.64 m. In the open-closed tube there was no vibration at all. The last experiment was with the closed-opened tube. Here the standing wave was visible on one frequency. It is very important to close the tube, to reduce as much as possible the loss of sound.

Technical form

The principal purpose of the EPS project is to be able to demonstrate the standing waves in a tube. To allow students to use the created system, a factsheet has been written. This factsheet contains the following elements: the objectives sought, the possible hypotheses adopted for the approach or the results expected, the methods envisaged, the means envisaged (equipment, protocol). At the end of each sheets, there is a table to complete during the experiment.

The Kundt's tube

1. To see the standing waves

) Equipment

- The plastic tube and its support
- The Styrofoam balls
- The piston
- The electric box

) Protocol

- Spread uniformly the Styrofoam balls inside the tube,
- Introduce the piston,
- Connect the electric box with the plug socket,
- Switch on the signal generator and choose one frequency,
- Move the piston in and out of the pipe till the resonance is obtained.

) Result

If a sort of wave and feel, some vibrations would be observed, the resonance and the formation of the standing waves would be seen.

) Exercise *(with example)*

Peaks	n (coefficient) 1, 2, 3 ...	Theory frequency (Hz) $\lambda=(2/n)*(L+0,8d)$	Experiment frequency (Hz)	Distance (m)
1 peak	*1*	*157*	*170*	*1*

11. Variant of Kundt's Tube

After the Kundt's tube experiment there is tried to make the cancelation of the waves in the tube. When the cancelation was tested, another phenomenon was discovered, the beat. In the first chapter the cancelation experiment will be discussed. After that, the beat phenomenon, what was discovered during the tests of the cancelation, will be explained.

Cancellation

In this chapter, the experiments implemented attempting to achieve the objective to cancel the sound inside the pipe are explained. The experiments that are designed are very primitive and with only the objective that some grade of cancellation is possible. To achieve that goal, the equipment changed. There has been made use of the same equipment as with the Kundt's tube experiment. Besides that, a new speaker with a piston is used for the other side of the tube. For this speaker, there is used another signal generator.

This experiment consists 2 speakers looking at each other inside the pipe with Styrofoam in between the speakers. Then one of the speakers is turned on. The signal generator sends a sinusoidal wave at the exact frequency to produce the fundamental standing wave (figure 79). Then the other speaker is also turned on and with another signal generator another sinusoidal wave is sent at the same frequency (figure 80). If it is not possible to achieve the cancel doing this, then it means that two signals are out-of-phase. To solve this the frequency of the second signal generator is reduced one hertz. Doing this beating phenomenon is produced and the last step needed to see the cancellation is to change to the frequency again to the initial frequency when the 'towers' produced are on it is minimum height doing that it is possible to achieve that waves were anti-phased.

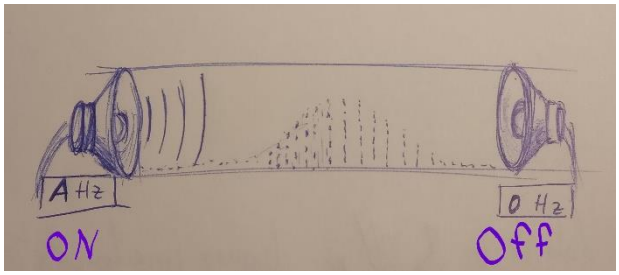


Figure 80: Sketch of the first step of the experiment

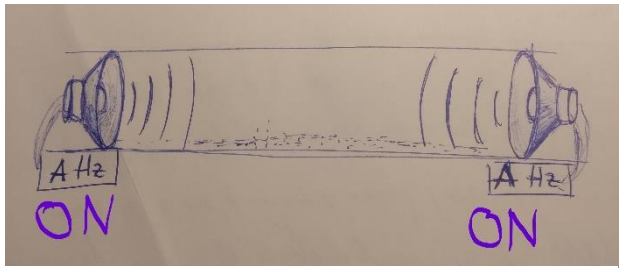


Figure 79: Sketch of the final step of the experiment

After doing the experiments described on previous part the results obtained were not the ones expected. When the same frequency is sent to the speakers standing waves produced by the speakers are not stable, the 'towers' created slowly reduce their height and then rise again.

Conclusion

Analysing the results obtained there can be concluded that the instability of the towers is caused by a slightly difference between the frequency of signal generators. That cause that the addition of signals (inverted and non-inverted) is not 0. Consequently, after a period this slight difference is accumulated and become bigger until the two signals are 'in-phase'. After that point after some time the signals becomes more and more 'out-of-phase' until they are anti-phased. Repeating this cycle again. This can be probed with the simulation (Figure 81).

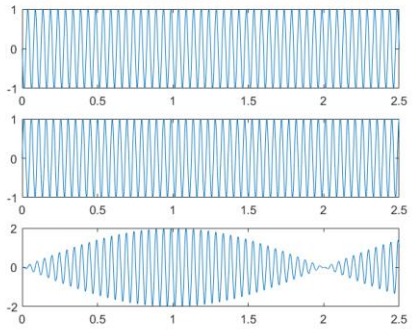
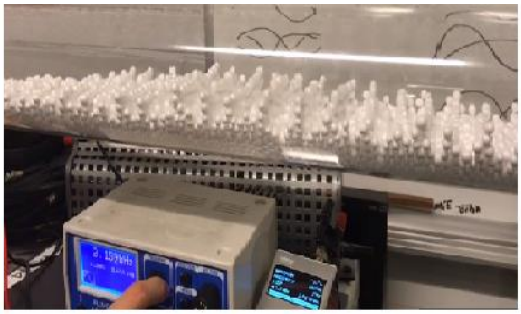


Figure 81: Simulation for 20Hz vs 20.5Hz

The beat phenomenon

In this chapter, the beat phenomenon will be studied. The reference frequency is 160 Hz. The beat is observed as the same way as in the theory part. The table below show the difference if the two signal generators sent the same frequency or close frequencies.

Table 50: Experiment beat phenomenon

$f1$	$f2$	Pictures	Beats
160	160		No
159	160	 	Yes (difference between the both amplitudes)

For these experiments two cases are treated. The first experiment studied is if the both frequencies are equal. There are two results: the wave is in the tube, or the cancelling wave is observed. If there is a wave, the noise is amplified, on the other hand, if there is not wave, the cancelling wave can be studied (this case has been studied in the previous chapter). The second experiment is if the two frequencies are close. Close means two or three hertz between the both. In this case, the noise is jerky and the amplitude difference can be considered.

The below table describes the case if the two frequencies are the same.

Same frequencies:

Table 51: Beat phenomenon with same frequencies

<table>
<tr><td>Experiment:</td><td colspan="3">Same frequencies</td></tr>
<tr><td rowspan="2">Materials used:</td><td rowspan="2">Closed plastic tube
Styrofoam balls
Speakers
Signal generators
Amplifier
Support</td><td>Length of the tube:</td><td>1m</td></tr>
<tr><td>Frequency:</td><td>160</td></tr>
<tr><td>Observations:</td><td colspan="3">The substance used move (up and down) slowly</td></tr>
<tr><td>Conclusions:</td><td colspan="3">We do not hear and see the beat</td></tr>
</table>

The below table describes the case if the two frequency are close.

Different frequencies:

Table 52: Beat phenomenon with different frequencies

<table>
<tr><td>Experiment</td><td colspan="3">Different frequencies</td></tr>
<tr><td rowspan="2">Materials used</td><td rowspan="2">Closed plastic tube
Styrofoam balls
Speakers
Signal generators
Amplifier
Support</td><td>Length of the tube</td><td>1m</td></tr>
<tr><td>Frequencies</td><td>159
160</td></tr>
<tr><td>Observations</td><td colspan="3">The substance used move (up and down) periodically</td></tr>
<tr><td>Conclusions:</td><td colspan="3">The beat phenomenon can be heard every second.
$f1 = 160Hz$
$f2 = 159\ Hz$
$fb = \lvert 160 - 159 \rvert = 1$
$t = \frac{1}{1} = 1s$</td></tr>
</table>

Conclusion

The team tried to reduce the noise and observed a beat phenomenon. The beat phenomenon is used to calibrate the musical notes of an instrument. On the other hand, the cancellation of the wave only works in intervals of seconds.

Technical form

The principal purpose of the EPS project is to be able to study the beat phenomenon. To allow students to use the created system a factsheet have been written. This factsheet contains the following elements: the objectives sought, the possible hypotheses adopted for the approach or the results expected, the methods envisaged, the means envisaged (equipment, protocol). At the end of each sheets, there is a table to complete during the experiment.

The Kundt's tube

2. To understand the beat phenomenon

〉 Equipment

- The plastic tube and its support
- The Styrofoam balls
- The speaker piston
- The electric box

〉 Protocol

- Spread uniformly the Styrofoam balls inside the tube,
- Introduce the speaker piston,
- Connect the electric box with the plug socket,
- Switch on the first signal generator and keep the same frequency,
- Move the piston to the same position as before,
- Switch on the second signal generator and adjust the same frequency.

〉 Result

In this case, you heard a continuous noise when the frequencies are the same and a jerky noise when the frequencies are closed.

〉 Exercise *(with example)*

Experiment (close) frequencies (Hz)	Beat frequency (Hz)	Time (s)
160 & 163	$fb = \|160 - 163\| = 3$	$t = \frac{1}{3} = 0{,}33s$

IV Project management and accountability report

To support the project, there was a project management course. In this way, it was possible to achieve the desired result. In this chapter, the project management and accountability report will be discussed. The first chapter is about Human Resource Management. This chapter includes the Belbin tests, the project roles and the RACI matrix. The second chapter is about Time management. This chapter includes the milestones, the Work Breakdown Structure the schedule and the project hours. The third chapter is about Communication management. This chapter includes the stakeholder analyse, the logo and business card and the website. After this, the Quality management, the Change management and the Cost management will be described.

Human Resource Management

Belbin tests

The Belbin test is a good method to get an idea of which kind of roles the team members can best fulfil. It was created by Meredith Belbin, a British psychologist. This test consists of a questionnaire which will result in a spider web plot of certain personality types. This will allow to discover the potential strengths and vigilance of team member.

Let's read the description of each people of the team:

Marie:

	Coordinator	Shaper	Plant	Monitor	Implementer	Resource investigator	Team worker	Finisher
1	1	1	1	3	2	1	1	0
2	1	3	1	1	1	0	1	2
3	0	1	1	0	3	2	2	1
4	1	0	1	1	3	1	1	2
5	0	2	2	0	1	0	3	2
6	0	0	2	1	2	0	2	3
7	3	2	2	0	1	0	2	0
Tot	6	9	10	6	13	4	12	10

think act

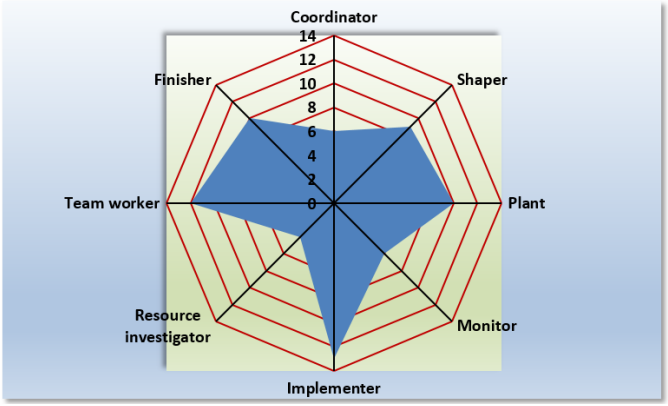


Figure 82: Belbin Test Marie

My best strengths role are team worker and implementer because my study permits (or allows) me to do lots of practical works and projects. I find it very interesting to work in a team, listen the idea of each person, compare and look for the best one. Also, when we have a problem, different people's skills can give their point of view and help to solve it. After, I need to plan a workable strategy and carry it out as efficiently as possible.

Sannah:

	Coordinator	Shaper	Plant	Monitor	Implementer	Resource investigator	Team worker	Finisher
1	1	1	0	1	2	2	2	1
2	2	2	1	2	2	0	1	0
3	2	1	0	2	1	1	2	1
4	1	2	0	2	1	2	2	0
5	0	1	1	2	2	3	0	1
6	2	2	0	1	0	2	1	2
7	2	3	0	0	0	3	1	1
Tot	10	12	2	10	8	13	9	6

think act

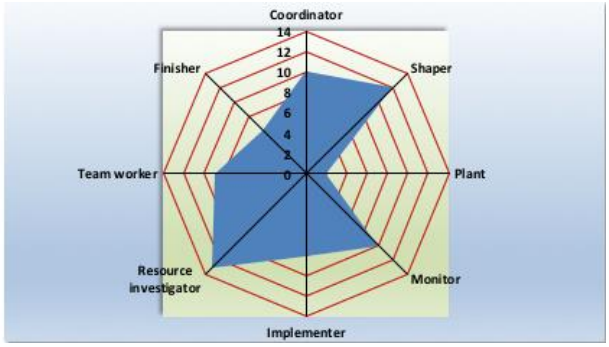


Figure 83: Belbin Test Sannah

According to the Belbin Test, my strengths in a project are the roles as Resource investigator, Shaper, Monitor, Coordinator and Team worker. My weaknesses in a project are the roles as Plant, Finisher and Implementer. In a project, I find it interesting to work and discuss with a group. It is useful to know everybody's strengths in a project. With knowing the strengths, everyone can do the task he/she is the best at. Looking to my weaknesses, I need to work on finishing things. This is also my main goal for this project.

Emma:

	Coordinator	Shaper	Plant	Monitor	Implementer	Resource investigator	Team worker	Finisher
1	1	2	1	2	0	2	2	0
2	2	1	0	2	1	1	2	1
3	2	3	0	3	1	0	1	0
4	2	2	0	1	2	0	3	1
5	1	1	0	3	2	0	3	0
6	0	1	3	3	2	1	0	0
7	1	2	0	3	1	1	2	0
Tot	9	12	4	17	9	5	13	2

think act

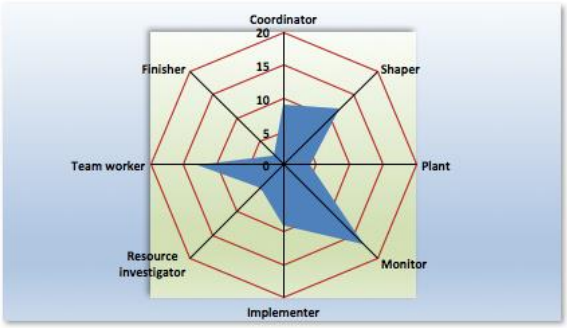


Figure 84: Belbin Test Emma

Clearly certain strengths were determined as a result of making the Belbin Test. My best strengths in a project are the roles as Monitor, Team worker, Shaper, Coordinator and Implementer. Monitor is by far my biggest strength. That means that I can judges impartially. An allowable weakness that comes with that is lacks drive and ability to inspire others. Besides that, you can conclude that I am more a thinker than I will act. My biggest weakness is Finisher, this means that it is important that we need someone in the group that ensures that we deliver on time. The Plant and Resource investigator are also not on my highest score.

Javier:

	Coordinator	Shaper	Plant	Monitor	Implementer	Resource investigator	Team worker	Finisher
1	0	1	3	2	2	1	0	1
2	0	4	3	2	1	0	0	0
3	0	0	0	3	1	1	1	4
4	0	3	1	2	2	0	1	1
5	2	0	0	3	0	0	3	2
6	0	3	3	1	2	0	1	0
7	0	3	2	1	0	3	0	1
Tot	2	14	12	14	8	5	6	9

think act

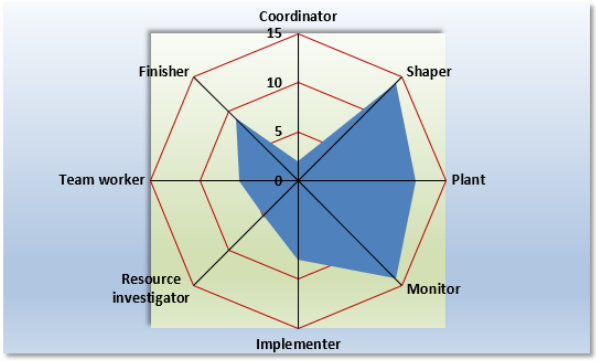


Figure 85: Belbin Test Javier

According to Belbin test when Javier works in a team tend to assume the roles of Shaper, Plant and Monitor roles, and try to avoid the roles of coordinator, resource investigator and team worker. That mean that he will contribute to team with creativity and different points of view to solve the problems that the team will face during the project. Also, with determination in crunch situations and he will thrive especially on pressure situations. However, as counterpoint there are allowed weaknesses related to these roles such as the lack of drive and ability to inspire others or being prone to provocation an easily offend people feelings.

Conclusion:

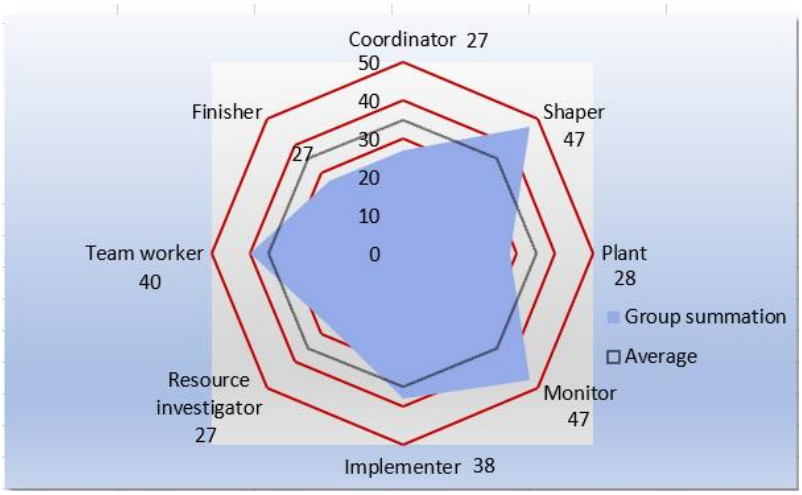


Figure 86: Belbin Test Combination

In the graphic is observable that there are some roles that are very much above the average like Shaper and Monitor. It could be a problem that Monitor is a dominant role due to the weakness associated, which is the lack of drive and the ability to inspire others. Also, the weakness associated to Shaper role which is prone to provocation and offending people feeling, nevertheless, it can be mitigated with the team worker role. The roles that are below the average are Coordinator, Finisher, Plant and Resource investigator. Some of those don't need to be that high, only need that some in the group got predominance to them for example the Coordinator, Resource Investigator and the Plant. That means that in the team maybe could be problems filtering errors.

Project roles

In the beginning of the project we made a team contract to lead the project with rules. In this team contract we divided the following roles; team manager, planner, secretary, final editor and administrator of Dropbox. In this paragraph, we will clarify these roles and who is responsible for this.

First you have the team manager. The team manager is responsible for the agenda of the meetings and lead these meetings. In our team Sannah van Duuren is responsible for this role. The second role is the planner. The planner is responsible for a good and feasible schedule, which is discussed with the team to come to a good dividing. The planner in our team is Emma Kleijn. After the planner, you have the secretary. The secretary is responsible for recording during the meetings. This concludes the team meetings and the meetings with the supervisor. The secretary in our team is Javier Valentin. We also have a final editor in our team. The final editor ensures that the report is checked when it is handed in and it looks neat. The final editor in our team is Marie Raynal. At least we also have an administrator of Dropbox. This administrator ensures that the Dropbox is clean and neat. This role belongs to Sannah van Duuren. The schedule and the agenda and secretary logbook is displayed in the appendix.

RACI

Delegation is an essential part of the project manager's role, identifying roles and responsibilities early in the project is important. That is why the RACI Matrix is made in the beginning of the project. It is important that the expectations of the people that are involved in the project are clear.

The RACI model is a straightforward tool used for identifying roles and responsibilities and avoiding confusion over those roles and responsibilities during this project. The acronym RACI stand for: Responsible, Accountable, Consulted and Informed.

The person who does the work to achieve the task is responsible. They have responsibility for getting the work done or decision made. The person who is accountable, is accountable for correct and thorough completion of the tasks. The consultant role is for people who provide information for the project. The opinion of this person or persons is important to a certain task. The last one is the informed role. The people kept information for a certain task. There is one-way communication. These are the people that are affected by the outcome, so need to be kept up-to-date.

