

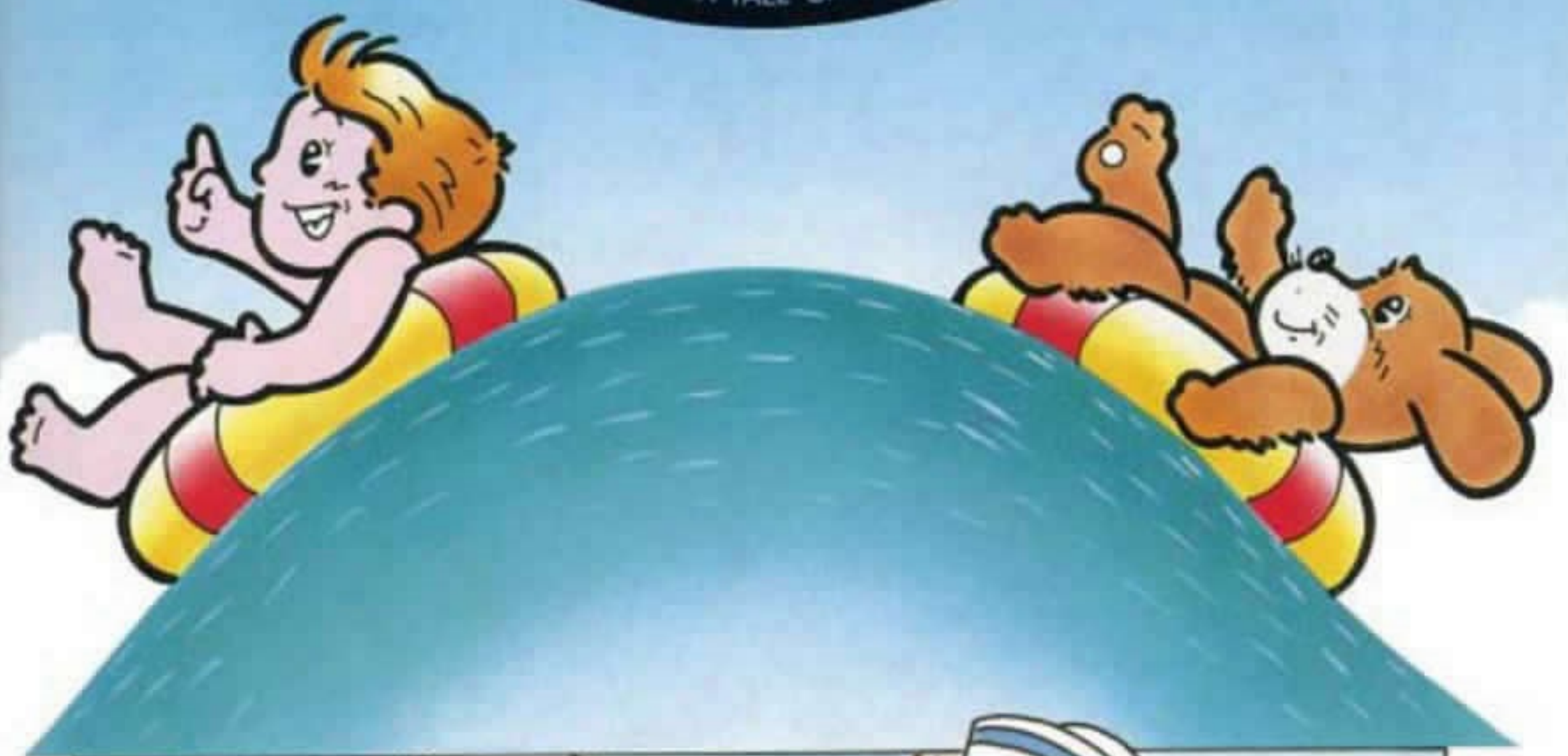
# FOURY and WAVY

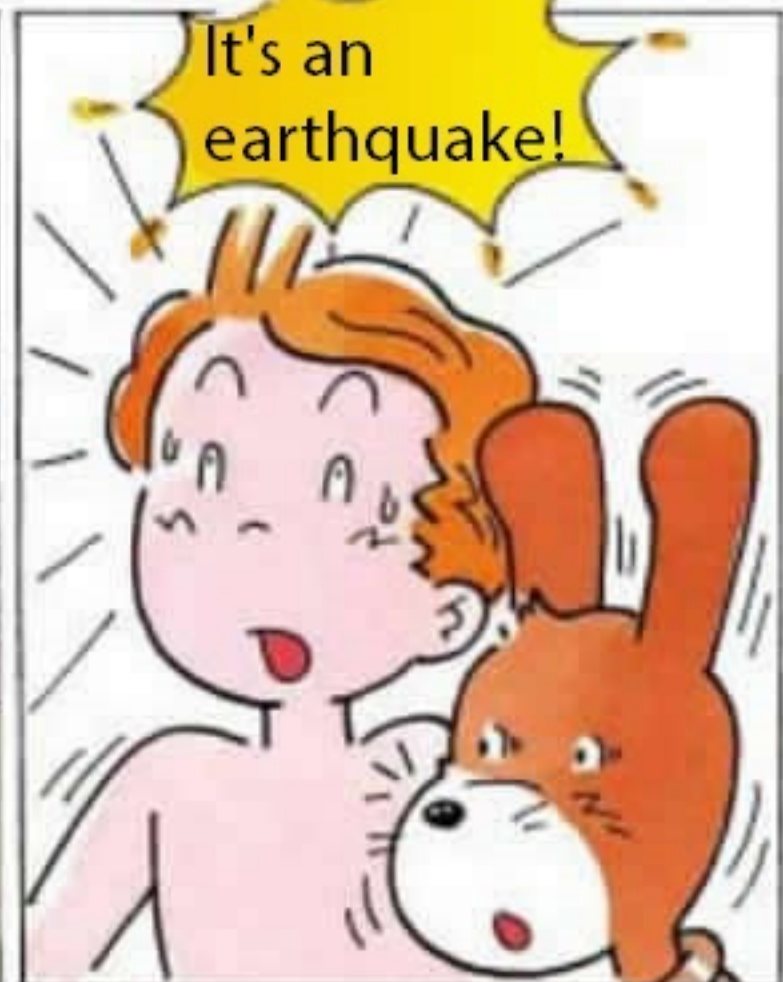
