

# The physics of music

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ABSTRACT. This is an introduction to the physics of sound and music, kept as elementary and accessible as possible, and with a constant look into the actual human music too.

## Preface

Music is as old as mankind, and you surely know a bit about it, perhaps even more than I do, say if you seriously practice it, alone, or with some friends. We are all so close to music, which is such an important part of our lives. And with this being a phenomenon which seems to grow over the time, as our human generations pass by.

Historically, music was born as something utilitarian, most likely as a trick, in order to keep wild animals away from the camp. In fact, you might already know this from hiking, where in temperate climates at least, the most dangerous animal of them all, that you can meet on the track, is a cute baby bear. In this case, the guidelines are well-known, freeze and temporarily stop your hike, and start singing. Although there have been stories of Chuck Norris and other Texans, surviving playing with that cute little bear.

Later on, music increasingly became something festive, as being associated, for the utilitarian reasons explained above, with the camp itself. That is, associated with the good life, relaxing in the evening, cooking and eating, talking to friends and family, plus of course, enjoying what sorts of poisonous drinks they had, at that time.

The next step, with music being now perceived as being something relaxing and pleasant, was to bring it to your workplace. Life in the fields is hard, and if you have a garden of reasonable size, allowing you to do gardening, say for 10 hours in a row, if looking for such an experience, you surely know what I'm talking about. So, people started singing in the fields, with music this time being some sort of a healthy drug.

This was for the beginnings, and fast forward now to the modern world, post WW2, many things have happened, with basically any generation having their say on music:

- Boomers, or hippies, were big fans of meetings and democracy, but with political meetings being such a boring affair, better sing together some nice songs, instead of listening to speeches, and so music became an essential part of their lives.

- Generation X, on the opposite, had little to no respect for politics and democracy, their credo being that a brutal amount of daily work, followed by some fun, is the best way to change the world. With the fun in question being, basically, loud music.

– Millennials, and later Generation Z, and perhaps Generation Alpha too, we have no data here yet, had to define themselves as opposed to the previous generations, and with this being not an easy task, imaginative anti-work philosophy and music proliferated.

In short, stuck with music, no matter what we want to do, and this since ages. But, what sounds and music exactly are, physically speaking? What about biology, and our way to listen to music? Also, what kind of data can be transmitted, via music? And so on, many interesting questions regarding music, of routine scientific nature.

The present book is an introduction to this, physics of sound and music, kept as elementary and accessible as possible, and with a constant look into the actual human music too. We will attempt to answer here some of the above questions.

Many thanks to all music and musicians in this world, MTV, nightclubs, legal and illegal parties, sound system makers and so on, and with this coming, you guessed right, from your beloved Gen X math professor, and by the way please work more, exams soon. Thanks as well to my cats, there is in fact nothing more relaxing as a sound, than that of a cat purring, and we will discuss this too, in this book.

*Cergy, December 2024*

*Teo Banica*

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Part I

Basic physics

*Fools said I, you do not know  
Silence like a cancer grows  
Hear my words that I might teach you  
Take my arms that I might reach you*

## CHAPTER 1

1a.

1b.

1c.

1d.

### 1e. Exercises

Exercises:

EXERCISE 1.1.

EXERCISE 1.2.

EXERCISE 1.3.

EXERCISE 1.4.

EXERCISE 1.5.

EXERCISE 1.6.

EXERCISE 1.7.

EXERCISE 1.8.

Bonus exercise.



## CHAPTER 2

**2a.**

**2b.**

**2c.**

**2d.**

### **2e. Exercises**

Exercises:

EXERCISE 2.1.

EXERCISE 2.2.

EXERCISE 2.3.

EXERCISE 2.4.

EXERCISE 2.5.

EXERCISE 2.6.

EXERCISE 2.7.

EXERCISE 2.8.

Bonus exercise.



## CHAPTER 3

**3a.**

**3b.**

**3c.**

**3d.**

### **3e. Exercises**

Exercises:

EXERCISE 3.1.

EXERCISE 3.2.

EXERCISE 3.3.

EXERCISE 3.4.

EXERCISE 3.5.

EXERCISE 3.6.

EXERCISE 3.7.

EXERCISE 3.8.

Bonus exercise.





## CHAPTER 4

4a.

4b.

4c.

4d.

### 4e. Exercises

Exercises:

EXERCISE 4.1.

EXERCISE 4.2.

EXERCISE 4.3.

EXERCISE 4.4.

EXERCISE 4.5.

EXERCISE 4.6.

EXERCISE 4.7.

EXERCISE 4.8.

Bonus exercise.



## Part II

# Sound and music

*The tide is high  
But I'm holding on  
I'm gonna be  
Your number one*

## CHAPTER 5

5a.