In this figure, the matrix is shown. In this matrix, the four project members are mentioned, besides that the supervisor of this project is included in the matrix.

Legend RACI Matrix	
Responsible	R
Accountable	A
Consulted	C
Informed	I

Table 53: RACI Matrix

RACI Matrix		*Project members*				*Supervisor*
Project area	*Activity*	**Marie**	**Sannah**	**Javier**	**Emma**	**Kaj Rintanen**
Project management	Project scope	A	C	I	R	I
	Schedule	A	A	A	R	I
	Quality management	I	A	R	A	I
	Project costs	A	I	I	R	C
	Risk management	R	A	C	I	I
Milestones	Midterm report	R	R	R	R	C
	Final report	R	R	R	R	C
	Presentations	R	R	R	R	C
Realize Kundt's tube and ANC	Gather data	R	R	R	R	I
	Buy components	I	R	A	I	C
	Create Kundt's tube (small)	R	R	R	R	C
	Create Kundt's tube (big)	R	R	R	R	C
	Create ANC	A	A	R	A	C
	Testing experiments	R	C	A	C	I

Time Management

Milestones

To achieve the desired result milestones have been created by the project group. In this way, everyone has a clear idea about what are the main steps to pursue the main goal. The different milestones are put on the timeline. The project started on 3 September 2018. The next milestone was the start-up presentation in the middle of September. The experiment of Kundt's tube should work before the midterm presentation on 23 October. If the experiment is accomplished, making the working ANC and the software that comes with this takes most of the remaining time of the project. At last, on 17 December the final presentation will take place. The team is ready to give their biggest effort to complete all these milestones and to perfect finish this project.

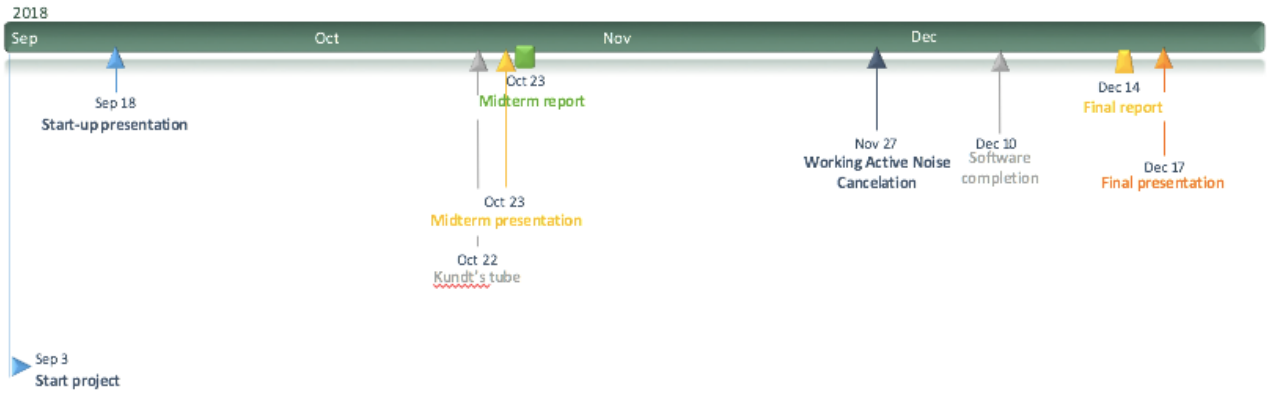


Figure 87: Timeline milestones

Work Breakdown Structure

This WBS gives a deliverable-oriented breakdown of the project into smaller components. In this way, it will be used to make the main tasks into manageable section. In the WBS the project is split down into five different main sections. Thereafter the WBS is further split down in subsections, in this way it gives insight into the needed time and resources. Below the elaborated WBS can be found.

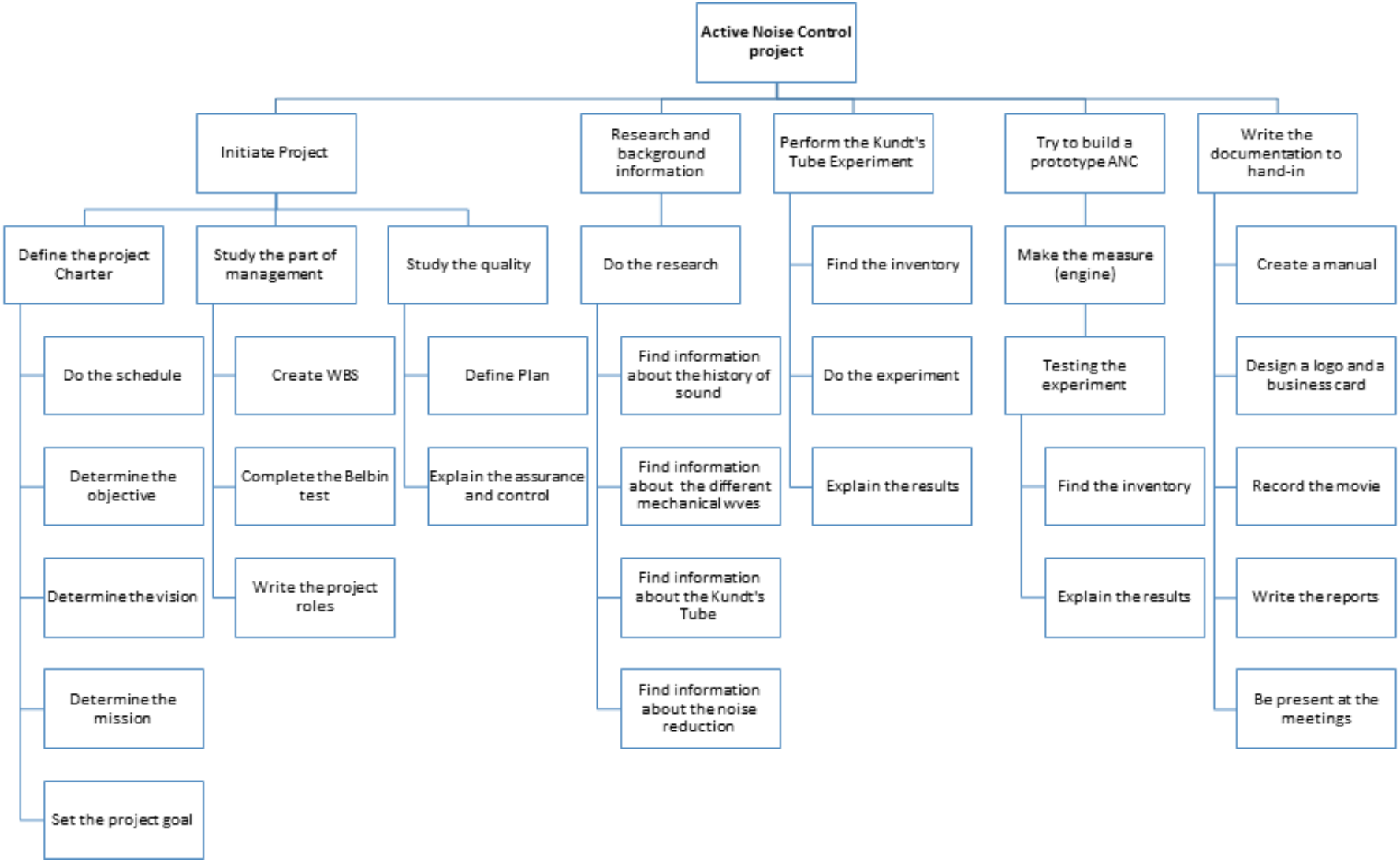


Figure 88: Work Breakdown Structure

Schedule

A precise constructed schedule is of great value for a good project. The schedule of the ANC project is based on Microsoft Excel. For each week is there a new planning. For each task, there is one person responsible. When the work must be finished is indicated with the deadline of the task. Besides that, in this planning the project members can indicate whether the work is finished or not. The schedule was managed by the planner.

During this project, the team members scheduled a meeting every week. During these weekly meetings, the important information and progress of the project were discussed. Also, during this meeting the goals for next week were set. Through this meeting every team member is informed, this prevents miscommunication. The most important things that were discussed during the meetings are written down by the project manager in the minutes of meetings. The minutes of meetings can be found in Annex 3.

Below, there is an example of the week planning. In this case, the schedule of week 11. The complete schedule is in Annex 2.

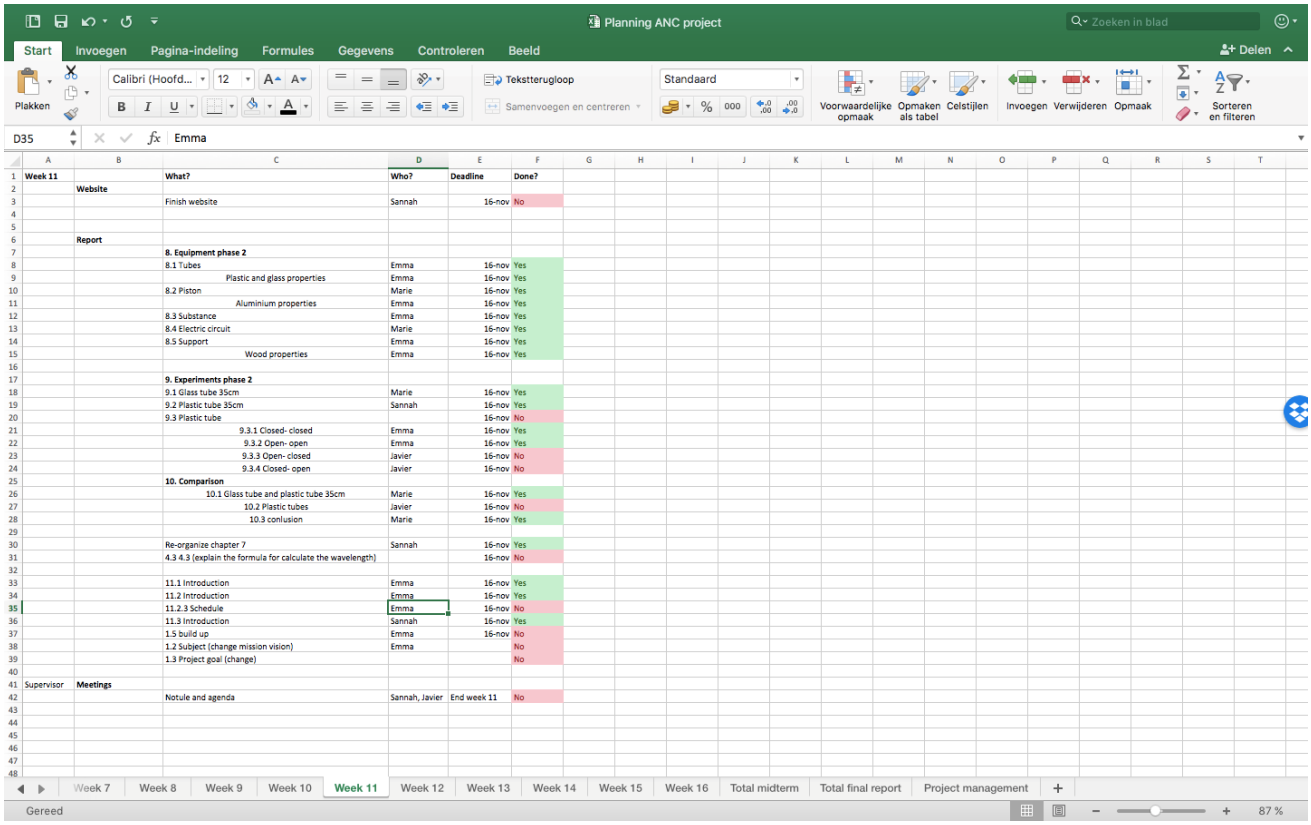


Figure 89: Planning

Project hours

This is a summary of the hours worked per week for each member of the team. In the beginning of the project, the team worked separately. It was difficult to talk together in a foreign language (English) about a scientific subject. So, both difficulties were met: to communicate and to work together. Final part of the project the team work together, regularly and similarly. To support the project hours the individual logbooks can be found in Annex 7.

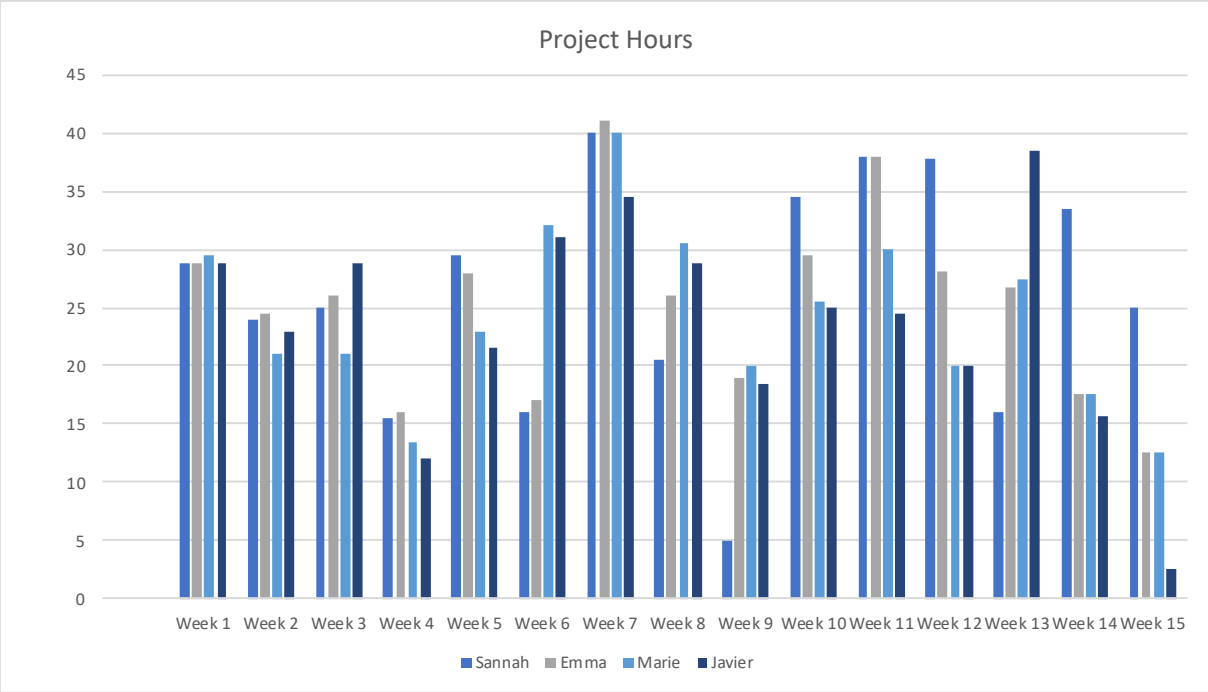


Figure 90: Project Hours

Communication Management

Stakeholder analysis

In communication management, it is about the dimension of communication. It can be divided into two groups, namely internal and the external stakeholders. The internal stakeholders are within the project. In this project, the internal stakeholders are the project team, Kaj Rintanen and Roger Nylund. The project team is working on the project, Kaj is the supervisor of the project and Roger is the leader of EPS and the teacher of Project Management.

The external stakeholders are outside the project, but they have different interests in the project. In this project, these are Hanna Latva, the other EPS students, students of Novia UAS or other universities in Vaasa and engineers in the branch. Hanna Latva is the English communication teacher. The other EPS students are also working on a project and need to give the team feedback. The students of Novia UAS or other universities in Vaasa can use the experiment to get more knowledge about the theory. Also, the research report can be used within another experiment/project about Active Noise Control. The engineers in the branch can use the research report to get more knowledge about the phenomenon.

After defining the different stakeholders in this project, it is necessary to divide them into the matrix that is shown below. Every stakeholder is divided into the matrix after the questions; how high/low is the power and how high/low is the interest. The division is shown for each stakeholder.

Project team

The project team is the stakeholder that is the closest involved in the project. They have high power and high interest. That is why they need to be **managed closely**.

Kaj Rintanen

Kaj is the supervisor of the project and checks the report. He has high power influence and high interest. That is why the team need to **manage closely**.

Roger Nylund

Roger is the leader of the EPS project and the teacher of Project Management. His interest is high, but his power is low. That is why the team need to **keep** him **informed**.

Hanna Latva

Hanna is the English communication teacher and checks the report on the grammar and spelling. Her power in the project is high, because she marks the report. The interest in the report is low. That is why the team need to **keep** her **satisfied**.

EPS students

The other EPS students have low power influence and low interest. That is why the team should **monitor** them.

Students

Students from different universities in Vaasa including Novia UAS, can use the experiment for more knowledge. On this moment, they have nothing with the project, but when the project is finished, the experiment and the research report can be used during lectures. For now, they only need to be **monitored**.

Engineers

The engineers in the branch can use the research report to move on with the research about the possibilities of active noise control in an open space. The project is not made for engineers, that is why they only need to be **monitored**.

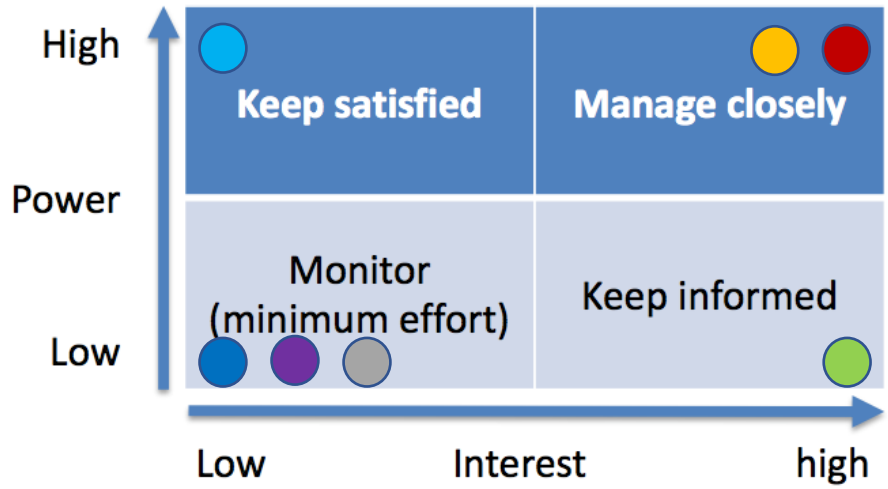


Figure 91: Stakeholder analysis

Concluded it is important to manage the project team and Kaj Rintanen closely. After this it is important to keep Roger Nylund informed and keep Hanna Latva satisfied. The other EPS students, the students of Novia or others and the engineers in the branch should be monitored. The team need to take this into account to succeed the project.

Logo and business card

The team of European Project Semester Active Noise Control decided that it would be a good idea to have its own logo to identify the team. The logo is to represent the team and it shows where the project stands for. It reflects the union between the sound and the wave. The logo shows a speaker that sends out a sound wave. The goal of the project is to cancel the noise, so the wave takes the form of the word “Silence”. The logo appears on all computer-generated documents such as: presentations, the midterm-report, the final report, minutes of meeting, the business card and agendas. The logo was chosen during one of the weekly meetings.

Figure 92: Logo

The business card makes it easier to share the project goal and contacts details. It can be given to other people and companies to make an easier contact.