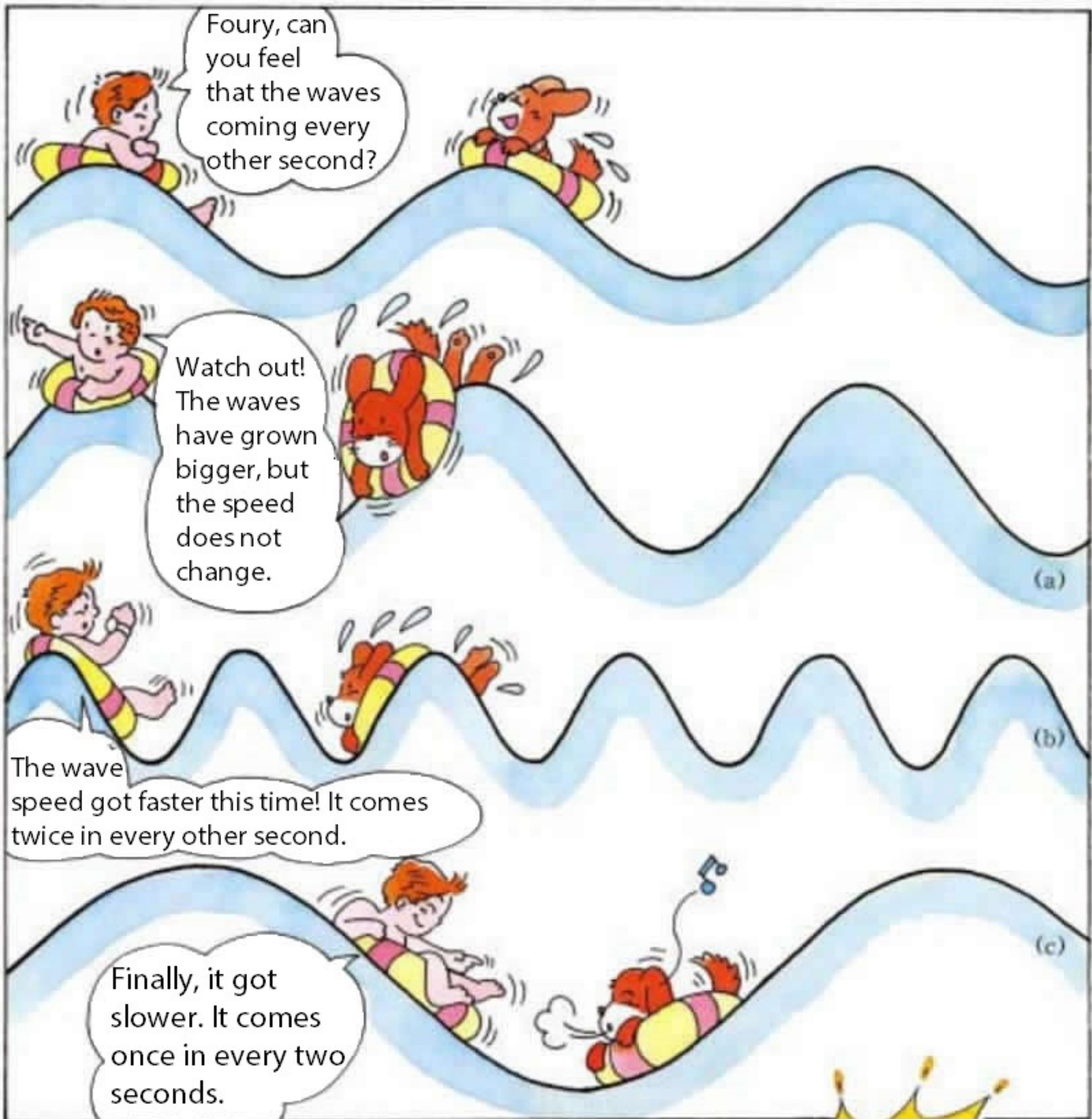
A TALE OF SOUND, WAVES and FFT