5b.

5c.

5d.

### 5e. Exercises

Exercises:

EXERCISE 5.1.

EXERCISE 5.2.

EXERCISE 5.3.

EXERCISE 5.4.

EXERCISE 5.5.

EXERCISE 5.6.

EXERCISE 5.7.

EXERCISE 5.8.

Bonus exercise.



## CHAPTER 6

**6a.**

**6b.**

**6c.**

**6d.**

### **6e. Exercises**

Exercises:

EXERCISE 6.1.

EXERCISE 6.2.

EXERCISE 6.3.

EXERCISE 6.4.

EXERCISE 6.5.

EXERCISE 6.6.

EXERCISE 6.7.

EXERCISE 6.8.

Bonus exercise.





## CHAPTER 7

7a.

7b.

7c.

7d.

### 7e. Exercises

Exercises:

EXERCISE 7.1.

EXERCISE 7.2.

EXERCISE 7.3.

EXERCISE 7.4.

EXERCISE 7.5.

EXERCISE 7.6.

EXERCISE 7.7.

EXERCISE 7.8.

Bonus exercise.



## CHAPTER 8

8a.

8b.

8c.

8d.

### 8e. Exercises

Exercises:

EXERCISE 8.1.

EXERCISE 8.2.

EXERCISE 8.3.

EXERCISE 8.4.

EXERCISE 8.5.

EXERCISE 8.6.

EXERCISE 8.7.

EXERCISE 8.8.

Bonus exercise.



## Part III

# Information, math

*I know what I want  
And I want it now  
I want you  
Cause I'm Mr. Vain*

## CHAPTER 9

**9a.**

**9b.**

**9c.**

**9d.**

### **9e. Exercises**

Exercises:

EXERCISE 9.1.

EXERCISE 9.2.

EXERCISE 9.3.

EXERCISE 9.4.

EXERCISE 9.5.

EXERCISE 9.6.

EXERCISE 9.7.

EXERCISE 9.8.

Bonus exercise.





## CHAPTER 10

**10a.**

**10b.**

**10c.**

**10d.**

**10e. Exercises**

Exercises:

EXERCISE 10.1.

EXERCISE 10.2.

EXERCISE 10.3.

EXERCISE 10.4.

EXERCISE 10.5.

EXERCISE 10.6.

EXERCISE 10.7.

EXERCISE 10.8.

Bonus exercise.



## CHAPTER 11

**11a.**

**11b.**

**11c.**

**11d.**

**11e. Exercises**

Exercises:

EXERCISE 11.1.

EXERCISE 11.2.

EXERCISE 11.3.

EXERCISE 11.4.

EXERCISE 11.5.

EXERCISE 11.6.

EXERCISE 11.7.

EXERCISE 11.8.

Bonus exercise.



## CHAPTER 12

**12a.**

**12b.**

**12c.**

**12d.**

**12e. Exercises**

Exercises:

EXERCISE 12.1.

EXERCISE 12.2.

EXERCISE 12.3.

EXERCISE 12.4.

EXERCISE 12.5.

EXERCISE 12.6.

EXERCISE 12.7.

EXERCISE 12.8.

Bonus exercise.



Part IV

**Communication**

*Happy nation  
Living in a happy nation  
Where the people understand  
And dream of perfect man*



## CHAPTER 13

**13a.**

**13b.**

**13c.**

**13d.**

**13e. Exercises**

Exercises:

EXERCISE 13.1.

EXERCISE 13.2.

EXERCISE 13.3.

EXERCISE 13.4.

EXERCISE 13.5.

EXERCISE 13.6.

EXERCISE 13.7.

EXERCISE 13.8.

Bonus exercise.



## CHAPTER 14

14a.

14b.

14c.

14d.

14e. Exercises

Exercises:

EXERCISE 14.1.

EXERCISE 14.2.

EXERCISE 14.3.

EXERCISE 14.4.

EXERCISE 14.5.

EXERCISE 14.6.

EXERCISE 14.7.

EXERCISE 14.8.

Bonus exercise.



## CHAPTER 15

**15a.**

**15b.**

**15c.**

**15d.**

**15e. Exercises**

Exercises:

EXERCISE 15.1.

EXERCISE 15.2.

EXERCISE 15.3.

EXERCISE 15.4.

EXERCISE 15.5.

EXERCISE 15.6.

EXERCISE 15.7.

EXERCISE 15.8.

Bonus exercise.



## CHAPTER 16

**16a.**

**16b.**

**16c.**

**16d.**

**16e. Exercises**

Congratulations for having read this book, and no exercises for this final chapter.





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