ASTRONOMY AND PHYSICS
Published: 17 August 2022
doi: 10.3389/frym.2022.804634

ACOUSTICS OF CLASSROOMS

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YOUNG REVIEWERS

SAINT BERNARD'S CATHOLIC HIGH SCHOOL

AGES: 11–13

In this article we will study sound—specifically, how sound allows us to communicate in a classroom and how we can improve that communication. You will learn how sound is measured and how people called acoustics engineers help architects and designers to make sure classrooms are not too noisy—or too quiet. We even have some experiments that you can do to measure sounds at home, at school, or in a football stadium.

THE SCIENCE OF SOUND

ACOUSTICS

The scientific study of sound and vibration.

Acoustics, the science of sound, is a science that you might not have heard much, if anything, about. Why do people know so little about the science of sound? Perhaps it is because many of us take sound and hearing for granted. Yet, imagine life without your sense of hearing! No music, no laughter, no talking, no singing? When you think of how much we rely on sound, it is surprising that so many people have never heard of acoustics! Of course, some people do not have the ability to hear. In the past 30 years, acoustic engineers have helped a million people across the world overcome hearing challenges using bionic implants, and they have helped hundreds of millions of people through hearing aids. One place acoustics has an especially big effect is in the classroom—you can not learn if cannot communicate!

CLEAR COMMUNICATION

What is a classroom for? Well, it is a space where people can learn by listening to a teacher and talking with other students. Classrooms are spaces where we communicate with others to help increase our knowledge and understanding of the world around us. However, creating a space where communication is easy is not actually as simple as it might seem. Students in a classroom need to be able to hear the teacher talking without being distracted by other sounds such as their friends chatting, the sound of a passing truck or a football match being played outside [1–3].

We call the sound a person wants to hear the **signal**. In our example, the signal is the teacher talking [4]. We call all the other sounds **noise**. Noise includes the distracting sounds the person does not want to hear. For a classroom to work well, students need to hear more of the signal and less of the noise. We call this the **signal-to-noise ratio**, and this is where acoustical engineering comes in! Acoustic engineers can help design classrooms to reduce the amount of distracting noise coming from outside and to help manage noise created by students inside. Acoustic engineers are often hired to improve the way schools are built and make sure they are made of the best materials, to ensure communication is as clear as possible. Acoustic engineers also provide guidance for builders and architects. The work of acoustic engineers helps create a comfortable place to learn, where students hear what their teachers are saying[1].

SIGNAL

A wanted sound that carries information.

NOISE

Unwanted sound.

SIGNAL-TO-NOISE RATIO

A comparison of the wanted sound level to that of the unwanted level. A positive result is helpful to communication of information.

[1] You can find more information on the standard guidance for designers here: https://www.gov.uk/government/publications/bb93-acoustic-design-of-schools-performance-standards.

ACOUSTICS

Sound is measured in a unit called **decibels** (dB). Sound involves unusual maths because it is measured on a logarithmic scale. We can use another logarithmic scale, the Richter scale, as an example. The Richter scale is used to measure earthquakes and runs from 0 to 10, while decibels run in a scale from 0 to 100. A magnitude 5 earthquake will shake your home and perhaps knock a garden wall down. A magnitude 6 earthquake is not just a little stronger—it is 10 times stronger than a magnitude 5! A magnitude 6 earthquake will destroy a house, a 7 (10 times stronger than a six) will destroy a town, an 8 will destroy a city, a 9 will destroy a small country and a 10 will destroy a large country. The largest earthquake ever measured was 9.2 on the Richter scale!

DECIBELS

The unit of measurement of sound, typically 0–100 dB.

Now back to acoustics. The dB scale works the same way, except that it runs from 1 to 100. The “dec” part of “decibel” means 10, which is the

ANECHOIC CHAMBER

A room without echo achieved by covering every surface with sound absorbing material such as foam.

[2] View a video here: https://www.youtube.com/watch?v=LQsz7SzmU8s&t=7s.

fold increase between numbers on a logarithmic scale. The quietest sound you can hear is 0 dB, and you can only hear this in a special room called an **anechoic chamber**, which means a room without echo—a very strange room (Figure 1)[2]. The sound of someone whispering is around 20 dB. 40 dB would be someone talking quietly, and if you were chatting to a friend, your voice would probably measure 60 dB. When a teacher is talking to a whole class, the teacher's voice probably measures 70 dB, but if the teacher is shouting, their voice would be around 80 dB.