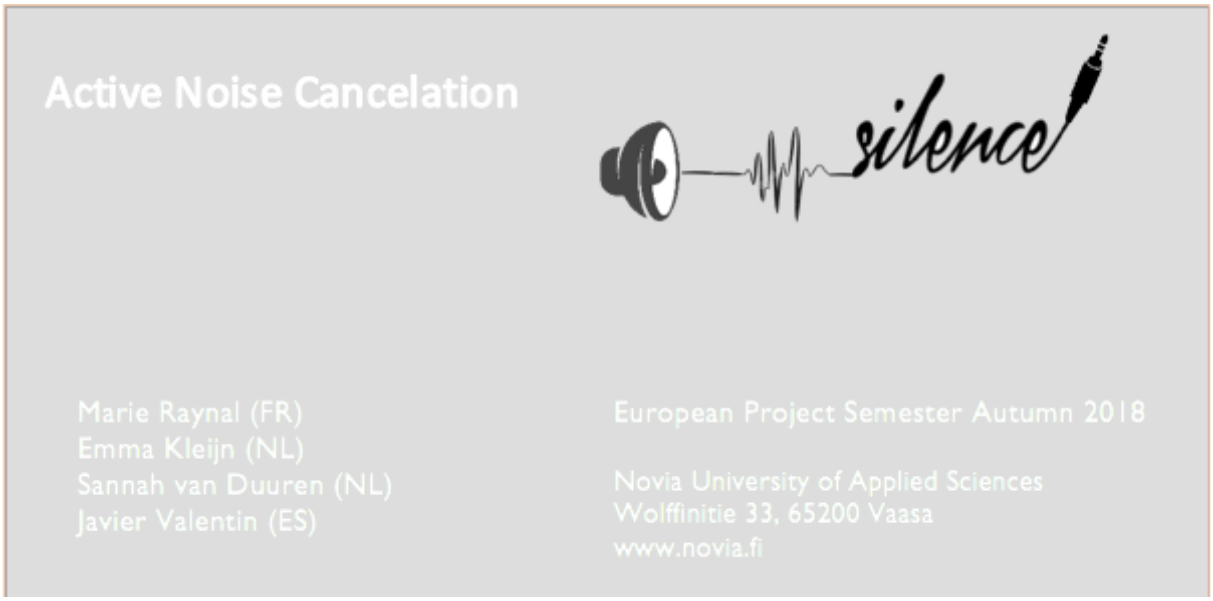


Figure 93: Business card

Website

According to the EPS course book it is described that the team should make a website to present the project. This is needed, because other students can visit the website if they want more information about the project.

The website is divided into three pages, namely 'Home', 'About' and 'Project'. In the homepage, there is a short explanation about the European Project Semester and about Novia University of Applied Sciences. When you click on the homepage on the bottom "About", you will be referred to the second page of the website. On this page, there is an explanation about the design of the logo. The mission, the vision and the objectives are described, and the team members present themselves.

At the project page, first the subpages are described. These are Kundt's tube and the experiments. In the part of Kundt's tube, the history, the theory and the protocol of the experiment are described. In the experiments part, there are two phases. The first phase of experiments is before the midterm. The second phase is after the midterm with a change in the equipment.

The pictures of the website and the URL can be find in the appendix.

Quality Management

To ensure a quality writing in the project it is important that the different parts added to the report have to be written in formal style. This involves the usage of an accurate grammar and spelling, complex words, complex expressions, single-word verbs, passive structures instead of active voice, impersonal tone and structures, also avoidance of contractions and slang as well as incomplete lists, emotions and humour. Furthermore, the report must be written to

convey relevant facts in an effective, objective and informative manner. Finally, it must be well-structured and easy to read.

To guarantee the quality content will be thoroughly researched and double checked via the four-eyes principle. To collect information, verified sources will be used which add credibility and reliability. Finally, if any type of discrepancy or doubts appear these will be consulted with experts.

The next figures are a cause and effect diagram or fishbone diagram for some of the problems associated with some of the quality aspects to keep in mind in this project.

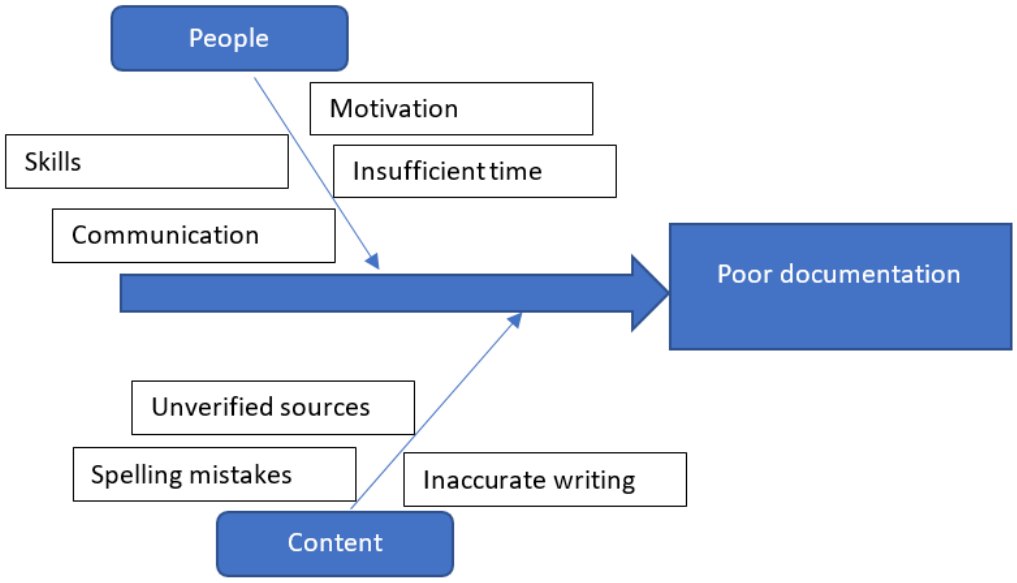


Figure 94: Fishbone diagram for poor documentation statement

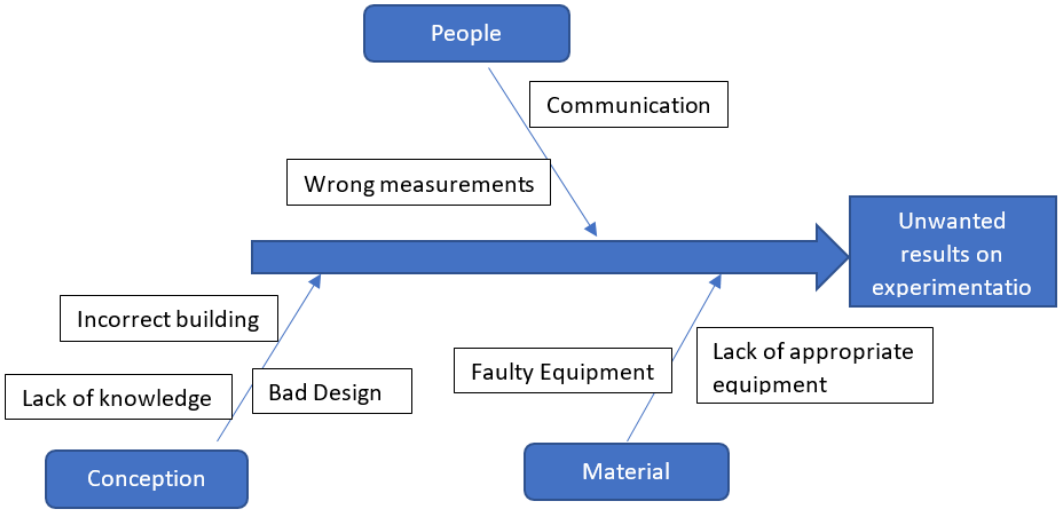


Figure 95: Fishbone diagram for unwanted results on experimentation statement

Change Management

The change control process establishes the stability necessary for the team to manage the multitude of changes that effect the project throughout its life cycle. (Heagney, 2011)

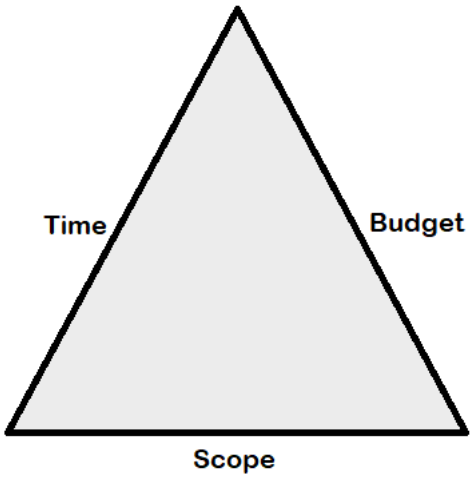


Figure 96: Triple constraints triangle

During the project, many problems can occur. That is why, the team decided to try as hard as possible to not meet them. The change control process is the result of the project scope, project cost or budget, project schedule, project roles, project quality and risk management. The change control progress can be compared with a triangle. Each side represents a word: budget, scope and time. If one of them is hit, they have an impact on the project. The goal for the team is to make necessary adjustments on its plans to keep the triangle balanced. For this project, the scope is defined by the tutor and can be changed. On the other hand, the team can meet problems encountered by engineering. The schedule is very important for the team. Indeed, the deadline is fixed for the beginning of the project. Finally, the budget is treated on the project budget part. To control the change, the team made a table where the changes are listed.

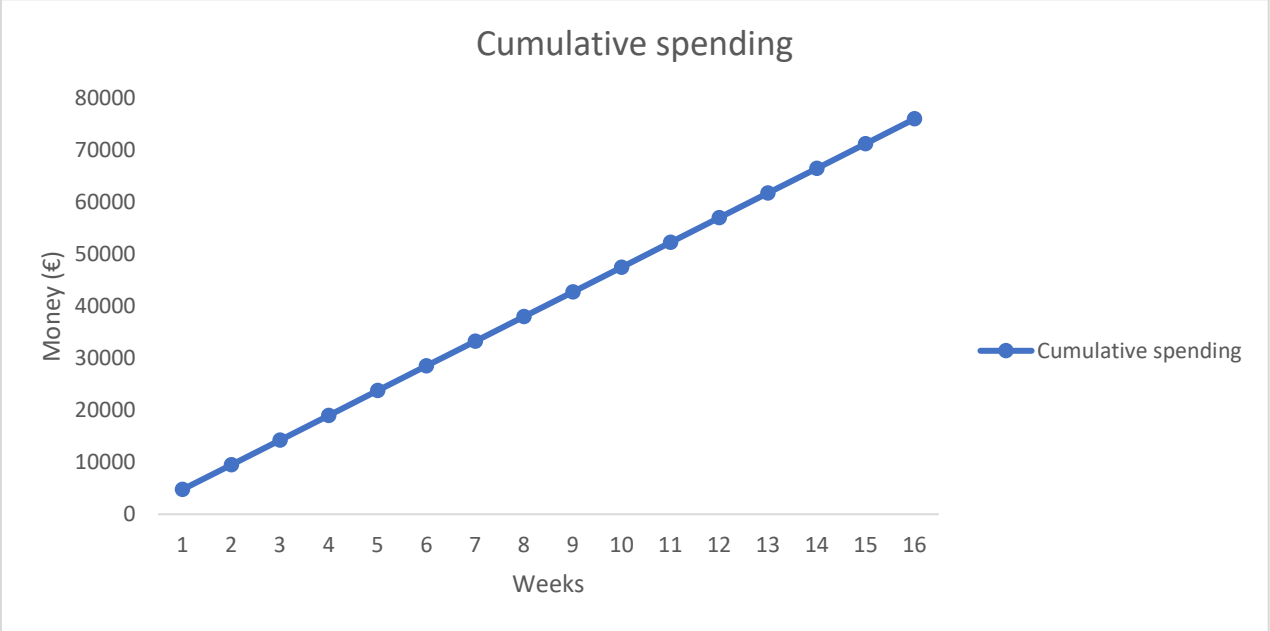
It is important to control and understand the changes because they can appear easily, but they may have a real impact on the project.

Change number	Date of change	Description of change	Requested by	Schedule impact	Budget impact	Comments
1	Tuesday 11-09-2018	To create an ANC system	The tutor	No	No	First project goal
2	Tuesday 02-10-2018	To build a pipe with standing waves to demonstrate them	The team and the tutor	Yes 1 week	No	So, difficult to build an ANC system, to make some research about standing waves
3	Monday 22-10-2018	To buy new equipment for the experiment (two new speakers, an amplifier, a power source, wires, Styrofoam balls, wooden plats and a glass pipe)	The team and the tutor	Yes 2 days	Yes (Budget cost)	Did not work with the first equipment, to assemble the different components
4	Tuesday 06-11-2018	To cancel the standing waves in a pipe	The team	No	Yes	To Cancel standing waves in a pipe whereas to cancel sound in a room

Table 54: Changes of the project

Cost Management

Concerning the budget managing the project group generated a list of every cost it will have to full fill. All possible fixed costs and variable costs will be defined. When all costs have been determined, the authorized costs baseline is obtained. The fixed costs correspond with the costs for the components of the tests. These costs are added up and can be seen in the table 40: Project costs. The other costs are the labour costs of the project group. This is determined based on the average wage of starting engineers. This is set up as a weekly salary of $ 1354,17 = € 1187,63. This amount has been multiplied by four.



Graphic 1: Cumulative spending

Table 55: Project costs

ANC Project Autumn semester	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**	**Week 6**	**Week 7**	**Week 8**	**Week 9**	**Week 10**	**Week 11**	**Week 12**	**Week 13**	**Week 14**	**Week 15**	**Week 16**
					135 €	← Signal generator										
					15 €	← Speaker 2W and AC powercord										
				Speaker 5W →				8,79 €								
				Speaker 30W →				11,25 €								
				Power source →				28,19 €								
				Amplifier →				23,39 €								
				AC powercord →				1,85 €								
				Speaker cable →				9,68 €								
								3,23 €	← Cable tie red							
								27,74 €	← Mounting box							
								2,50 €	← Accesoires piston							
								19,00 €	← Styrofoam balls							
								12,95 €	← Wood							
	← Hypotetichal Engineering Saleries 4750,52 €/week →															
Weekly spending	4750,52	4750,52	4750,52	4750,52	4750,52	4750,52	4750,52	4750,52	4750,52	4750,52	4750,52	4750,52	4750,52	4750,52	4750,52	4750,52
Cumulative spending	4750,52	9501,04	14251,6	19002,1	23752,6	28503,1	33253,6	38004,2	42754,7	47505,2	52255,7	57006,2	61756,8	66507,3	71257,8	76008,3

VI Conclusion

In this chapter, there is a look back to the report. Besides that, the results, the critical reflection of the team and a personal reflection of the team members will be discussed.

12. Conclusion

At the start of the project it was clear that there is a lack of knowledge of the team about Active Noise Control. During the research the team came to a compromise to take a step back in the difficulty of the project. After this decision, the research part about the mechanical waves has started. Because of this decision, the mission and vision were changed regarding the beginning of the project. During these weeks, there was not only research, but also tests for the Kundt's Tube experiment and the variants. In the first place, the tests were done to find the working equipment. There were different substances tested and different kind of tubes. To figure out which one is the best to observe the standing waves.

After the midterm report it was for the team time to start with the experiments, to show the standing waves and make cancelation in the tube. After the testing phase in the midterm report it was clear what was needed to make the experiments work. There was a lot of background information and the results that needed to be achieved were clear. After a lot of experiments there could be seen that the theory is not always working in practice. The closed-closed end the closed-open of 1 meter are both working very well on the three calculated frequencies. The open-open and the open-closed tube, on the other hand, do not work. After that, the cancelation was tested this was a more difficult challenge for the project team. This cancelation works to a certain extent. It was not possible for the team to find out more about this because there was not enough time. During the tests of the cancelation, the beat phenomenon was observed. After this, the project team did research to the phenomenon.

In conclusion, the mission and vision for this project are achieved. After a lot of research about Active Noise Control and the theory about Kundt's tube, and a lot of experiments further, the project team was able to show the standing waves on certain frequencies. Last, the team can show something and explain about the Active Noise Control and even about the beat phenomenon.

If there was more time the project team would further discussed the cancelation. More research needed to be done. Experiment after experiment needed to be performed to see what is happening and try to make the cancelation work.

13. Reflection

Critical reflection

In our project, we did research about all the technology needed to build an ANC system. We did research about physics, specially acoustics, electronics, treatment of signals, control systems and adaptive algorithms. We achieved a good understanding of those subjects but, nevertheless the difficulty of pass from the theory part to practice part is difficult, especially when several subjects as in our case are involved. In our case the availability of commercial electronic devices especially designed to treat signal and process data of the different sources was a mayor problem to build the ANC device.

During the semester, we have got some problems caused by the initial definition of the scope of the project. From the beginning, it was not realistic with the time that we had, the previous knowledge in the different subjects involved in active noise control and the complexity of those subjects. On summary, it was too ambitious. For this reason, we had to resize the scope of the project several times and redo some of the work done previously. Consequently, it also has reduced the total effective time and may have caused some disappointment at certain moments. However, we solved those issues to deliver the project in time and with the actual targets complete.

General reflection

Javier:

Doing a project like EPS Vaasa for me has been an enriching experience. Work in a team with people from other countries made me realize advantages and difficulties of working in an international group, and with help of the courses inside the EPS how to take profit or overcome those situations. It also allowed me to visit a country completely different from Spain. If I had to choose again I would do it without hesitation.

Marie:

This EPS was for me a rewarding experiment. I was able to learn different things about the acoustic and the Kundt's tube experiment. I did not know that it is possible to see standing waves in a tube. On the other hand, this semester taught me how to work in international student group and how to lead a project. I visited many countries and cities. If I had to recommend an exchange semester, the EPS in Finland will be my first choice.

Sannah:

These last 4 months in Finland were an amazing experience. During the project, I learned a lot about the acoustics and the cancellation. Besides that, I also learned from the supporting courses and workshops. I learned about my straights and my position in the team. Besides the project, I also did amazing trips in the area. This semester was a lifetime experience I would never forget.

Emma:

This 4 months working on this project was an amazing experience. I learned a lot from all the people around me. Besides that, it was rewarding to work in a project group with people from other countries. It was more difficult, but I learned a lot from it. It was a good advantage that I could do a whole different project. I learned things about acoustics and cancelation. I think Finland is a beautiful country and I do not regret my choice for the EPS in Vaasa.

List of figures

List of tables

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Appendices

Annex 1: Website

As mentioned in the report, there is made a website to present the project to students or persons who are interested in the topic/project. Beneath are pictures of the website but to see the real website you can visit: http://active-noise-control.jimdosite.com

Active Noise Control

The logo chosen to represent the team and shows where the project stands for. It's a reflection of the union between the sound and the wave. The logo shows a speaker that send out a sound wave. The goal of the project is to cancel the noise, so the wave takes the form of the word "Silence".

Mission and vision

The definition of the problem of the project the lack of knowledge about Active Noise Cancelation. To accomplish the project, we intend to make a mission and vision statement.

The mission statement is about what there is intend to accomplish with the project. The mission of the project is as follows; The mission of this project is to get more overall knowledge for people about ANC. The vision emerged from the mission. Namely, the people understand the standing wave and have basic knowledge about ANC.

The objectives of the project are clearly formulated with the SMART model. This method is used when you have to identify specific marketing objectives, your long-term goals. When setting future objectives for marketing it is useful to look hard at each measure and consider if it is essential. The SMART model helps as a test or filter which you can use to assess the quality of the project

Specific
Give a demonstration about standing waves and noise reduction.

Measurable
Be able to observe the standing waves. One wave around the frequency of 100 Hz, two around 230 Hz and three waves around 340 Hz. Besides this, it needs to be able to see the noise reduction. This is possible when the waves are gone.

Attainable
With the available equipment, it should be attainable.

Realistic
The Kundt's Tube experiment and ANC system already exists in the market (Headphones).

Time limited
It must be finished before the 17th of December.

Team members

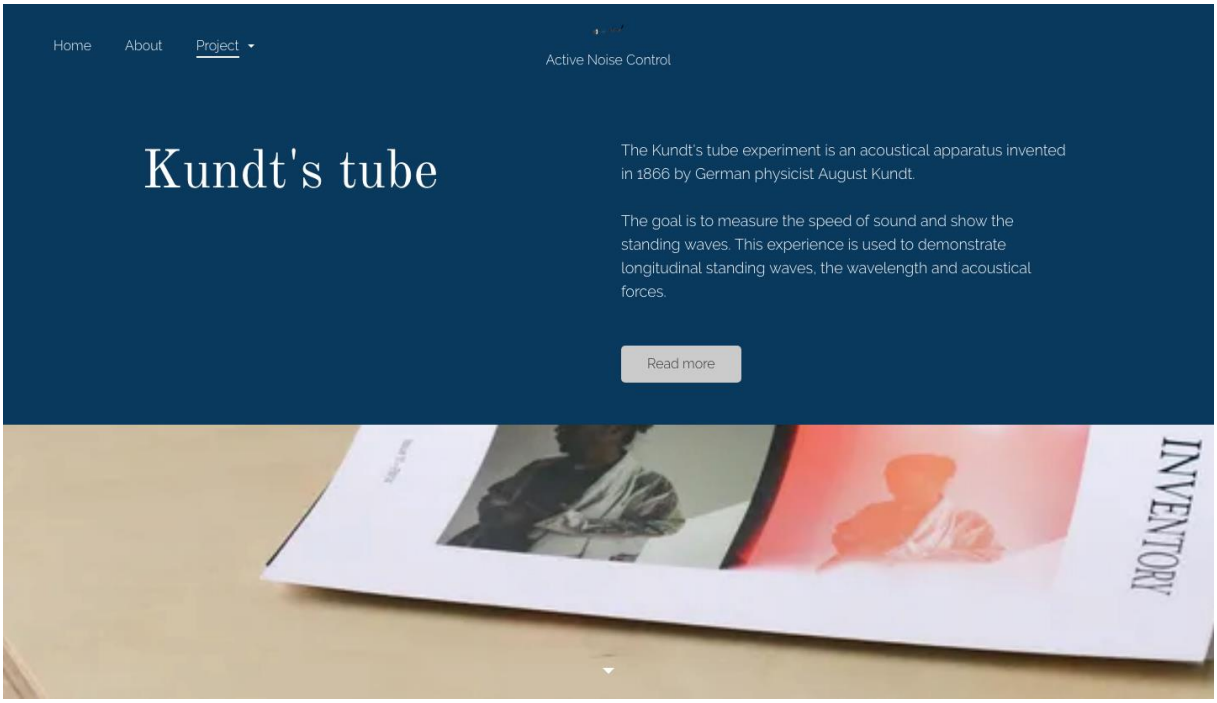
The team contains four students from different nationalities and studies around Europe. These students will present themselves below.