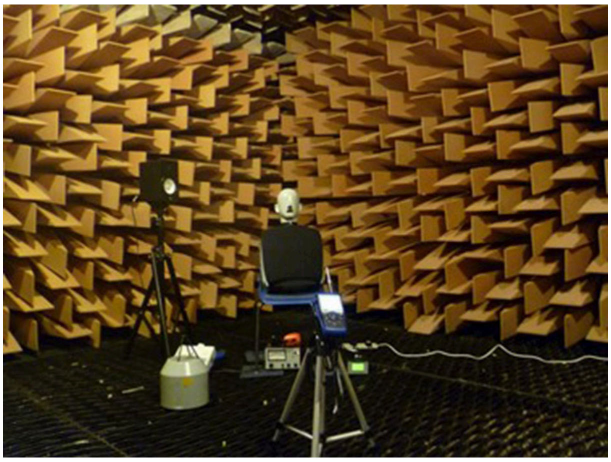

Figure 1

Figure 1

An anechoic chamber a special room that does not have echoes. Note the thousands of sound-absorbing foam wedges.

CLASSROOM ACOUSTICS

REVERBERATION TIME

The length of time (in seconds) that a sound takes to be stopped being heard. The sound is usually created by an impulsive sound (balloon burst).

Not only can we measure how loud a sound is, we can also measure how echoey a room might be. This is measured in seconds and called **reverberation time** (RT). RT is defined as the length of time it takes a sound to completely disappear. For example, if you sneeze, how long is it before the whole sound of that sneeze has gone? This depends on whether you sneeze at a swimming pool or in the gym. An anechoic chamber has a reverberation time of 0 s. Here is a simple experiment you can try at home or school to illustrate this point. You will need a balloon and a sharp pencil since sneezing is not very reliable signal!

First blow up the balloon and tie a knot in the end so it stays inflated. Next, make sure everyone in the room is completely silent. Now pop the balloon using the pencil. BANG! As you do so, start counting or use a timer. In a normal classroom, the sound should take about 1 s to disappear. Now repeat the experiment in your school hallway, an echoey corridor, or the gym. You will probably discover that the sound takes longer to disappear in bigger spaces, especially spaces with fewer carpets, curtains, or furniture.

So, RT is different depending on where you are. Acoustic engineers aim for the RT in modern classrooms to be around 0.8 s (Figure 2). This means that any sounds will disappear after 0.8 s. Classrooms in old buildings with high ceilings might have a higher RT because they are more echoey (Figure 3). It can be much harder to hear what the teacher is saying in these kinds of spaces.

Figure 2

Figure 2

A modern classroom, where reverberation time is usually around 0.8 s.

Figure 3

Figure 3

A Victorian classroom, where reverberation time is around 1.5 s. It was harder to hear the teacher back then!

Where the RT of a room is too high and sound is echoing around and making a lot of noise, adding soft materials such as cushions, carpets, and curtains can help absorb, or soak up, the sound. Acoustic engineers use a number called an **absorption coefficient** to describe how well materials soak up sound. A rock has an absorption coefficient of 0, and something that completely absorbs all sound has an absorption coefficient of 1. An open window also has an absorption

ABSORPTION COEFFICIENT

A material characteristic describing the amount of sound that is absorbed. Ranges from 0 for hard materials (marble) to 1 for soft material (foam).

coefficient of 1, because the sound goes out the window and does not come back. Glass has an absorption coefficient of 0.03, and wood is around 0.1.Cushions have an absorption coefficient of 0.9[3].

[3] For more information, see: https://www.engineeringtoolbox.com/accoustic-sound-absorption-d_68.html.

With the correct information, we can work out the RT of any room, We do this using the following equation:

$$RT = \frac{0.16 \ast V}{S\alpha}$$

V is the size of the room (volume) in cubic meters (m^3). *S* is the walls, ceiling, and floor combined, measured in square meters (m^2) and α is the absorption coefficient of whatever the room is made from.

Imagine a greenhouse made entirely from glass that is 2 m long, 2 m wide and 2 m high. The size or volume of the greenhouse is $2 \times 2 \times 2 = 8\ m^3$. Each wall, floor and ceiling would each have an area of $2 \times 2\,m = 4\ m^2$. There are four walls plus one floor and one ceiling). So $S = 6 \times 4 = 24\ m^2$. We know the absorption coefficient of glass is 0.03. The equation becomes:

$$RT = 0.16{\times}8/24{\times}0.03 = 1.78s.$$

In other words, inside our small room made entirely of glass, any loud sound made would last for 1.78 s.

In the real world, however, most rooms or indoor spaces are made up of lots of different materials—the brick of the walls, the glass of the windows, curtains, carpets, furniture, and even people. So, calculating the RT of real spaces can be a bit trickier!

WHEN ACOUSTICS MADE A BIG DIFFERENCE

Acoustics are not just important in classrooms. They affect all sorts of things in our world, including sport. In the semi-finals of the UEFA Champions League, in 2011, when Arsenal was playing Barcelona, the referee blew his whistle to draw the attention of the players. Robin Van Persie ignored the referee and kicked the ball at the goal, after which he was sent off. In an interview after the match, he said he had not heard the whistle and could not be expected to hear such a sound above the noise of 90,000 shouting fans. Perhaps if the stadium had had better acoustics, the player would have heard the referee and not been sent off?[4].

How loud *is* a crowd of 90,000 people? Here is an experiment you can do to find out!

First, you or a teacher will need to download a sound-measuring application onto a smartphone[5].

[4] You can watch a video of this moment here: https://www.youtube.com/watch?v=pu537wHKyGc.

[5] Check out these apps: www.studiosixdigital.com Smartphone App. 2021. www.Faberacoustical.com Smartphone App 2021. https://apps.apple.com/us/app/splnfft-noise-meter/id355396114. https://apps.apple.com/gb/app/decibel-x-db-sound-level-meter/id448155923.

Then you will need 100 students to gather in your school hall, with the person with the phone at the front.

To start, with the app running, one person in the middle of the hall stands up and shouts "Hello!." Everyone else should be quiet. The app will record how loud the sound is in dB.

Next, 10 classmates in the center of the hall stand up and all shout "Hello!" at the same time. Everyone else should be quiet. Record the result from the smartphone.

Finally, all 100 classmates stand up and all shout, "Hello" at the same time. Record the results from the smartphone.

As you increase the number of people shouting, you should see the sound level increase. One person shouting should be around 80 dB,10 people around 90 dB and 100 people around 100 dB. Now imagine increasing this amount of shouting by 10 times again, again and again! That is how loud 100,000 football fans would be!

Is it any wonder that footballers sometimes find it hard to hear the referee? Perhaps if the stadium had been empty and everyone was watching from home, the whistle-blowing might have been a bit clearer!

FINAL THOUGHTS

How noisy is your classroom? Is it easy to hear your teacher or are you distracted by the sound of other things going on in the room? Now that you understand more about how the science of acoustics works, you might have some helpful suggestions that could help reduce classroom noise and make it easier to concentrate! But be careful—if you bring in too many cushions, you might get just a little bit *too* comfortable![6]

[6] If you would like to discover more about what is happening in the world of acoustics look at these sites: www.acoustics.ac.uk. lsbu-acoustics.blogspot.com.

FUNDING

This study was supported by the EPSRC UK Acoustics Network Plus EP/V007866/1.

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SUBMITTED: 29 October 2021; **ACCEPTED:** 25 July 2022;
PUBLISHED ONLINE: 17 August 2022.

EDITOR: Christian J. Sumner, Nottingham Trent University, United Kingdom

SCIENCE MENTOR: Rebecca Susan Dewey

CITATION: Dance S and Ballestero E (2022) Acoustics Of Classrooms. Front. Young Minds 10:804634. doi: 10.3389/frym.2022.804634

CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Saint Bernard's Catholic High School is a Catholic Secondary in South Yorkshire. These KS3 students volunteered to be part of the peer review group. They read the article and made detailed notes in their own time. They loved having an active role in real peer review of this Science article—not just hearing about the process but being actively involved. Having adult authors not just listen but respond too was very empowering for them. Students involved: Sarah, Grace, Alice, Zara, Amelia, Alicja, Emilja, Megan, Edna, and Kate.

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