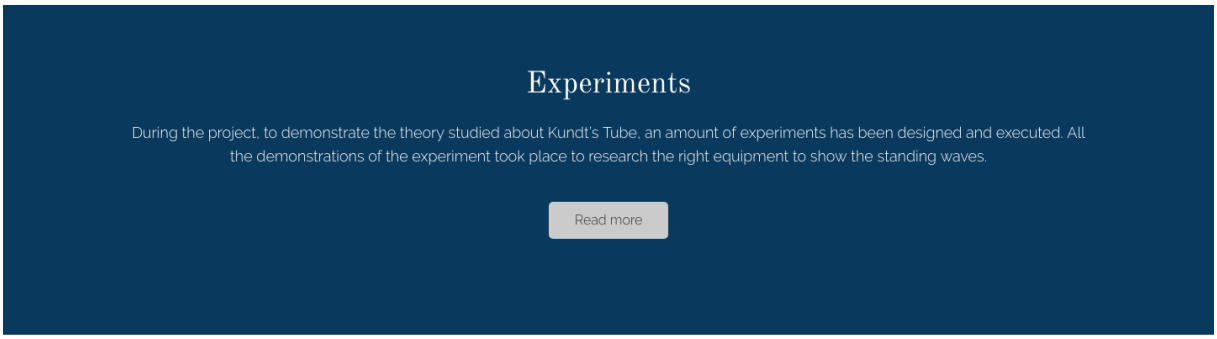
My name is Marie Raynal. I am from Tarbes, a city located in the south of France. I study in a mechanical engineering school: ENIT (Ecole nationale d'ingénieurs de Tarbes). So, I'm studying mechanical engineering and manufacturing.

My name is Sannah van Duuren. I am from Helmond, a city located in the south of the Netherlands. I am an industrial engineering and management student at Avans University of Applied Sciences. It is situated in 's-Hertogenbosch. I am in my third year of my bachelor degree. The European Project Semester is my internship.

My name is Emma Kleijn. I am from the Netherlands and study in the south part of the country. I am an industrial engineering and management student at Avans University of Applied Sciences in 's-Hertogenbosch. I am now in my third year and the EPS (European project semester) is for me an interpretation of my internship

I am Javier Valentín Colén and I am from Spain. I am studying Industrial Electronics and Automation Engineering at University of Lleida.





Active Noise Control

Novia University of Applied Sciences
Wolffintie 33, 56200 Vaasa

The Kundt's tube experiment is an acoustical apparatus invented in 1866 by German physicist August Kundt. The goal of this experiment is to measure the speed of sound and show the standing waves. This experience is used to demonstrate longitudinal standing waves, the wavelength and acoustical forces.

This method consists to create a standing wave in a circular tube, a pipe. The big tube permits to measure the low frequencies whereas the little tube measures high frequencies. The big diameter (100mm) measures between 90 Hz and 1900 Hz, the other between 800 Hz and 6500 Hz. The pipe used has a diameter to 100mm, so it is a big tube. This pipe contains a fine powder. At the end of the tube, there is a loudspeaker which converts the sinusoidal signal in sound wave. The loudspeaker is the sound source for this experience because it sends especially accurate frequencies, called resonance frequencies.

Two ways can be used for the Kundt's tube: opened or closed. The tube could be closed by a piston. It should be insert in the tube without touching it. The difference between opened and closed tube will be explained in the next part.

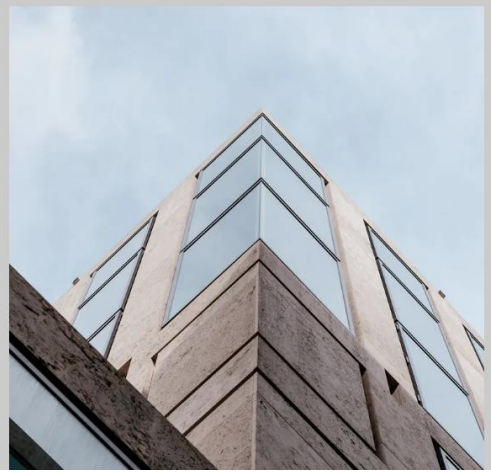
A standing wave is present in a tube because there is one incident wave (send by the loudspeaker) and one reflexive wave. When the end tube is closed, the wave is reflexive by the piston. Otherwise, when the tube is opened, the reflexion results of the different impedance. The acoustic impedance is the measure of the opposition that a system flow resulting of an acoustic pressure applied of the system.

The Protocol

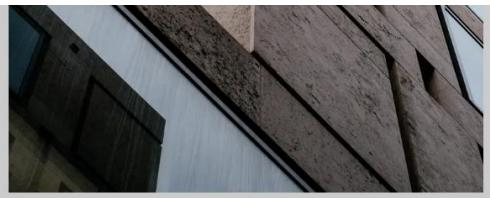
To show the standing wave, the team decided to try the experiment of the Kundt's tube. To observe the standing wave, the team followed this protocol:

- Take the tube (in glass or Plexiglas) and put some substance in it, for example styrofoam balls.
- Link the signal generator, the loudspeaker, the amplifier and the power source to each other.
- Spread uniformly the substance inside the tube,
- Fix the tube into the support,
- (Introduce the piston to the other end of the tube),
- Generate signal with the signal generator,
- Move the piston in and out of the tube till the resonance is obtained.

When a sort of wave and feel, some vibrations would be observed, the resonance and the formation of the standing waves would be see.



On the spot of the loudspeaker, there is a node because the speaker's membrane vibrates and constitutes a region of maximum displacement. A node is a point along a standing wave where the wave has a minimum amplitude (constant pressure). It is fixed. The opposite of the node is an anti-node, a point where the amplitude of the standing wave is a maximum. This occur midway between two nodes.



Experiments

During the project, an amount of experiments has been designed and executed. All the demonstrations of the experiment took place to research the right equipment and frequency to show the standing waves.

Read more

During the project, there have been two experiment phases to show the standing waves. The first phase was the start of the project. In this phase, many different tests have been carried out. After analysis of this first phase there are made conclusions. The conclusions made changes in the experiment for the second phase. During this phase, the tests were detailed with more analysis.

Experiment phase 1

In the first phase the following equipment have been used. The tube can be made of plastic or glass (bottle). Beside the tube there is a substance. In this experiment there have been tests with the following substances, namely flour, plastic balls and styrofoam balls. To make the sound, a speaker and signal generator are also needed.

- Experiment 1 - Plastic tube with flour +
- Experiment 2 - Plastic tube with plastic balls +
- Experiment 3 -Plastic tube with styrofoam balls +
- Experiment 4 - Bottle with plastic balls +
- Experiment 5 - Bottle with styrofoam balls +

Concluded to experiment phase 1 it is possible to say that the equipment that have been used isn't enough to show the standing waves. According to the substance, the styrofoam balls are the best material because they are the lightest substance. According to the sound, there's more power needed. This can be achieved by changing the speaker to a speaker with more power. Also, the tube need to be closed. This is possible by closing it with a piston and make a support to keep the tube closed.

After these conclusions the experiment phase 2 can be started.

Experiment phase 2

To move on to the previous experiment there have been a change in the equipment. There are two different constructions in this phase. The first one is with a small glass tube of 35 cm, with a small speaker with the power of 5 till 8 Watt. The second one is a big plastic tube of 100/150 cm. The different in length is because of using a piston. There's used a speaker with the power of 30 till 50 Watt. To add more power there's been used an amplifier and a power source. In both constructions, the substance that have been used are styrofoam balls.

- Experiment 1 - Glass tube: 35 cm +
- Experiment 2 - Plastic tube: 35 cm +
- Experiment 3 - Plastic tube: 100/150 cm +

Annex 2: Schedule

Every week during the project, a schedule has been made to device the tasks between the team members. In the beginning, the different deadlines made clear when something needed to be hand in.

Deadlines		
1.	Midterm Presentation	23-okt
2.	English Report	21-nov
3.	Personal reflection Camilla	12-dec
4.	Final Report	14-dec
5.	Final Presentation	17-dec

Week 1		What?	Who?	Deadline	Done?
Start project	**Research**				
		Start research about the ANC subject	Everybody		Yes

Week 2		What?	Who?	Deadline	Done?
Define fase	**Brainstorm**				
		Mission	Everybody	14-09-18	Yes
		Vision	Everybody	14-09-18	Yes
		Objectives	Everybody	14-09-18	Yes
		Risks	Everybody	14-09-18	Yes
	Research				
		Research about ANC	Everybody		Yes
Supervisor	**Meetings**				
		Notule and agenda	Sannah, Javier	End week 2	Yes

Week 3		What?	Who?	Deadline	Done?
Define fase	**Report**				
		Mission	Emma	23-09-18	Yes
		Vision	Emma	23-09-18	Yes
		Objectives	Emma	23-09-18	Yes
		Risks	Emma	23-09-18	Yes
		Different methods anc	Marie	24-09-18	Yes
		Write introduction about anc	Sannah	24-09-18	Yes
Measure fase		Write the questions about the measurements	Everybody	24-09-18	Yes
		Analyse records	Javier	24-09-18	Yes
	Brainstorm	Scopes	Everybody	21-09-18	Yes
Supervisor	**Meetings**				
		Notule and agenda	Sannah, Javier	End week 3	Yes

Week 4		What?	Who?	Deadline	Done?
	Research general				
		Research dB	Marie	30-sep	Yes
		Research waves	Emma	30-sep	Yes
		Research company	Sannah	30-sep	Yes
		Research ANC history	Javier	30-sep	Yes
		Research products	Everyone	30-sep	Yes
Supervisor	**Meetings**				
		Notule and agenda	Sannah, Javier	End week 4	Yes

Week 5		What?	Who?	Deadline	Done?
	Introduction				
		1.1.1 Novia Univeristy of applied sciences	Sannah	05-okt	Yes
		1.1.2 Team introduction	Sannah	07-okt	Yes
		1.1.2 Team introduction	Javier	07-okt	Yes
		1.1.2 Team introduction	Marie	07-okt	Yes
		1.1.2 Team introduction	Emma	07-okt	Yes
		Belbin team roles	Sannah	07-okt	Yes
		Belbin team roles	Javier	07-okt	Yes
		Belbin team roles	Marie	07-okt	Yes
		Belbin team roles	Emma	07-okt	Yes
		Research algoritm ANC	Javier	07-okt	Yes
		Research Kundt's tube	Marie	07-okt	Yes
Supervisor	**Meetings**				
		Notule and agenda	Sannah, Javier	End week 5	Yes

Week 6		What?	Who?	Deadline	Done?
	Introduction				
		1.2 Subject	Emma	14-okt	Yes
		1.3 Project goal	Sannah	14-okt	Yes
	Research and background info				
		2. History of sound	Javier	14-okt	Yes
		3. Different mechanical waves	Emma	17-okt	Yes
		4.Kundt's tube	Marie	17-okt	Yes
		5.1 Methods of noise reduction	Marie	09-okt	yes
		5.2.2 + 5.2.3 + 5.2.4	Sannah	09-okt	Yes
		5.2.1 Electronic control system	Javier	17-okt	Yes
		5.3 Companies	Sannah	10-okt	Yes
		6.1 + 6.3 + 6.5	Sannah	19-okt	Yes
		6.2 Piston + 6.4 Signal generator	Marie	19-okt	Yes
		Research	Everyone	14-okt	Yes
Supervisor	**Meetings**				
		Notule and agenda	Sannah, Javier	End week 6	Yes

Week 7		What?	Who?	Deadline	Done?
		3. Different mechanical waves	Emma	17-okt	Yes
		4.Kundt's tube	Marie	17-okt	Yes
		5.2.1 Electronic control system	Javier	17-okt	Yes
		6.1 + 6.3 + 6.5	Sannah	19-okt	Yes
		6.2 Piston + 6.4 Signal generator	Marie	19-okt	Yes
		9.1 Project roles	Sannah	19-okt	Yes
		9.3 Logo	Marie + Emma	19-okt	Yes
		Business card	Emma	18-okt	Yes
		Acknowledgements	Emma	19-okt	Yes
		Milestones	Emma	19-okt	Yes
		Project budget		19-okt	Yes
		Project hours	Javier	19-okt	Yes
		Conclusion	Sannah	19-okt	Yes
		View midterm report	Sannah + Emma	19-okt	Yes
		Logo (write part)	Marie	19-okt	Yes
		Decibel (where in the report?)	Marie	19-okt	Yes
	General	Research	Everyone	20-okt	Yes
Supervisor	**Meetings**				
		Notule and agenda	Sannah, Javier	End week 7	Yes
		Add paragragh 2.1		19-okt	Yes
		Chapter 2 Introduction and conclusion	Marie	19-okt	Yes
		Chapter 3 Introduction and conclusion	Emma	19-okt	Yes
		Missing figure chapter 3	Emma	19-okt	Yes
		Introduction 4.2	Marie	19-okt	Yes
		Chapter 5 Introduction (in generous or per paragraaf)	Sannah	19-okt	Yes
		5.2 conlusion	Javier	19-okt	No
		6.2.3 Introduction	Marie	19-okt	Yes
		Chapter 7 Experiments	Javier	19-okt	No
		Chapter 8 Results	Javier	19-okt	No
		Chapter 9 introduction	Emma	19-okt	Yes
		5.2.1.3 introduction	Javier	19-okt	No

Week 8		What?	Who?	Deadline	Done?
		View midterm report	Sannah+Emma	22-okt	Yes
		Presentation	Everyone	23-okt	Yes
	Experiments				
		Buy components	Everyone	24-okt	Yes
		Testing glass tube	Everyone	25-okt	Yes
		Write down measurments	Marie	25-okt	Yes
		Make program frequency	Javier	01-nov	Yes
Supervisor	**Meetings**				
		Notule and agenda	Sannah, Javier	End week 8	Yes

Week 9		What?	Who?	Deadline	Done?
	Report				
		Components	Marie	04-nov	Yes
		Materials	Emma	04-nov	Yes
	Experiments				
		Testing	Javier/Marie/Emma	01-nov	Yes
		Make program for frequency	Javier	01-nov	Yes
		Test with the plastic tube	Javier/Marie/Emma	01-nov	Yes
Supervisor	**Meetings**				
		Notule and agenda	Sannah, Javier	End week 9	Yes

Week 10		What?	Who?	Deadline	Done?
	Experiments				
		Make closed plastic tube (wood+speaker)	Everyone	09-nov	Yes
		Testing plastic tube	Everyone	09-nov	Yes
	Project management				
		Project budget/costs	Emma	09-nov	Yes
		Communication (stakeholder analyse)	Sannah	09-nov	Yes
		Quality management	Javier	09-nov	Yes
		Risk management	Marie	09-nov	Yes
		Change management	Marie	09-nov	Yes
		Human resource management	Emma	09-nov	Yes
	Website				
		Brainstorm website	Everyone	06-nov	Yes
		Start up website	Sannah		Yes
Supervisor	**Meetings**				
		Notule and agenda	Sannah, Javier	End week 10	Yes

Week 11		What?	Who?	Deadline	Done?
	Website				
		Finish website	Sannah	16-nov	Yes
	Report				
		8. Equipment phase 2			
		8.1 Tubes	Emma	16-nov	Yes
		Plastic and glass properties	Emma	16-nov	Yes
		8.2 Piston	Marie	16-nov	Yes
		Aluminium properties	Emma	16-nov	Yes
		8.3 Substance	Emma	16-nov	Yes
		8.4 Electric circuit	Marie	16-nov	Yes
		8.5 Support	Emma	16-nov	Yes
		Wood properties	Emma	16-nov	Yes
		9. Experiments phase 2			
		9.1 Glass tube 35cm	Marie	16-nov	Yes
		9.2 Plastic tube 35cm	Sannah	16-nov	Yes
		9.3 Plastic tube		16-nov	Yes
		9.3.1 Closed- closed	Emma	16-nov	Yes
		9.3.2 Open- open	Emma	16-nov	Yes
		9.3.3 Open- closed	Javier	16-nov	Yes
		9.3.4 Closed- open	Javier	16-nov	Yes
		10. Comparison			
		10.1 Glass tube and plastic tube 35cm	Marie	16-nov	Yes
		10.2 Plastic tubes	Javier	16-nov	Yes
		10.3 conlusion	Marie	16-nov	Yes
		Re-organize chapter 7	Sannah	16-nov	Yes
		4.3 4.3 (explain the formula for calculate the wavelength)		16-nov	Yes
		11.1 Introduction	Emma	16-nov	Yes
		11.2 Introduction	Emma	16-nov	Yes
		11.2.3 Schedule	Emma	16-nov	Yes
		11.3 Introduction	Sannah	16-nov	Yes
		1.5 build up	Emma	16-nov	Yes
		1.2 Subject (change mission vision)	Emma	21-nov	Yes
		1.3 Project goal (change)	Marie	21-nov	Yes
Supervisor	**Meetings**				
		Notule and agenda	Sannah, Javier	End week 11	Yes

Week 12		What?	Who?	Deadline	Done?
	Report				
		Final view for English	→Total final report		Yes
		1.2 Subject (change mission vision)	Emma	21-nov	Yes
		1.3 Project goal (change)	Marie	23-nov	Yes
		1.5 Build up report	Emma	23-nov	Yes
		Assessment (midterm)	Marie	23-nov	Yes
		Assessment (midterm)	Emma	23-nov	Yes
		Assessment (midterm)	Sannah	23-nov	Yes
		Assessment (midterm)	Javier	23-nov	Yes
		Website text	Sannah	23-nov	Yes
		Conclusion	Everybody	23-nov	Yes
		Matrix (comparison plastic tube)	Javier	23-nov	Yes
		Support	Emma	23-nov	Yes
		fact sheet for the experiment	Marie	23-nov	Yes
		Schedule	Emma	23-nov	Yes
		Website phase 2	Sannah	25-nov	Yes
		Picture wooden support	Emma		Yes
	Experiment ANC				
		Testing with new support	Everyone	23-nov	Yes
		Testing ANC	Everyone	23-nov	Yes
Supervisor	**Meetings**				
		Notule and agenda	Sannah, Javier	End week 12	Yes

Week 13		What?	Who?	Deadline	Done?
		fact sheet for the experiment	Marie	30-nov	Yes
		Written part factsheet	Marie	30-nov	Yes
		Build-up	Emma	30-nov	Yes
		Introduction phase 1	Emma	30-nov	Yes
		Conclusion phase 1	Emma	30-nov	Yes
		Introduction phase 2	Javier	30-nov	Yes
		Conclusion phase 2	Javier	30-nov	Yes
	Report phase 3				
		Introduction phase 3	Marie	30-nov	Yes
		Equipment	Javier	30-nov	Yes
		Experiment/ Cancel + beat	Javier	30-nov	Yes
		2. Beat theory	Marie	30-nov	Yes
		2. beat program	Javier	30-nov	Yes
		Conclusion phase 3	Marie	30-nov	Yes
	Conclusion	Conclusion			
		Critical reflection theories	Javier	30-nov	Yes
		Critical reflection teamwork	Javier	30-nov	Yes
Supervisor	**Meetings**				
		Notule and agenda	Sannah, Javier	End week 13	Yes

Week 14		What?	Who?	Deadline	Done?
	Report				
		Closed-openned	Marie	07-nov	Yes
		Phase 3 - Cancelling	Emma	07-nov	Yes
		Comparison reality/program	Javier	07-nov	Yes
		Personal feedback	Javier	07-nov	Yes
		Personal feedback	Marie	07-nov	Yes
		Personal feedback	Emma	07-nov	Yes
		Personal feedback	Sannah	07-nov	Yes
		Build-up report	Emma	07-nov	Yes
		II Step 1 - The equipment	Javier/Marie	03-dec	Yes
		III Step 2 - Kundt's tube	Emma	03-dec	Yes
		IV Step 3 - Cancellation	Emma	03-dec	Yes
Supervisor	**Meetings**				
		Notule and agenda	Sannah, Javier	End week 14	Yes

Week 15		What?	Who?	Deadline	Done?
		Movie	Emma	13-dec	No
	Report				
		Project hours	Sannah	13-dec	No
		Conclusion	Emma	13-dec	No
		Critical reflection Theories	Javier	12-dec	Yes
		Critical reflection teamwork	Javier	12-dec	Yes
		Build up	Emma	05-dec	Yes
		Add URL in appedix website	Sannah		Yes
	To do list				
		Edit website	Sannah	13-dec	No
		Make conclusion	Emma	13-dec	No
		Movie	Emma	13-dec	No
		Project hours	Javier/Sannah	13-dec	No
		Make presentation	Marie	13-dec	No
		Edit WBS	Marie	13-dec	yes
		Comments Roger	Sannah	13-dec	Yes
		Change 'specific' of SMART	Sannah	13-dec	Yes
		Introduction main chapters	Sannah	13-dec	No
	Appendix				
		Schedule in appendix	Emma	13-dec	Yes
		Project hours calculation	Sannah	13-dec	No
		Reflection peer and self	Everyone	13-dec	No
		Minutes of meetings	Sannah	13-dec	Yes
		Logbook	Sannah	13-dec	No
		Website pictures	Sannah	13-dec	Yes
Supervisor	**Meetings**				
		Notule and agenda	Sannah, Javier	End week 15	Yes

Annex 3: Minutes of meetings

Minutes of meeting - 10 September – Supervisor

Date: Monday 10-09-2018
Time: 14.00 – 15.00
Location: Novia, EPS Room
Participants: Sannah van Duuren, Emma Kleijn, Marie Raynal, Javier Valentín, Kaj Rintanen

Agenda:

1. Opening
Start the meeting

2. Discuss the presentation
Kaj gave a presentation to explain the project during the kick-off of the semester. In this meeting, we discussed about the information that Kaj gave during the presentation.

3. Information about Silentium
Kaj gave information about the company Silentium. He told that it is a company who is active in the Active Noise Control industry.

4. Activities to do
What should we do next week?
- Do research about Silentium
- Do research about Active Noise Control. How it works and companies who are active.
- Team contract

5. Questions
Are there still questions or unqualifiable?
There were no specific questions because there was no knowledge yet.

6. Schedule next meeting
The next meeting is scheduled on 21 September at 11.00.

Minutes of meeting - 18 September – Team

Date: Tuesday 218-19-2018
Time : 11.30 – 12.30
Location : Novia, EPS Group
Participants : Sannah van Duuren, Emma Kleijn, Marie Raynal, Javier Valentin

Agenda:

1. Opening
Start the meeting

2. Trademarks
The team looked for information about trademarks which produce acoustic equipment with noise reduction.

3. Contact companies
The companies who were found during the research and this meeting were contacted with an e-mail. We asked them for information about the subject and product availability.

4. Activities next week
What should we do next week?
- More research about Active Noise Control
- Mission, vision and objectives
- Risks

5. Schedule next meeting
The next meeting with the supervisor is on 21 September.

Minutes of meeting - 21 September – Supervisor

Date: Friday 21-09-2018
Time: 11.00 – 13.30
Location: Novia, EPS Room + Engines LAB
Participants: Sannah van Duuren, Emma Kleijn, Marie Raynal, Javier Valentín, Kaj Rintanen

Agenda:

1. Opening
Start the meeting

2. Value answers from companies
The plan was to value the feedback from the companies, but there were not much answers yet. Only from one company that we should inform Silentium because of their lack of knowledge.

3. Measurements from engines
We went to the engine LAB to do different measurements on the diesel engine and analyses.

4. Activities next week
What should we do next week?
- Mission, Vision and Objectives
- Risks
- Describe different methods ANC
- Analyse the records
- Scopes

5. Questions
- Are there still questions or unqualifiable?

6. Schedule next meeting
The next meeting is 25 September at 14.00.

Minutes of meeting - 24 September – Team

Date: Monday 24-09-2018
Time: 13.00 – 15.00
Location: Novia, EPS Room
Participants: Sannah van Duuren, Emma Kleijn, Marie Raynal, Javier Valentin

Agenda:

1. Opening
Start the meeting

2. Discuss the measurements

3. Build the prototype
The team debated about other possibilities to build the prototype.

4. Activities next week
What should we do next week?
- Research about ANC

5. Schedule next meeting
Next meeting with the supervisor will be 25 September.

6. Questions
- Are there still questions or unqualifiable?

Minutes of meeting - 25 September – Supervisor

Date: Tuesday 25-09-2018
Time: 14.00 – 16.00
Location: Novia
Participants: Sannah van Duuren, Emma Kleijn, Marie Raynal, Javier Valentín, Kaj Rintanen

Agenda:

1. Meeting
The meeting is postponed to 27 September, because the supervisor had obligations with the university.

2. Team meeting
The team worked on the research and documentation the researched information for the report.

Minutes of meeting - 27 September – Supervisor

Date: Thursday 27-09-2018
Time: 14.00 – 15.00
Location: Novia, EPS Room
Participants: Sannah van Duuren, Emma Kleijn, Marie Raynal, Javier Valentin, Kaj Rintanen

Agenda:

1. Meeting
The meeting is postponed to 2 October, because the supervisor had obligations with the university.

2. Team meeting
The team worked on the research and documentation the researched information for the report.

Meeting 2 October - Supervisor

Date: Tuesday 25-09-2018
Time: 14.00 – 15.00
Location: Novia
Participants: Sannah van Duuren, Emma Kleijn, Marie Raynal, Javier Valentín, Kaj Rintanen

Agenda:

1. Opening
Start the meeting

2. Discuss the measurements
Compare the differences in processed measurements between Kaj and Javier.

3. Scope of the project
We modified a short-term scope for the midterm presentation. We decided to build a tube with standing waves to demonstrate how sound interact with the environment.

4. Tube
We received a tube to use in the experiment to observe the standing waves.

5. Activities next week
What should we do next week?
- Start with the documentation for the report about the team and the Belbin test.

6. Schedule next meeting
The next meeting is 3 October at 10.00

7. Questions
- Are there still questions or unqualifiable?

Minutes of meeting - 3 October – Supervisor

Date: Wednesday 03-10-2018
Time: 10.00 – 12.30
Location: Novia, EPS Room
Participants: Sannah van Duuren, Emma Kleijn, Marie Raynal, Javier Valentin, Kaj Rintanen

Agenda:

1. Opening
Start the meeting

2. Receiving equipment
We received the equipment from Kaj to start with the experiments.
We got a signal generator, a loudspeaker and wire.

3. Research
Research about the standings waves in the tube. Searching for experiments that use the technology.

4. Activities next week
What should we do next week?
- Start with the documentation for the report

5. Schedule next meeting
The next meeting is 8 October at 14.00.

6. Questions
- Are there still questions or unqualifiable?

Minutes of meeting - 5 October – Team

Date: Friday 05-10-2018
Time: 14.00 – 16.30
Location: Novia, EPS Room
Participants: Sannah van Duuren, Emma Kleijn, Marie Raynal, Javier Valentin

Agenda:

1. Opening
Start the meeting

2. Prototype
We tried to build the first prototype of the experiment, with the equipment we got last week.

3. Analyses
Analyse the results from the building of the experiment.

4. Reorganize the planning
We reorganised the work for next week in the schedule to have it up-to-date.

5. Activities next week
What should we do next week?
- Start with the documentation for the report

6. Schedule next meeting
The next meeting with the supervisor will be 8 October.

7. Questions
- Are there still questions or unqualifiable?

Minutes of meeting - 8 October – Supervisor

Date: Monday 08-10-2018
Time: 14.00 – 17.45
Location: Novia, EPS Room + TechLab
Participants: Sannah van Duuren, Emma Kleijn, Marie Raynal, Javier Valentín, Kaj Rintanen

Agenda:

1. Opening
Start the meeting

2. Discuss materials
We discussed materials to use in steady sound.

3. Piston
We designed and build a piston for steady sound in the tube.

4. Activities next week
What should we do next week?

5. Schedule next meeting
The next meeting is 22 October at 09.00.

6. Questions
- Are there still questions or unqualifiable?

Minutes of meeting - 18 October – Team

Date: Thursday 18-10-2018
Time: 11.00 – 16.30
Location: Novia EPS Room
Participants: Sannah van Duuren, Emma Kleijn, Marie Raynal, Javier Valentin

Agenda:

1. Opening
Start the meeting

2. Tests
We tested different experiments with the tube and tried to observe the standing waves.
It was unfortunately not possible to observe it.

3. Analysis
We analysed the results of the experiments and we concluded that we don't have the right equipment. So, we need other equipment to finish the experiment.

4. Personal work
Everybody worked on the mid-term report and the presentation. We helped each other where needed.

5. Activities next week
What should we do next week?

6. Schedule next meeting
The meeting with the supervisor is 22 October at 9.00.

7. Questions
- Are there still questions or unqualifiable?

Minutes of meeting - 22 October – Supervisor

Date: Monday 22-10-2018
Time: 09.00 – 16.00
Location: Novia, EPS Room + TechLab + Shops
Participants: Sannah van Duuren, Marie Raynal, Javier Valentín, Kaj Rintanen

Agenda:

1. Opening
Start the meeting

2. Finish the piston
We went to the TechLab and finished the design and construction of the piston for the experiment. It was too late to use it for the mid-term presentation, but we can test with it after the presentation.

3. Presentation
We worked on the presentation, to design it. We also divided all the slides.

4. Shopping
We went with Kaj to different stores to buy equipment for the experiment. We bought two new speakers, an amplifier, a power source, wire, Styrofoam balls, a wooden stick and wooden plats.

5. Activities next week
What should we do next week?

6. Schedule next meeting
The next meeting with the supervisor is 7 November at 14.00.

7. Questions
- Are there still questions or unqualifiable?

Minutes of meeting - 24 October – Team

Date: Wednesday 24-10-2018
Time: 12.00 – 16.00
Location: Novia, EPS Room + Soundproof room
Participants : Sannah van Duuren, Marie Raynal, Javier Valentin

Agenda:

1. Opening
Start the meeting

2. Assemble
We assembled the parts for the amplifier. This is needed to add extra power to the signal generator and the speaker. We need this to observe the standing waves in the tube.

3. Tests
We tested with the small glass tube to observe the standing waves and it worked.

4. Activities next week
What should we do next week?

5. Schedule next meeting
The next meeting is 7 November at 14.00.

6. Questions
- Are there still questions or unqualifiable?

Minutes of meeting - 7 November – Supervisor

Date: Wednesday 07-11-2018
Time: 14.00 – 16.00
Location: Novia, EPS Room + Soundproof room
Participants: Sannah van Duuren, Emma Kleijn, Marie Raynal, Javier Valentín, Kaj Rintanen

Agenda:

1. Opening
Start the meeting

2. Design
We designed a creation for the base to build the support for Kundt's tube.

3. Set of experiments
We started with a set of experiments We tried Open-Opened, Closed-Open, Open-Closed and Closed-Closed.

4. Activities next week
What should we do next week?

5. Schedule next meeting
The next meeting with the supervisor is 13 November at 17.00.

6. Questions
- Are there still questions or unqualifiable?

Minutes of meeting - 8 November – Team

Date: Thursday 08-11-2018
Time: 10.00 – 16.30
Location: Novia, EPS Room + Soundproof room
Participants: Sannah van Duuren, Emma Kleijn, Marie Raynal, Javier Valentín

Agenda:

1. Opening
Start the meeting

2. Set of experiments
We completed the set of Experiments where we started with last meeting.

3. Activities next week
What should we do next week?

4. Schedule next meeting
The next meeting is 13 November at 17.00.

5. Questions
- Are there still questions or unqualifiable?

Minutes of meeting - 13 November – Supervisor

Date: Tuesday 13-11-2018
Time: 17.00 – 18.00
Location: Novia, EPS Room
Participants: Sannah van Duuren, Kaj Rintanen

Agenda:

1. Opening
Start the meeting

2. Piston
We created the piston with the attached speaker. It is made from wood.

5. Activities next week
What should we do next week?

6. Schedule next meeting
The next meeting is 14 November at 17.00.

7. Questions
- Are there still questions or unqualifiable?

Minutes of meeting - 14 November – Team

Date: Wednesday 14-11-2018
Time: 14.00 – 16.30
Location: Novia, EPS Room + Soundproof room
Participants: Sannah van Duuren, Emma Kleijn, Marie Raynal, Javier Valentín

Agenda:

1. Opening
Start the meeting

2. Test sets
We did some test sets with the new piston. The piston is made of wood with a small speaker inside.

3. Activities next week
What should we do next week?

4. Schedule next meeting
The next meeting with the supervisor is 14 November at 17.00.

5. Questions
- Are there still questions or unqualifiable?

Minutes of meeting - 14 November – Supervisor

Date: Wednesday 14-11-2018
Time: 17.00 – 18.00
Location: Novia, EPS Room
Participants: Sannah van Duuren, Emma Kleijn, Javier Valentin, Kaj Rintanen

Agenda:

1. Opening
Start the meeting

2. Damping
We discussed about the damping of the sound according to the tube and the support.

3. Glue testing
We tested different glues with the materials that we use to see which one is the best one.

4. Sealing the tube
We sealed the tube with silicone to the wooden support. This is the part were the speaker is stored.

5. Activities next week
What should we do next week?

6. Schedule next meeting
The next meeting with the supervisor is 16 November at 09.30.

7. Questions
- Are there still questions or unqualifiable?

Minutes of meeting - 15 November – Team

Date: Thursday 15-11-2018
Time: 10.00 – 18.00
Location: Novia, EPS Room + Soundproof room
Participants: Sannah van Duuren, Emma Kleijn, Marie Raynal, Javier Valentín

Agenda:

1. Opening
Start the meeting

2. Tests
We test a set of experiments with the sealed silicone tube. It was possible to observe the standing waves.

3. Support
We stacked the bases of the holders for the support of the tube. This is because with the holders the support has more surface on the table/ground.

4. Brainstorm
During the test sets we observed the standing waves, but they were less than before. That's why we had a brainstorm to solve the problem for the decreasing of the effect of the standing waves.

5. Broken support
The support for the tube was stacked with silicone to the tube. At the end of the test set it broke. That's why we had a brainstorm with ideas to seal the tube. This will be discussed with Kaj tomorrow.

6. Activities next week
What should we do next week?

7. Schedule next meeting
The next meeting is 16 November at 09.30.

8. Questions
- Are there still questions or unqualifiable?

Minutes of meeting - 16 November – Supervisor

Date: Friday 16-11-2018
Time: 09.30 – 11.00
Location: Novia, EPS Room + Soundproof room
Participants: Sannah van Duuren, Emma Kleijn, Marie Raynal, Javier Valentín, Kaj Rintanen

Agenda:

1. Opening
Start the meeting

2. Solved the problem
During the tests of the experiments, the standing waves were observed, but not as high as the other experiment. We were searching to the cause of the problem and find out that the batteries of the signal generator were too low. That is why we changed them.

3. Glue
We obtained new glue to seal the tube, because there was still air escaping. With the new glue this shouldn't be possible anymore.

4. Activities next week
What should we do next week?

5. Schedule next meeting
The next meeting with the supervisor is ……

6. Questions
- Are there still questions or unqualifiable?

Minutes of meeting - 16 November – Team

Date: Friday 16-11-2018
Time: 11.00 – 16.30
Location: Novia, EPS Room + Soundproof room + Workshop
Participants: Sannah van Duuren, Emma Kleijn, Marie Raynal, Javier Valentín

Agenda:

1. Opening
Start the meeting

2. Samples
We made samples to test the best glue. We attached the glue to different materials to prove the efficiency.

3. Electronic components
We designed and build the box to keep all the electronic components in the same spot.

4. Activities next week
What should we do next week?

5. Schedule next meeting
The next meeting with the supervisor is ……

6. Questions
- Are there still questions or unqualifiable?

Minutes of meeting - 21 November – Team

Date: Wednesday 21-11-2018
Time: 13.30 – 16.00
Location: Novia, EPS Room + Soundproof room
Participants: Sannah van Duuren, Emma Kleijn, Marie Raynal, Javier Valentin, Kaj Rintanen

Agenda:

1. Opening
Start the meeting

2. Tests
Testing with two speakers and the signal generator borrowed for the laboratory.

4. Activities next week
What should we do next week?

5. Schedule next meeting
The next meeting with the supervisor is the 28th of November at 15.30.

6. Questions
- Are there still questions or unqualifiable?

Minutes of meeting - 22 November – Team

Date: Thursday 22-11-2018
Time: 14.30 – 16.00
Location: Soundproof room
Participants: Sannah van Duuren, Emma Kleijn, Javier Valentin,

Agenda:

1. Opening
Start the meeting

2. Extra speaker
We obtained the 3rd speaker.

3. Wiring
We received help from a teacher in the soundproof room. He helped us with the wiring of the 2 speakers and the signal generator to test.

4. Activities next week
What should we do next week?

5. Schedule next meeting
The next meeting with the supervisor is the 28th of November at 15.30.

6. Questions
- Are there still questions or unqualifiable?

Minutes of meeting - 26 November – Team

Date: Monday 26-11-2018
Time: 12.00 – 14.00
Location: Novia, EPS Room + Soundproof room
Participants: Sannah van Duuren, Emma Kleijn

Agenda:

1. Opening
Start the meeting

2. Test
We tested with two speakers and a new signal generator form the laboratory. We were testing to observe the standing waves and cancel the waves after it.

4. Activities next week
What should we do next week?

5. Schedule next meeting
The next meeting with the supervisor is the 28th of November at 15.30.

6. Questions
- Are there still questions or unqualifiable?

Minutes of meeting - 27 November – Team

Date: Tuesday 27-11-2018
Time: 14.00 – 15.00
Location: Novia, EPS Room + Soundproof room
Participants: Sannah van Duuren, Javier Valentin

Agenda:

1. Opening
Start the meeting

2. Tests
Testing with two speakers and the signal generator borrowed from the laboratory. The tests were to observe the cancellation.

3. Error
The equipment stopped working.

4. Activities next week
What should we do next week?

5. Schedule next meeting
The next meeting with the supervisor is the 28th of November at 15.30.

6. Questions
- Are there still questions or unqualifiable?

Minutes of meeting - 28 November – Team

Date: Wednesday 28-11-2018
Time: 11.00 – 14.00
Location: Novia, EPS Room + Soundproof room
Participants: Sannah van Duuren, Emma Kleijn, Marie Raynal, Javier Valentin

Agenda:

1. Opening
Start the meeting

2. Batteries
Because the equipment did not work as it should be we changed the batteries. The problem was solved.

3. Tests
Testing with two speakers and the signal generator borrowed from the laboratory. The tests were to observe the cancellation.

4. Activities next week
What should we do next week?

5. Schedule next meeting
The next meeting with the supervisor is the 28th of November at 15.30.

6. Questions
- Are there still questions or unqualifiable?

Minutes of meeting - 28 November – Supervisor

Date: Wednesday 28-11-2018
Time: 15.30 – 17.00
Location: Novia, EPS Room + Soundproof room
Participants: Sannah van Duuren, Emma Kleijn, Marie Raynal, Javier Valentin, Kaj Rintanen

Agenda:

1. Opening
Start the meeting

2. Tests
- Test beaming on acoustics;
- Tried to cancel noise inside the tube;
- Tried to cancel noise outside the tube.

3. Activities next week
What should we do next week?

4. Schedule next meeting
There is no next meeting with the supervisor anymore.

5. Questions
- Are there still questions or unqualifiable?

Minutes of meeting - 29 November – Team

Date: Thursday 29-11-2018
Time: 13.30 – 17.30
Location: Novia, EPS Room + Soundproof room
Participants: Emma Kleijn, Marie Raynal, Javier Valentin

Agenda:

1. Opening
Start the meeting

2. Manufacture
We manufactured the 3rd speaker to adapt it to the tube.

3. 3rd speaker
We wired the 3rd speaker to have a nice-looking speaker.

4. Activities next week
What should we do next week?

5. Schedule next meeting
There is no next meeting with the supervisor anymore.

6. Questions
- Are there still questions or unqualifiable?

Minutes of meeting - 30 November – Team

Date: Friday 30-11-2018
Time: 11.30 – 15.00
Location: Novia, EPS Room + Soundproof room
Participants: Emma Kleijn, Marie Raynal, Javier Valentin

Agenda:

1. Opening
Start the meeting

2. Tests
Testing with the third speaker and the signal generator borrowed for the laboratory.

3. 3rd speaker
The 3rd speaker broke. It was no longer possible to use it.

4. Activities next week
What should we do next week?

5. Schedule next meeting
There is no next meeting with the supervisor anymore.

6. Questions
- Are there still questions or unqualifiable?

Minutes of meeting – 3 December – Team

Date: Monday 3-12-2018
Time: 16.00 – 17.00
Location: Novia, EPS Room
Participants: Sannah van Duuren, Emma Kleijn, Marie Raynal, Javier Valentin

Agenda:

1. Opening
Start the meeting

2. Table of contents
We had a brainstorm about the table of contents. We agreed to change the index of the project to summarize better the content.

3. Activities next week
What should we do next week?

4. Schedule next meeting
There is no next meeting anymore.

5. Questions
- Are there still questions or unqualifiable?

Annex 4: Simulation cancellation and beat phenomenon

```
%{
This script uses the addition of 2 sinusoidal waves with the objective
of simulate and demonstrate the beating phenomenon on acoustics, and the
wave interference (destructive and constructive).


%}
fm = 2^13;              % Sampling frequency
a=2^9;                  % Frequency for the for loop

total_time = 6;         % Time
f1 = 21;                % Frequency of first sample
f2 = 20;                % Frequency of second sample

% Definition of functions
t = 0:1/fm:total_time;
a1 = sin(2*pi*f1*t);
a2 = sin(2*pi*f2*t);

% Creation of figures, definition of axes and markers for animation
figure;
ax1 = subplot(3,1,1);
plot(t,a1)
ax2 = subplot(3,1,2);
plot(t,a2)
ax3 = subplot(3,1,3);
total = a1+a2;
```

```
hold on;
plot(t,total)
x = 0;
y = 0;
h = plot(x,y,'y*','MarkerSize',10);
h.XDataSource = 'x';
h.YDataSource = 'y';
hold off;

% Play the sound of the addition of the waves
sound(a1+a2, fm);
pause(total_time)

% Animation
linkaxes([ax1,ax2],'xy');
axis(ax3,[0 total_time -2 2])

for i = 1:a:fm*total_time+1
   axis(ax1,[i/fm i/fm+0.25 -1 1])
   y = total(i);
   x = (i)/(fm);
   refreshdata;
   pause(1/fm);
end
axis([ax1 ax2],[0 total_time -1 1])
axis(ax3,[0 total_time -2 2])
```

Annex 5: Assessment

Team: Active Noise Control Student: Emma

Date: Midterm

Evaluation type: **Peer** / Self

The assessment has the following elements: individual contribution to the group report, the documentation submitted (questions 1 and 2) individual contribution to the teamwork, the process performed (questions 3, 4, 5, 6, 7)

	Poor				Excellent
1. Technical contribution (quality)	1	2	3	4	5
2. Technical contribution (quantity)	1	2	3	4	5
3. Willingness to build on the ideas of others	1	2	3	4	5
4. understanding of team process	1	2	3	4	5
5. leadership at appropriate times	1	2	3	4	5
6. positive attitude	1	2	3	4	5
7. initiative shown	1	2	3	4	5

Team: Active Noise Control Student: Emma

Date: Midterm

Evaluation type: Peer / **Self**

The assessment has the following elements: individual contribution to the group report, the documentation submitted (questions 1 and 2) individual contribution to the teamwork, the process performed (questions 3, 4, 5, 6, 7)

	Poor				Excellent
1. Technical contribution (quality)	1	2	3	4	5
2. Technical contribution (quantity)	1	2	3	4	5
3. Willingness to build on the ideas of others	1	2	3	4	5
4. understanding of team process	1	2	3	4	5
5. leadership at appropriate times	1	2	3	4	5
6. positive attitude	1	2	3	4	5
7. initiative shown	1	2	3	4	5

Team: Active Noise Control Student: Marie

Date: Midterm

Evaluation type: **Peer** / Self

The assessment has the following elements: individual contribution to the group report, the documentation submitted (questions 1 and 2) individual contribution to the teamwork, the process performed (questions 3, 4, 5, 6, 7)

	Poor				Excellent
1. Technical contribution (quality)	1	2	3	**4**	5
2. Technical contribution (quantity)	1	2	**3**	4	5
3. Willingness to build on the ideas of others	1	2	3	**4**	5
4. understanding of team process	1	2	3	4	**5**
5. leadership at appropriate times	1	2	3	**4**	5
6. positive attitude	1	2	3	4	**5**
7. initiative shown	1	2	3	4	**5**

Team: Active Noise Control Student: Marie

Date: Midterm

Evaluation type: Peer / **Self**

The assessment has the following elements: individual contribution to the group report, the documentation submitted (questions 1 and 2) individual contribution to the teamwork, the process performed (questions 3, 4, 5, 6, 7)

	Poor				Excellent
1. Technical contribution (quality)	1	2	3	**4**	5
2. Technical contribution (quantity)	1	2	**3**	4	5
3. Willingness to build on the ideas of others	1	2	3	**4**	5
4. understanding of team process	1	2	3	4	**5**
5. leadership at appropriate times	1	2	3	**4**	5
6. positive attitude	1	2	3	4	**5**
7. initiative shown	1	2	3	4	**5**

Team: Active Noise Control Student: Sannah

Date: Midterm

Evaluation type: **Peer** / Self

The assessment has the following elements: individual contribution to the group report, the documentation submitted (questions 1 and 2) individual contribution to the teamwork, the process performed (questions 3, 4, 5, 6, 7)

	Poor				Excellent
1. Technical contribution (quality)	1	2	3	**4**	5
2. Technical contribution (quantity)	1	2	**3**	4	5
3. Willingness to build on the ideas of others	1	2	3	**4**	5
4. understanding of team process	1	2	3	**4**	5
5. leadership at appropriate times	1	2	3	**4**	5
6. positive attitude	1	2	**3**	4	5
7. initiative shown	1	2	**3**	4	5

Team: Active Noise Control Student: Sannah

Date: Midterm

Evaluation type: Peer / **Self**

The assessment has the following elements: individual contribution to the group report, the documentation submitted (questions 1 and 2) individual contribution to the teamwork, the process performed (questions 3, 4, 5, 6, 7)

	Poor				Excellent
1. Technical contribution (quality)	1	2	3	**4**	5
2. Technical contribution (quantity)	1	2	3	4	**5**
3. Willingness to build on the ideas of others	1	2	3	**4**	5
4. understanding of team process	1	2	3	4	**5**
5. leadership at appropriate times	1	2	3	**4**	5
6. positive attitude	1	2	3	**4**	5
7. initiative shown	1	2	3	**4**	5

Team: Active Noise Control Student: Javier

Date: Midterm

Evaluation type: **Peer** / Self

The assessment has the following elements: individual contribution to the group report, the documentation submitted (questions 1 and 2) individual contribution to the teamwork, the process performed (questions 3, 4, 5, 6, 7)

	Poor				Excellent
1. Technical contribution (quality)	1	2	**3**	4	5
2. Technical contribution (quantity)	1	2	3	4	**5**
3. Willingness to build on the ideas of others	1	2	3	**4**	5
4. understanding of team process	1	2	3	**4**	5
5. leadership at appropriate times	1	2	**3**	4	5
6. positive attitude	1	2	3	**4**	5
7. initiative shown	1	2	3	**4**	5

Team: Active Noise Control Student: Javier

Date: Midterm

Evaluation type: Peer / **Self**

The assessment has the following elements: individual contribution to the group report, the documentation submitted (questions 1 and 2) individual contribution to the teamwork, the process performed (questions 3, 4, 5, 6, 7)

	Poor				Excellent
1. Technical contribution (quality)	1	2	3	4	**5**
2. Technical contribution (quantity)	1	2	**3**	4	5
3. Willingness to build on the ideas of others	1	2	3	4	**5**
4. understanding of team process	1	2	3	4	**5**
5. leadership at appropriate times	1	2	**3**	4	5
6. positive attitude	1	2	3	**4**	5
7. initiative shown	1	2	3	**4**	5

Team: Active Noise Control Student: Emma

Date: Final

Evaluation type: **Peer** / Self

The assessment has the following elements: individual contribution to the group report, the documentation submitted (questions 1 and 2) individual contribution to the teamwork, the process performed (questions 3, 4, 5, 6, 7)

	Poor				Excellent
1. Technical contribution (quality)	1	2	3	4	5
2. Technical contribution (quantity)	1	2	3	4	5
3. Willingness to build on the ideas of others	1	2	3	4	5
4. understanding of team process	1	2	3	4	5
5. leadership at appropriate times	1	2	3	4	5
6. positive attitude	1	2	3	4	5
7. initiative shown	1	2	3	4	5

Team: Active Noise Control Student: Emma

Date: Final

Evaluation type: Peer / **Self**

The assessment has the following elements: individual contribution to the group report, the documentation submitted (questions 1 and 2) individual contribution to the teamwork, the process performed (questions 3, 4, 5, 6, 7)

	Poor				Excellent
1. Technical contribution (quality)	1	2	3	4	5
2. Technical contribution (quantity)	1	2	3	4	5
3. Willingness to build on the ideas of others	1	2	3	4	5
4. understanding of team process	1	2	3	4	5
5. leadership at appropriate times	1	2	3	4	5
6. positive attitude	1	2	3	4	5
7. initiative shown	1	2	3	4	5

Team: Active Noise Control Student: Marie

Date: Final

Evaluation type: **Peer** / Self

The assessment has the following elements: individual contribution to the group report, the documentation submitted (questions 1 and 2) individual contribution to the teamwork, the process performed (questions 3, 4, 5, 6, 7)

	Poor				Excellent
1. Technical contribution (quality)	1	2	3	4	5
2. Technical contribution (quantity)	1	2	3	4	5
3. Willingness to build on the ideas of others	1	2	3	4	5
4. understanding of team process	1	2	3	4	5
5. leadership at appropriate times	1	2	3	4	5
6. positive attitude	1	2	3	4	5
7. initiative shown	1	2	3	4	5

Team: Active Noise Control Student: Marie

Date: Final

Evaluation type: Peer / **Self**

The assessment has the following elements: individual contribution to the group report, the documentation submitted (questions 1 and 2) individual contribution to the teamwork, the process performed (questions 3, 4, 5, 6, 7)

	Poor				Excellent
1. Technical contribution (quality)	1	2	3	4	5
2. Technical contribution (quantity)	1	2	3	4	5
3. Willingness to build on the ideas of others	1	2	3	4	5
4. understanding of team process	1	2	3	4	5
5. leadership at appropriate times	1	2	3	4	5
6. positive attitude	1	2	3	4	5
7. initiative shown	1	2	3	4	5

Team: Active Noise Control Student: Sannah

Date: Final

Evaluation type: **Peer** / Self

The assessment has the following elements: individual contribution to the group report, the documentation submitted (questions 1 and 2) individual contribution to the teamwork, the process performed (questions 3, 4, 5, 6, 7)

	Poor				Excellent
1. Technical contribution (quality)	1	2	3	4	5
2. Technical contribution (quantity)	1	2	3	4	5
3. Willingness to build on the ideas of others	1	2	3	4	5
4. understanding of team process	1	2	3	4	5
5. leadership at appropriate times	1	2	3	4	5
6. positive attitude	1	2	3	4	5
7. initiative shown	1	2	3	4	5

Team: Active Noise Control Student: Sannah

Date: Final

Evaluation type: Peer / **Self**

The assessment has the following elements: individual contribution to the group report, the documentation submitted (questions 1 and 2) individual contribution to the teamwork, the process performed (questions 3, 4, 5, 6, 7)

	Poor				Excellent
1. Technical contribution (quality)	1	2	3	4	5
2. Technical contribution (quantity)	1	2	3	4	5
3. Willingness to build on the ideas of others	1	2	3	4	5
4. understanding of team process	1	2	3	4	5
5. leadership at appropriate times	1	2	3	4	5
6. positive attitude	1	2	3	4	5
7. initiative shown	1	2	3	4	5

Team: Active Noise Control Student: Javier

Date: Final

Evaluation type: **Peer** / Self

The assessment has the following elements: individual contribution to the group report, the documentation submitted (questions 1 and 2) individual contribution to the teamwork, the process performed (questions 3, 4, 5, 6, 7)

	Poor				Excellent
1. Technical contribution (quality)	1	2	3	4	5
2. Technical contribution (quantity)	1	2	3	4	5
3. Willingness to build on the ideas of others	1	2	3	4	5
4. understanding of team process	1	2	3	4	5
5. leadership at appropriate times	1	2	3	4	5
6. positive attitude	1	2	3	4	5
7. initiative shown	1	2	3	4	5

Team: Active Noise Control Student: Javier

Date: Final

Evaluation type: Peer / **Self**

The assessment has the following elements: individual contribution to the group report, the documentation submitted (questions 1 and 2) individual contribution to the teamwork, the process performed (questions 3, 4, 5, 6, 7)

	Poor				Excellent
1. Technical contribution (quality)	1	2	3	4	5
2. Technical contribution (quantity)	1	2	3	4	5
3. Willingness to build on the ideas of others	1	2	3	4	5
4. understanding of team process	1	2	3	4	5
5. leadership at appropriate times	1	2	3	4	5
6. positive attitude	1	2	3	4	5
7. initiative shown	1	2	3	4	5

Annex 6: Properties materials

Plastic

Plastics are organic substances formed by macro cells called polymers. Plastics have a low production cost. It has an acceptable acoustic insulation (Characteristics and properties of plastic, sd). Plastics can absorb mechanical energy by transforming it into heat. Plastic is often use to absorb sound. For a good absorb material plastic is not the best option. However, it cannot be used for desorption.

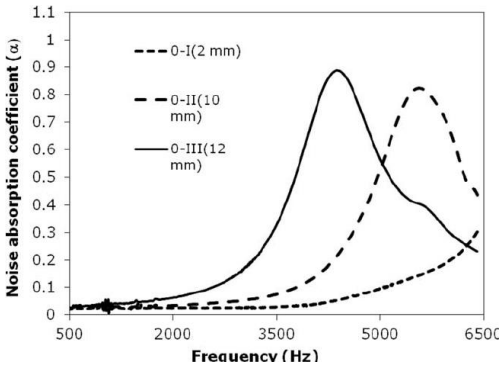


Figure 97: Absorption coefficient of PVC polymer as a function of thickness

Wood

Wood the material that grows from a tree. It is a relative cheap material. There are hundreds of different species of trees.

Physically, wood is strong and stiff. It is light and flexible. Wood is comparing to many different other materials anisotropic. This means a lump of wood has different properties in different directions. Dry wood produces a great deal of heat energy. Although wood can absorb sound very effectively, wooden object can also be designed to transmit and amplify sounds. It conducts sound because it is easy to move but it also absorbs like a sponge blocking sound (Woodford, sd). Thereafter wood is suitable to contribute to a good sound insulation (Characteristics of wood, 2013). The average absorption coefficient of wood is 0,05 – 0,90. It depends on the quality of the wood. This applies to frequencies between 500 and 2000 Hz (Table with absorbing materials, sd).

MATERALS	COEFFICIENTS					
	125 CPS	250 CPS	500 CPS	1000 CPS	2000 CPS	4000 CPS
Bricks	.03	.03	.03	.04	.05	.07
Carpet heavy on concrete Carpet with impermeable backing	.02	.06	.14	.37	.60	.65
Concrete block, course	.08	.24	.57	.69	.71	.73
Concrete block, painted	.08	.27	.39	.34	.48	.63
Light fabric	.03	.04	.06	.07	.09	.08
Medium fabric	.07	.31	.49	.75	.70	.60
Concrete, terrazzo, marble or glazed tile	.01	.01	.02	.02	.02	.02
Wood	.15	.11	.10	.07	.06	.07
Heavy glass	.18	.06	.04	.03	.02	.02
Ordinary glass	.35	.25	.18	.12	.07	.04
Gypsum board, 1/2"	.29	.10	.05	.04	.07	.05
Plaster	.01	.02	.02	.03	.04	.05
Water surface	.01	.01	.01	.02	.02	.03
Air, sabins 1000 cubic feet	–	–	–	–	2.3	7.2
People	4 sabins					

Figure 98: Table of coefficients

Glass

Glass is very acoustically reflective because it is flat and rigid. But the problem with glass is that it depends on the thickness. The average absorption coefficient of glass is < 0,05. This applies to frequencies between 500 and 2000 Hz (Table with absorbing materials, sd). Glass is a relative expensive material especially in different shapes. for example, a tube.

Aluminium

Aluminium is a silvery-white, soft, nonmagnetic, corrosion resistant and ductile aluminium. Aluminium is the world's most abundant metal and is the third most common element comprising 8% of the earth's crust. The versatility of aluminium makes it the most widely used metal after steel. Aluminium is one of the lightest engineering metals, having a strength to weight ratio superior to steel. Aluminium is not able to absorb sound waves. In contrast, it reflects the waves back. Aluminium is compared to steel three times more expensive. In comparing to copper it is cheap.

Conclusion

After gathering this information there are made several choices. To start with the tube. There was an available plastic tube. It will become difficult to see the standing waves in this tube because of the absorption of the plastic. For the tube glass is the best option, it is transparent and it does not have a high absorption coefficient.

Thereafter there is a piston needed for in the plastic tube. This one is made from aluminium, aluminium is light and not very expensive. The aluminium piston is also for the reflection of the waves. To make the piston with a material that absorb the waves was not possible.

There must be a sort of tripod for the tube. In this way, there is no need to hold the tube and lose waves. This need to be made from a cheap and easy material to work with. The best option in this project is to make it from wood.

Annex 7: Logbook

Javier:

Date	Place	Name	Time	Hours	What have you done?
			Week 1		
03-09-18	Novia	Javier	08:00:00 - 17:00	9	Introduction day
04-09-18	Novia	Javier	08:00:00 - 10:00	2	Presentation projects
04-09-18	Roger	Javier	13.00 - 18.00	5	Dinner at Roger's place
05-09-18	Novia	Javier	10.00 - 16.00	6	Pteambuilding and project management
06-09-18	Archipelago	Javier	11.45 - 15.30	4,25	Trip to the archipelago
07-09-18	Novia	Javier	08:00 - 10.30	2,5	Team work
Total				28,75	

			Week 2		
10-09-18	Novia	Javier	12.00 - 14.00	2	Teambuilding with belbin
10-09-18	Novia	Javier	14.00 - 15.00	1	Meeting
11-09-18	Tritonia	Javier	10.00 - 12.00	2	Team work
11-09-18	Abo	Javier	16.30 - 18.00	1,5	Swedish lesson
12-09-18	Novia	Javier	14.00 - 16.00	2	Meeting
12-09-18	Tritonia	Javier	16.00 - 18.00	2	Research
13-09-18	Novia	Javier	08.00 - 15.00	7	Cross cultural understanding
13-09-18	Abo	Javier	16.30 - 18.00	1,5	Swedish lesson
14-09-18	Novia	Javier	09.00 - 13.00	4	Cross cultural understanding
Total				23	

			Week 3		
17-09-18	Tritonia	Javier	12.00 - 14.30	2,5	Working on the presentation and WBS
18-09-18	Novia	Javier	08.00 - 13.00	5	Progression presentation, English lesson, Meeting with Kai
18-09-18	Abo	Javier	16.30 - 18.00	1,5	Swedish lesson
18-09-18	Tritonia	Javier	10:00 - 11:30	1,5	Research
19-09-18	Novia	Javier	13.00 - 15.30	2,5	Team work
20-09-18	Abo	Javier	16.30 - 18.00	1,5	Swedish lesson
20-09-18	At home	Javier	19:30 - 21:00	1,5	Research
21-09-18	Tritonia	Javier	8:15 - 11:00	2,75	Research
21-09-18	Novia	Javier	11:00 - 13:30	2,5	Meeting
23-09-18	At home	Javier	17.30 - 21:00	3,5	Processing of messures
23-09-18	At home	Javier	23:00 - 3:00	4	Processing of messures + Secretary Logbook
Total				28,75	

			Week 4		
24-09-18	Novia	Javier	13.00 - 15.30	2,5	Meeting + Research
24-09-18	At home	Javier	17.00 - 18.00	1	Homework from EPS_English
25-09-18	Novia	Javier	10:00 - 11:30	1,5	English
25-09-18	Novia	Javier	13:00 - 14:00	1	Project managment
25-09-18	Novia	Javier	14.00 - 15.30	1,5	Research
25-09-18	Abo Academi	Javier	15.30 - 18.00	2,5	Swedish lesson
27-09-18	Abo Academi	Javier	17.00 - 19.00	2	Swedish lesson
Total				12	

			Week 5		
02-10-18	Novia	Javier	10.00 - 16.30	7	English + Project Management + meeting
02-10-18	Abo Acedemi	Javier	16.30 - 18.00	1,5	Swedish lesson
03-10-18	Novia	Javier	10.00 - 12.30	2,5	Meeting
04-10-18	Abo Acedemi	Javier	16.30 - 18.00	1,5	Swedish lesson
04-10-18	At home	Javier	20.00 - 22.00	2	Mechanical waves
05-10-18	Novia	Javier	14.00 - 17.00	3	Experiment testing
07-10-18	At home	Javier	18.00 - 20.00	2	Edit logbook + Belbin Teamroles
07-10-18	At home	Javier	23.00 - 1.00	2	Belvin Teamroles + Presentation Team
Total				21,5	

Week 6					
08-10-18	Novia	Javier	10.00 - 18.00	8	Business Analysis + teamwork + meeting
09-10-18	Novia	Javier	10.00 - 16.30	6,5	Business Analysis + teamwork
09-10-18	Abo Academi	Javier	16.30 - 18.00	1,5	Swedish lesson
10-10-18	Novia	Javier	10.00 - 11.00	1	Business Analysis
10-10-18	Novia	Javier	11.00 - 12.30	1,5	History of sound cancellation
10-10-18	Novia	Javier	13.00 - 17.00	4	Electronic control system + Adaptative Filters
11-10-18	Abo Academi	Javier	16.30 - 18.00	1,5	Swedish lesson
11-10-18	At home	Javier	18.00 - 20.00	2	Study Sweedish
12-10-18	At train	Javier	16.00 - 18.00	2	Study Sweedish
13-10-18	At home	Javier	19.00 - 20.00	1	Study Sweedish
14-10-18	At train	Javier	20.00 - 22.00	2	Study Sweedish
Total				31	

Week 7					
15-10-18	At home	Javier	10.00 - 14.00	4	Study Sweedish
16-10-18	At home	Javier	10.00 - 12.00	2	Study Sweedish
16-10-18	Abo Academi	Javier	16.30 - 18.00	1,5	Swedish Exam
17-10-18	Novia	Javier	10.00 - 12.30	2,5	Adaptative algorithms
17-10-18	Novia	Javier	13.00 - 16.30	3,5	Adaptative algorithms
19-10-18	Novia	Javier	11.00 - 17.00	6	Meeting - Experiment - Final report
19-10-18	At home	Javier	18.00 - 20.00	2	Study Sweedish
20-10-18	At home	Javier	10.00 - 13.00	3	Study Sweedish
20-10-18	At home	Javier	16.00 - 20.00	4	5.2 Introduction, 5.2.1.3 Conclusions, Chapter 7, Chapter 8
20-10-18	At home	Javier	20.00 - 22.00	2	Study Sweedish
21-10-18	At home	Javier	18.00 - 22.00	4	Midterm Presentation
Total				34,5	

Week 8					
22-10-18	Novia	Javier	9.00 - 16.00	7	Meeting - Design of piston
23-10-18	At home	Javier	00.00 - 6.00	6	Presentation - 9.6 Project hours
23-10-18	Novia	Javier	10.00 - 14.15	4,25	Presentation
24-10-18	Novia	Javier	12.00 - 18.00	6	Meeting - Assembling some pieces - experiment
25-10-18	Novia	Javier	11.00 - 16.30	5,5	Meeting - Assembling some pieces - experiment
Total				28,75	

Week 9					
30-10-18	Novia	Javier	8.00 - 17.00	9	Project Management - English - Spectrum analyzer
31-10-18	Novia	Javier	12.00 - 14.00	2	Spectrum analyzer
31-10-18	Novia	Javier	15.00 - 19.00	4	Experiment - Spectrum analyzer
31-10-18	At home	Javier	19.30 - 20.00	0,5	Spectrum analyzer
01-11-18	Novia	Javier	13.00 - 16.00	3	Experiments
Total				18,5	

Week 10					
05-11-18	Tritonia	Javier	9.00 - 13.00	4	Study Sweedish
06-11-18	Novia		10.00 - 16.30	6,5	Project management: Quality
07-11-18	Novia		12.15 - 16.45	4,5	Experiment
08-11-18	Novia		10.00 - 17.00	7	Experiment + Retake
08-11-18	At home		22.00 - 1.00	3	Project management: Quality
Total				25	

Week 11					
13-11-18	Novia	Javier	13.30 - 17.00	3,5	Experiments
14-11-18	Novia		14.00 - 18.00	4	Meeting + Experiments
14-11-18	At home		23.00 - 1.00	2	9.3.3 + 9.3.4
15-11-18	Novia		10.00 - 18.00	8	Experiments + 9.3.3 + 9.3.4
16-11-18	Novia		9.30 - 16.30	7	Meeting + Building of box and pipe
Total				24,5	

Week 12					
21-11-18	Novia	Javier	8.30 - 12.30	4	Strenghtsfinder
21-11-18	Novia		13.00 - 20.00	7	Experimentation + 10.2 + Homework + Personal Feedback
22-11-18	Novia		13.30 - 17.30	4	Strenghtfinder meeting + Evaluation report + Logbook
23-11-18	Novia		9.00 - 11.00	2	Strenghtsfinder Class
25-11-18	At home		18.00 - 21.00	3	Strenghtsfinder work for coaching session
Total				20	

Week 13					
26-11-18	Novia	Javier	14.00 - 17.00	3	Strenghtsfinder coaching + Check previous parts
27-11-18	Novia		9.30 - 17.30	8	Strenghtsfinder homework + Critical Reflection + Testing
28-11-18	Novia		10.30 - 17:30	7	English and project experiment
29-11-18	Novia		13:30 - 17:30	4	Testing + Simulation of beats
30-11-18	Novia		11:00 - 19:00	8	Testing + Simulation + Assessment
01-12-18	At home		16.00 - 21.00	5	Complete the simulation of beats + Phase 3 Cancelling
01-12-18	At home		23.00 - 0.45	1,45	Phase 2 Introduction + Phase 2 Conclusion
02-12-18	At home		17.00 - 19.00	2	Beat - program(introduction, simulations, conclusion)
Total				38,45	

Week 14					
03-12-18	Novia	Javier	11.00 - 17.30	6,5	Report + Table of contents
04-12-18	At home		00.00 - 02.30	2,5	Phase 1 Tube + Piston + Substance
04-12-18	Novia		10.00 - 12.00	2	Movie
05-12-18	Novia		13.00 - 17.45	4,75	Report
Total				15,75	

Week 15					
13-12-18	Novia	Javier	14.00 - 16.30	2,5	Meeting
Total				2,5	

Marie:

Date	Place	Name	Time	Hours	What have you done?
				Week 1	
03-09-18	Novia	Everybody	08:00:00 - 17:00	9	Introduction day
04-09-18	Novia	Everybody	08:00:00 - 10:00	2	Presentation projects
04-09-18	Roger	Everybody	13.00 - 18.00	5	Dinner at Roger's place
05-09-18	Novia	Everybody	10.00 - 16.00	6	Pteambuilding and project management
06-09-18	Archipelago	Everybody	11.45 - 15.45	5	Trip to the archipelago
07-09-18	Novia	Everybody	08:00 - 10.30	2,5	Team work
Total				29,5	
				Week 2	
10-09-18	Novia	Everybody	12.00 - 14.00	2	Teambuilding with belbin
10-09-18	Novia	Everybody	14.00 - 15.00	1	Meeting
11-09-18	Tritonia	Everybody	10.00 - 12.00	2	Team work
11-09-18	Abo	Everybody	16.30 - 18.00	1,5	Swedish lesson
12-09-18	Novia	Everybody	14.00 - 16.00	2	Meeting
13-09-18	Novia	Everybody	08.00 - 15.00	7	Cross cultural understanding
13-09-18	Abo	Everybody	16.30 - 18.00	1,5	Swedish lesson
14-09-18	Novia	Everybody	09.00 - 13.00	4	Cross cultural understanding
Total				21	
				Week 3	
17-09-18	Tritonia	Marie, Javier	12.00 - 14.30	2,5	Working on the presentation and WBS
17-09-18	Tritonia	Marie	14:30 - 16:00	1,5	WBS research
18-09-18	Novia	Everybody	08.00 - 13.00	5	Progression presentation. English lesson. Meeting with Kai
18-09-18	Abo	Everybody	16.30 - 18.00	1,5	Swedish lesson
19-09-18	Novia	Everybody	13.00 - 15.30	2,5	Team work
20-09-18	Abo	Everybody	16.30 - 18.00	1,5	Swedish lesson
20-09-18	Tritonia	Marie	14:00 - 16:00	2	Research
21-09-18	Novia	Everybody	11:00 - 13:30	2,5	Meeting
21-09-18	Tritonia	Marie	14:00 - 16:00	2	Research + Final report
Total				21	
				Week 4	
24-09-18	Novia	Everybody	13.00 - 15.30	2,5	Meeting + Research
24-09-18	Abo Academi	Marie	17:00 - 19:00	2	Swedish
25-09-18	Novia	Everybody	10:00 - 11:30	1,5	English
25-09-18	Novia	Everybody	13:00 - 14:00	1	Project managment
25-09-18	Novia	Marie	14:00 - 16:30	2,5	Research about dB
27-09-18	At home	Marie	14:00 - 16:00	2	Research about dB - spectrum & Fourier series
29-09-18	At home	Marie	14:00 - 16:00	2	Research about Spectrum & Fourier series
Total				13,5	
				Week 5	
01-10-18	At home	Marie	14:00 - 16:00	2	Presention - Analyse team bulbin - Swedish
01-10-18	Abo Acedemi	Marie	17:00- 19:00	2	Swedish lesson
02-10-18	Novia	Marie	10:00 - 17:00	7	English - Project management - meeting
03-10-18	At home	Marie	13:00 - 15:00	2	Swedish
04-10-18	At home	Marie	10:00 - 17:00	7	Swedish - Research Kundt's tube
05-10-18	Novia	Marie	14:00 - 17:00	3	Experiment testing
Total				23	
				Week 6	
08-10-18	Novia	Marie	10:00 - 18:00	8	Buisness lesson - Midterm report - Meeting - Swedish homework
08-10-18	At home	Marie	19:00 - 20:00	1	Swedish
09-10-18	Novia	Marie	10:00 - 18:00	8	Buisness lesson - Buisness presetation - Meeting - Swedish courses
10-10-18	Novia	Marie	10:00 - 17:00	7	Buisness lesson - Final report - research - logo
11-10-18	Novia	Marie	14:00 - 17:00	3	Swedish - Final report
12-10-18	Novia	Marie	14:00 - 17:00	3	Swedish - Final report
14-10-18	At home	Marie	16:00 - 18:00	2	Swedish - Belbin test - reaserch machining
Total				32	
				Week 7	
15-10-18	Abo academi	Marie	17:00 - 19:00	2	Swedish lesson
16-10-18	At home	Marie	13:00 - 15:00	2	Research about milling machine
16-10-18	Abo academi	Marie	16:30 - 18:00	1,5	Swedish exam
17-10-18	Novia	Marie	10:00 - 17:00	7	Piston - Milling machine
17-10-18	Abo academi	Marie	17:00 - 19:00	2	Swedish lesson
18-10-18	Novia	Marie	10:00 - 17:00	7	Meeting - Experiment - Final report
18-10-18	At home	Marie	17:00 - 19:00	2	Catia
19-10-18	Novia	Marie	11:00 - 18:00	6	Meeting - Experiment - Final report
20-10-18	At home	Marie	14:00 - 18:00	4	Final report - presentation
20-10-18	At home	Marie	20:00 - 22:00	2	Swedish
21-10-18	At home	Marie	13:30 - 18:00	4,5	Swedish - presentation
Total				40	

Week 8					
22-10-18	Novia	Marie	9:00 - 16:00	7	Meeting - shop - machinig
22-10-18	Abo academi	Marie	16:00 - 19:00	3	Swedish lesson
23-10-18	Novia	Marie	10:00 - 17:00	7	Meeting - swedish
23-10-18	Abo academi	Marie	17:00 - 19:00	2	Swedish exam
24-10-18	Novia	Marie	12:00 - 18:00	6	Meeting - Assembling some pieces - experiment
25-10-18	Novia	Marie	11:00 - 16:30	5,5	Meeting - Assembling some pieces - experiment
Total				30,5	

Week 9					
29-10-18	Novia	Marie	14:00 - 15:00	1	Components
30-10-18	Novia	Marie	08:00 - 15:00	7	Project managment - English - components
31-10-18	Novia	Marie	13:00 - 17:00	4	Experiments
01-11-18	Novia	Marie	13:00 - 16:00	3	Experiments
02-11-18	On train	Marie	14:00 - 15:00	1	Picture experiment table
05-11-18	On train	Marie	14:00 - 18:00	4	Components + picture experemient table
Total				20	

Week 10					
06-11-18	Novia	Marie	10:00 - 16:30	6,5	picture experemient table + risk managment
07-11-18	Novia	Marie	12:15 - 16:45	4,5	Experiment
07-11-18	At home	Marie	20:00 - 22:00	2	Risk managment
08-11-18	Novia	Marie	10:00 - 16:30	6,5	Experiment
09-11-18	Novia	Marie	13:00 - 17:00	4	Final report
10-11-18	At home	Marie	12:00 - 14:00	2	Report
Total				25,5	

Week 11					
12-11-18	Novia	Marie	10:00 - 17:00	7	Report
13-11-18	Novia	Marie	13:30 - 17:00	3,5	Report - meeting
14-11-18	At home	Marie	10:30 - 12:30	2	Report on my stay - report
14-11-18	Novia	Marie	14:00 - 16:0	2,5	Experiment
15-11-18	Novia	Marie	10:00 - 18:00	8	Report - experiment
16-11-18	Novia	Marie	9.30 - 16.30	7	Meeting + experiment
Total				30	

Week 12					
19-11-18	Novia / At home	Marie	14:00 - 16:00	2	Readind report - Experiment
20-11-18	At home	Marie	10:00 - 18:00	8	Strenghtsfinder homework - Report (copy all texts)
21-11-18	Novia	Marie	8:30 - 17:00	9,5	Strenghtsfinder - experiment
22-11-18	Novia	Marie	13:00 - 13:30	0,5	Strenghtsfinder
Total				20	

Week 13					
27-11-18	At train	Marie	20:00 - 22:00	2	Strenghtsfinder homework
28-11-18	Novia	Marie	10.30 - 17:30	7	English and project experiment
28-11-18	At home	Marie	19:00 - 20:30	1,5	Strenghtsfinder homework
29-11-18	Novia	Marie	13:30 -17:30	4	Project experiment + report
29-11-18	Novia	Marie	19:00 - 21:00	2	Strenghtsfinder homework + report
30-11-18	Novia	Marie	11:00 - 19:00	8	Experiment + report
02-11-18	At home	Marie	11:00 - 14:00	3	Report
Total				27,5	

Week 14					
03-12-18	Novia	Marie	11:00 - 18:00	7	Report
03-12-18	Novia	Marie	19:00 - 21:00	2	Report
04-12-18	Novia	Marie	10:00 - 13:00	3	Movie
05-12-18	Novia	Marie	12:30 - 18:00	5,5	Report
Total				17,5	

Week 15					
11-12-18	At home	Marie	10:00 - 12:00	2	Report
12-12-18	Novia	Marie	13:00 - 16:30	3,5	Report
12-12-18	At home	Marie	17:00 - 19:00	2	Repot + WBS
13-12-18	At home	Marie	10:00 - 12:00	2	Presentation
13-12-18	Novia	Marie	14:00 - 17:00	3	Report
Total				12,5	

Emma:

Date	Place	Name	Time	Hours	What have you done?
			Week 1		
03-09-18	Novia	Emma	08:00:00 - 17:00	9	Introduction day
04-09-18	Novia	Emma	08:00:00 - 10:00	2	Presentation projects
04-09-18	Roger	Emma	13.00 - 18.00	5	Dinner at Roger's place
05-09-18	Novia	Emma	10.00 - 16.00	6	Pteambuilding and project management
06-09-18	Archipelago	Emma	11.45 - 15.30	4,25	Trip to the archipelago
07-09-18	Novia	Emma	08:00 - 10.30	2,5	Team work
Total				28,75	
			Week 2		
10-09-18	Novia	Emma	12.00 - 14.00	2	Teambuilding with belbin
10-09-18	Novia	Emma	14.00 - 15.00	1	Meeting
11-09-18	Novia	Emma	15.00-15.15	0,15	Brainstorm mission
12-09-18	Novia	Emma	15.15-15.30	0,15	Brainstorm vission
13-09-18	Novia	Emma	15.30-15.45	0,15	Brainstorm objectives
11-09-18	Tritonia	Emma	10.00 - 12.00	2	Team work
11-09-18	At home	Emma	14.00 - 15.00	1	Research
11-09-18	Abo	Emma	16.30 - 18.00	1,5	Swedish lesson
12-09-18	At home	Emma	10.00 - 12.00	2	Research
12-09-18	Novia	Emma	14.00 - 16.00	2	Meeting
13-09-18	Novia	Emma	08.00 - 15.00	7	Cross cultural understanding
13-09-18	Abo	Emma	16.30 - 18.00	1,5	Swedish lesson
14-09-18	Novia	Emma	09.00 - 13.00	4	Cross cultural understanding
Total				24,45	
			Week 3		
17-09-18	At home	Emma	20.00 - 23.00	3	Working on the presentation and WBS
17-09-18	Tritonia	Emma	14:30 - 16:00	1,5	WBS, research
18-09-18	Novia	Emma	08.00 - 13.00	5	Progression presentation, English lesson, Meeting with Kaj
18-09-18	Abo	Emma	16.30 - 18.00	1,5	Swedish lesson
18-09-18	Tritonia	Emma	10:00 - 11:30	1	Research
19-09-18	Novia	Emma	13.00 - 15.30	2,5	Team work
20-09-18	Abo	Emma	16.30 - 18.00	1,5	Swedish lesson
21-09-18	Tritonia	Emma	8:15 - 11:00	2	Research
21-09-18	Novia	Emma	11:00 - 13:30	2,5	Meeting
23-09-18	At home	Emma	10.00-11.00	1.5	Mission
23-09-18	At home	Emma	11.00-12.00	1	Objectives
23-09-18	At home	Emma	11.00-12.01	1	Vission
23-09-18	At home	Emma	13.00-15.00	1	Measurments analyse
23-09-18	At home	Emma	15.00-16.30	0,5	Scopes
23-09-18	At home	Emma	12.00-13.00	0,5	Risks
Total				26	
			Week 4		
24-09-18	Novia	Emma	13.00 - 15.30	4	Meeting + Research
24-09-18	At home	Emma	17.00 - 18.00	1	Homework from EPS_English
24-09-18	Abo Academi	Emma	17:15 - 18:45	1,5	Swedish
25-09-18	Novia	Emma	10:00 - 11:30	1,5	English
25-09-18	Novia	Emma	13:00 - 14:00	1	Project managment
25-09-18	Novia	Emma	14:00 - 17:00	3	Research about dB - spectrum & Fourier series
27-09-18	Novia	Emma	14.00-18.00	4	Meeting
Total				16	

Week 5					
01-10-18	At home	Emma	14:00 - 16:00	3	Presention - Analyse team belbin - Swedish
01-10-18	Abo Acedemi	Emma	17:15 - 18:45	1,5	Swedish lesson
02-10-18	At home	Emma	10.00-13.00	3	Research
03-10-18	At home	Emma	10.00-11.00	1	Team introduction
03-10-18	At home	Emma	11.00-12.00	1	Belbin team roles
04-10-18	Abo Acedemi	Emma	16.30-18.00	1,5	Swedish lesson
04-10-18	Novia	Emma	10.00 - 17.00	7	Working with project team
04-10-18	at home	Emma	9.00-11.00	2	learning Swedish
05-10-18	Novia	Emma	14:00 - 17:00	3	Expirment testing
06-10-18	At home	Emma	9.00-17.00	5	Report
Total				28	

Week 6					
08-10-18	Novia	Emma	10.00 - 16.30	7	English + Project Management + meeting
09-10-18	Abo Acedemi	Emma	16.30 - 18.00	1,5	Swedish lesson
09-10-18	Home	Emma	18.00-20.00	2	Subject
09-10-18	Abo Acedemi	Emma	16.30 - 18.00	1,5	Swedish lesson
09-10-18	Novia	Emma	10.00-15.00	5	Different mechanical waves
10-10-18 14-10-18	Sint Petersburg				
Total				17	

Week 7					
15-10-18	At home	Emma	10.00-18.00	6	Learning Swedish exam
16-10-18	At home	Emma	8.00-14.00	6	Learning Swedish exam
16-10-18	Abo Acedemi	Emma	16.00-18.00	2	Swedish exam
17-10-18	Novia	Emma	10.00-17.00	7	Working day on school
18-10-18	Novia	Emma	9.00-14.00	5	Report
18-10-18	Novia	Emma	16.00-18.00	2	Expirment testing
19-10-18	Novia	Emma	10.00-17.00	7	School working day project group
19-10-18	At home	Emma	18.00-20.00	2	Introductions + conclusions
20-10-18	At home	Marie	14:00 - 18:00	4	Final report - presentation
Total				41	

Week 8					
22-10-18	Novia	Emma	9:00 - 16:00	7	Meeting - shop - machinig
22-10-18	Abo academi	Emma	16:00 - 19:00	3	Swedish lesson
23-10-18	Novia	Emma	10:00 - 17:00	7	Meeting - swedish
23-10-18	Abo academi	Emma	17:00 - 19:00	2	Swedish exam
24-10-18	At home	Emma	15.00 - 16.30	1,5	Working project (research and acess documentation)
25-10-18	Novia	Emma	11:00 - 16:30	5,5	Meeting - Assembling some pieces - experiment
Total				26	

Week 9					
29-10-18	At home	Emma	14.00 - 16.00	2	Materials research
30-10-18	Novia	Emma	08.00 - 13.00	5	Project managment - English
30-10-18	At home	Emma	19.30 - 22.00	2	Materials writting
31-10-18	Novia	Emma	13.00-17.00	4	Experiments
01-10-18	At home	Emma	09.00 - 12.00	3	Research plastic tube
01-10-18	Novia	Emma	13:00 - 16:00	3	Experiments
Total				19	

Week 10					
05-10-18	At home	Emma	15:00 - 18.00	3	Research + project management
06-10-18	Novia	Emma	10:00 - 16:30	6,5	picture experemient table + project costs
07-10-18	Novia	Emma	12:15 - 16:45	4,5	Experiment
07-10-18	At home	Emma	20:00 - 22:00	2	Project costs
08-10-18	Novia	Emma	10.00 - 17.00	7	Project working on school
09-11-18	Novia	Emma	14:00 - 16:30	2,5	Experiment
10-11-18	At home	Emma	14.00 - 16.30	2,5	Chapter 9
11-11-18	At home	Emma	14.30 - 16.00	1,5	Report
Total				29,5	

Week 11					
12-11-18	Novia	Emma	10.00 - 16.00	6	Project working on school
12-11-18	At home	Emma	17.00 - 18.30	1,5	Report
13-11-18	At home	Emma	9.30 - 12.30	3	Report
13-11-18	Novia	Emma	13.30 - 17.00	3,5	Report + meeting
14-11-18	At home	Emma	9.00 - 10.30	1,5	Report and planning
14-11-18	Novia	Emma	14.00 - 18.00	4	Experiments + report
15-11-18	Novia	Emma	10.00 - 17.30	7,5	Experiements + report
16-11-18	Novia	Emma	09.30 - 16.30	7	Experiment + report
17-11-18	At home	Emma	13.00 - 16.00	4	Report controlling
Total				38	

Week 12					
19-11-18	Stockholm				
20-11-18	Stockholm				
20-11-18	At home	Emma	19.00 - 21.00	2	Report controlling
21-11-18	Novia	Emma	08.30 - 17.00	8,5	Guest lecture + experiment
21-11-18	At home	Emma	17.00 - 23.00	5	Report controlling
22-11-18	At home	Emma	09.00 - 12.00	3	Strength finder
22-11-18	Novia	Emma	13.45 - 16.00	2,15	Strength finder + project experiments
22-11-18	Home	Emma	17.00 - 18.30	1,5	Reflection
23-11-18	Novia	Emma	9.00 - 13.00	4	Geust lecture
23-11-18	Home	Emma	15.00 - 17.00	2	Report
Total				28,15	

Week 13					
26-11-18	Novia	Emma	12.00 - 15.00	3	Session Peter, experiment
26-11-18	Home	Emma	17.00 - 18.00	1	Planning + report
27-11-18	Novia	Emma	10.00 - 12.30	2,5	Experiment + report
27-11-18	At home	Emma	16.00 - 17.00	1	Report
28-11-18	Novia	Emma	10.30 - 17.30	7	English and project experiment
29-11-18	At home	Emma	11.00 - 12.00	1	Stengthsfinder homework
29-11-18	Novia	Emma	13.30 - 14.45	1,25	Experiment
29-11-18	At home	Emma	15.00 - 17.30	2,5	Improve report with comments Hanna
30-11-18	Novia	Emma	11.00 - 15.00	4	Experiment
30-11-18	At home	Emma	15.15 - 17.00	1,45	Finish homework Peter Menger
02-11-18	At home	Emma	14.00 - 16.00	2	Report
Total				26,7	

Week 14					
03-12-18	Novia	Emma	11.00 - 15.00	4	Report
03-12-18	Novia	Emma	15.30 - 17.00	1,5	Table of contents
03-12-18	At home	Emma	17.30 - 20.00	1,5	Report
04-12-18	Novia	Emma	10.00 - 13.00	3	Video
04-12-18	At home	Emma	14.00 - 17.00	3	Video
05-12-18	Novia	Emma	13.30 - 18.00	4,5	Report and video
06-12-18 till 11-12-18	Lapland trip				
Total				17,5	

Week 15					
10-12-18	At home	Sannah	11.00 - 18.00	7	Report
10-12-18	At home	Sannah	22.00 - 00.00	2	Report
11-12-18	At home	Sannah	10.00 - 13.00	3	Report
11-12-18	At home	Sannah	14.30 - 16.00	1,5	Reflection
11-12-18	At home	Sannah	17.00 - 19.00	2	Report
12-12-18	Novia	Sannah	13.00 - 16.30	3,5	Presentation + report
13-12-18	Novia	Sannah	14.00 - 17.30	3,5	Meeting
13-12-18	At home	Sannah	19.00 - 21.30	2,5	Report
Total				25	

Sannah:

Date	Place	Name	Time	Hours	What have you done?
				Week 1	
03-09-18	Novia	Sannah	08:00:00 - 17:00	9	Introduction day
04-09-18	Novia	Sannah	08:00:00 - 10:00	2	Presentation projects
04-09-18	Roger	Sannah	13.00 - 18.00	5	Dinner at Roger's place
05-09-18	Novia	Sannah	10.00 - 16.00	6	Pteambuilding and project management
06-09-18	Archipelago	Sannah	11.45 - 15.30	4,25	Trip to the archipelago
07-09-18	Novia	Sannah	08:00 - 10.30	2,5	Team work
Total				28,75	
				Week 2	
10-09-18	Novia	Sannah	12.00 - 14.00	2	Teambuilding with belbin
10-09-18	Novia	Sannah	14.00 - 15.00	1	Meeting
11-09-18	Tritonia	Sannah	10.00 - 12.00	2	Team work
11-09-18	At home	Sannah	14.00 - 15.00	1	Research
11-09-18	Abo	Sannah	16.30 - 18.00	1,5	Swedish lesson
12-09-18	At home	Sannah	10.30 - 12.30	2	Research
12-09-18	Novia	Sannah	14.00 - 16.00	2	Meeting
13-09-18	Novia	Sannah	08.00 - 15.00	7	Cross cultural understanding
13-09-18	Abo	Sannah	16.30 - 18.00	1,5	Swedish lesson
14-09-18	Novia	Sannah	09.00 - 13.00	4	Cross cultural understanding
Total				24	
				Week 3	
17-09-18	At home	Sannah	20.00 - 23.00	3	Working on the presentation and WBS
18-09-18	Novia	Sannah	08.00 - 13.00	5	Progression presentation, English lesson, Meeting with Kaj
18-09-18	Abo	Sannah	16.30 - 18.00	1,5	Swedish lesson
19-09-18	Novia	Sannah	13.00 - 15.30	2,5	Team work
20-09-18	Abo	Sannah	16.30 - 18.00	1,5	Swedish lesson
20-09-18	At home	Sannah	13:00 - 16:00	3	Research
21-09-18	Novia	Sannah	11:00 - 13:30	2,5	Meeting
21-09-18	At home	Sannah	14:00 - 17:00	3	Research + Final report
22-09-18	At home	Sannah	11.00 - 14.00	3	Research + Final report
Total				25	
				Week 4	
24-09-18	Novia	Sannah	13.00 - 15.30	2,5	Meeting + Research
24-09-18	At home	Sannah	17.00 - 18.00	1	Homework from Swedish
25-09-18	Abo Academi	Sannah	15.30 - 18.00	2,5	Swedish lesson
25-09-18	Novia	Sannah	10:00 - 11:30	1,5	English
25-09-18	Novia	Sannah	13:00 - 14:00	1	Project managment
26-09-18	At home	Sannah	12.00 - 14.00	2	Introduction report
26-09-18	At home	Sannah	15.00 - 18.00	3	Research
27-09-18	Abo Academi	Sannah	17.00 - 19.00	2	Swedish lesson
Total				15,5	
				Week 5	
02-10-18	Abo Acedemi	Sannah	16.30 - 18.00	1,5	Swedish lesson
02-10-18	At home	Sannah	19.00 - 21.00	2	Learning Swedish
02-10-18	Novia	Sannah	10.00 - 16.30	7	English + Project Management + meeting
03-10-18	Novia	Sannah	10.00 - 12.30	2,5	Meeting
05-10-18	Novia	Sannah	14.00 - 17.00	3	Experiment testing
04-10-18	Abo Acedemi	Sannah	16.30 - 18.00	1,5	Swedish lesson
05-10-18	At home	Sannah	11.00 - 13.00	2	Research
06-10-18	At home	Sannah	12.00 - 16.00	4	Report introduction + research
07-10-18	At home	Sannah	12.00 - 18.00	6	Report companies + Report design
Total				29,5	

Week 6					
08-10-18	Novia	Sannah	10.00 - 18.00	8	Business Analysis + teamwork + meeting
09-10-18	Novia	Sannah	10.00 - 16.30	6,5	Business Analysis + teamwork
09-10-18	Abo Academi	Sannah	16.30 - 18.00	1,5	Swedish lesson
10-10/14-10	Rusia				ESN Trip to Saint Petersburg
Total				16	

Week 7					
15-10-18	At home	Sannah	10.00 - 18.00	8	Learned Swedish
16-10-18	At home	Sannah	10.00 - 16.00	6	Learned Swedish
16-10-18	Abo Academi	Sannah	16.30 - 18.00	1,5	Swedish exam
18-10-18	Novia	Sannah	10.00 - 15.00	5	Report
18-10-18	At home	Sannah	21.00 - 23.30	2,5	Report design
19-10-18	At home	Sannah	20.30 - 22.00	1,5	Report introductions
19-10-18	Novia	Sannah	11.00 - 17.00	6	Report + presentation + experiment
20-10-18	At home	Sannah	13.00 - 16.00	3	Report
21-10-18	At home	Sannah	12.00 - 13.00	1	Report
21-10-18	At home	Sannah	13.00 - 16.00	3	Swedish
21-10-18	At home	Sannah	16.30 - 17.30	1	Report + presentation
21-10-18	At home	Sannah	21.00 - 22.30	1,5	Report conclusion
Total				40	

Week 8					
22-10-18	Novia	Sannah	9:00 - 16:00	7	Meeting - shop - machinig
22-10-18	Abo academi	Sannah	16:00 - 19:00	3	Swedish lesson
23-10-18	Novia	Sannah	10:00 - 17:00	7	Meeting - swedish
23-10-18	Abo academi	Sannah	17:00 - 19:00	2	Swedish exam
24-10-18	Novia	Sannah	12:00 - 13.30	1,5	Meeting - Assembling some pieces - experiment
Total				20,5	

Week 9					
25-10 / 4-11	Netherlands	Sannah			The external essay

Week 10					
06-11-18	Novia	Sannah	10:00 - 16:30	6,5	picture experemient table + risk managment
07-11-18	Novia	Sannah	12:15 - 16:45	4,5	Experiment
07-11-18	At home	Sannah	20:00 - 22:00	2	Communication management
08-11-18	Novia	Sannah	10:00 - 18:00	8	Experiment
09-11-18	Novia	Sannah	13:00 - 17.00	4	Experiment
09-11-18	AT home	Sannah	19.00- 21.30	2,5	Report
10-11-18	At home	Sannah	15.30 - 17.30	2	Website
11-11-18	At home	Sannah	13.00 - 15.00	2	Website
11-11-18	At home	Sannah	19.00 - 22.00	3	Chapter 7
Total				34,5	

Week 11					
12-11-18	Novia	Sannah	10.00 - 17.30	7,5	Experiment + report
12-11-18	At home	Sannah	20.00 - 22.00	2	Website
13-11-18	At home	Sannah	09.30 - 11.00	1,5	Report + Website
13-11-18	Novia	Sannah	13.30 - 18.30	5	Experiment + report
14-11-18	Novia	Sannah	14.00 - 18.00	4	Experiment + report
15-11-18	Novia	Sannah	10.00 - 18.00	8	Experiment + report
16-11-18	Novia	Sannah	09.30 - 16.30	7	Experiment + report
17-11-18	At home	Sannah	13.00 - 16.00	3	Report controlling
Total				38	

Week 12					
19-11-18	Stockholm				
20-11-18	Stockholm				
20-11-18	At home	Sannah	19.00 - 21.00	2	Report controlling
21-11-18	Novia	Sannah	08.30 - 17.00	8,5	Straigthsfinder + experiment + controlling
21-11-18	At home	Sannah	17.30 - 23.30	5	Report controlling
22-11-18	At home	Sannah	10.00 - 12.30	2,5	Straigthfinder
22-11-18	Novia	Sannah	13.45 - 17.30	3,45	Experiment + report
23-11-18	Novia	Sannah	09.00 - 15.00	6	Straigthfinder + experiment
23-11-18	At home	Sannah	18.00 - 22.00	4	Report + Website
24-11-18	At home	Sannah	12.00 - 14.00	2	Report + Website
25-11-18	At home	Sannah	19.00 - 23.00	4	Straigthfinder
Total				37,45	

Week 13					
26-11-18	Novia	Sannah	12.00 - 15.00	3	Session peter + Experiment
26-11-18	At home	Sannah	19.00 - 21.30	2,5	Report + Straigthfinder
27-11-18	Novia	Sannah	10.00 - 13.00	3	Experiment + Report
28-11-18	Novia	Sannah	10.30 - 12.00	1,5	English + Report
29-11-18	At home	Sannah	20.00 - 23.00	3	Straigthfinder
30-11-18	At home	Sannah	16.00 - 19.00	3	Straigthfinder
29 -11 / 3-12	Lapland				
Total				16	

Week 14					
03-12-18	Novia	Sannah	16.00 - 17.30	1,5	Table of contents
04-12-18	Novia	Sannah	10.00 - 13.00	3	Video
04-12-18	At home	Sannah	20.00 - 22.00	2	New report
05-12-18	At home	Sannah	10.00 - 12.30	2,5	New report
05-12-18	AT Home	Sannah	15.30 - 19.00	3,5	New report
05-12-18	At home	Sannah	21.00 - 22.30	1,5	Checking report
06-12-18	At home	Sannah	09.30 - 14.00	4,5	Report
06-12-18	At home	Sannah	17.00 - 00.00	7	Report
08-12-18	At home	Sannah	14.00 - 17.00	3	Report
09-12-18	At home	Sannah	10.00 - 13.00	3	Report
09-12-18	At home	Sannah	22.00 - 00.00	2	Report
Total				33,5	

Week 15					
10-12-18	At home	Sannah	11.00 - 18.00	7	Report
10-12-18	At home	Sannah	22.00 - 00.00	2	Report
11-12-18	At home	Sannah	10.00 - 13.00	3	Report
11-12-18	At home	Sannah	14.30 - 16.00	1,5	Reflection
11-12-18	At home	Sannah	17.00 - 19.00	2	Report
12-12-18	Novia	Sannah	13.00 - 16.30	3,5	Presentation + report
13-12-18	Novia	Sannah	14.00 - 17.30	3,5	Meeting
13-12-18	At home	Sannah	19.00 - 21.30	2,5	Report
Total				25	

Annex 8: Team contract

Supervisor: Kaj Rintanen

Members of the group:

Name	E-mail	Mobile number
Marie Raynal	marie.raynal16@gmail.com	+33615195132
Emma Kleijn	emma.kleijn@ziggo.nl	+31618610501
Sannah van Duuren	sannahvanduuren@hotmail.com	+31630426247
Javier Valentin	valentincolen@outlook.com	+34644560456

Agreements about:

1. How do you reach each other and the supervisor?

We reach each other via Whatsapp. Also, the contact with the supervisor is with an Whatsapp group, we can also send him e-mails. We agreed that everyone needs to respond as soon as possible.

2. Working language

The general working language is English. The project will be written in English. Besides that, the speaking languages of the project group needs to be English.

3. Time and places to work

We agreed that we work 37,5 hours per week on the project, we keep this up with a logbook. The places where we can work on the project are:

- Novia university of applied sciences;
- Technobotnia;
- Tritonia;
- At home.

4. How we deal with errors in the delivered documents?

The author must improve the document in question. The document must be checked again with groupmates.

5. What if:

- Absent with valid reason

If you have a valid reason it is okay to be absent. In discussion with group we can arrange another meeting. If it happens to often the group discuss a consequence. It is important to always send a message.

- Absent without valid reason

Without a valid reason the group will discuss what to do. When it happens to often we can discuss with Roger of Kaj.

- Don’t keep the agreements

It needs to be discussed in the group, the person who don’t keep the agreement must try to make up for it.

- Too late on a meeting

Without a valid reason the group will discuss what to do. When it happens to often we can discuss it together and otherwise with Roger or Kaj.

6. What is the group target?

We want to have a good English communication with the project group. Besides that, we want to pass the project and found a good solution for reduce the active noise.

7. What can the supervisor expect from us and what can the supervisor mean for us?

The supervisor can expect a good communication and work spirit. Besides that, the supervisor can help us with advice and tips.

8. Learning goals

Name student	Learning goal	How are you going to achieve this goal? How can the project group help you with this?
Marie Raynal	*To improve my English, and learn to work with students who have another culture*	*To share my ideas and spend time with my group*
Emma Kleijn	*Improve my English language, and learn more about technical subjects.*	*Try to talk much English and don't be afraid to do that. Besides that, I want to do research on the technical subject to understand as much as possible.*
Sannah van Duuren	*To improve my English communication and working skills.*	*To listen to my team and learn from them. Try to talk not that much Dutch.*
Javier Valentin	*To gain knowledge about control systems, improve my teamwork.*	*To gain knowledge I will study and to improve my teamwork I will try to understand the team and fit the best way possible.*

9. Team roles

Team roles	Name student
Project manager	Sannah
Planner	Emma
Secretary	Javier
Final editor	Marie
Administrator of dropbox	Sannah