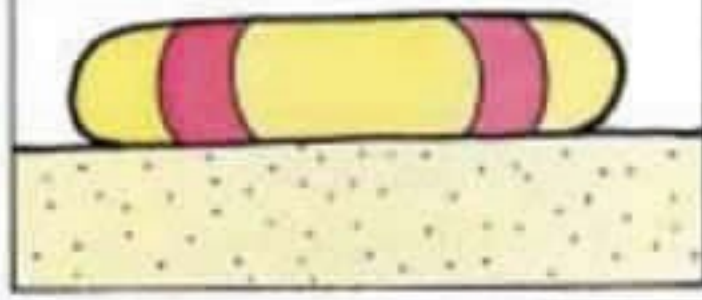
ONOSOKKI

# 1. Secret of the wave

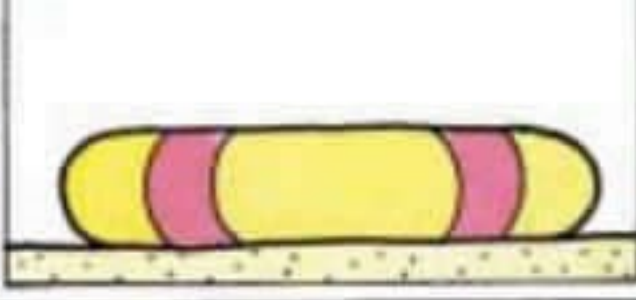




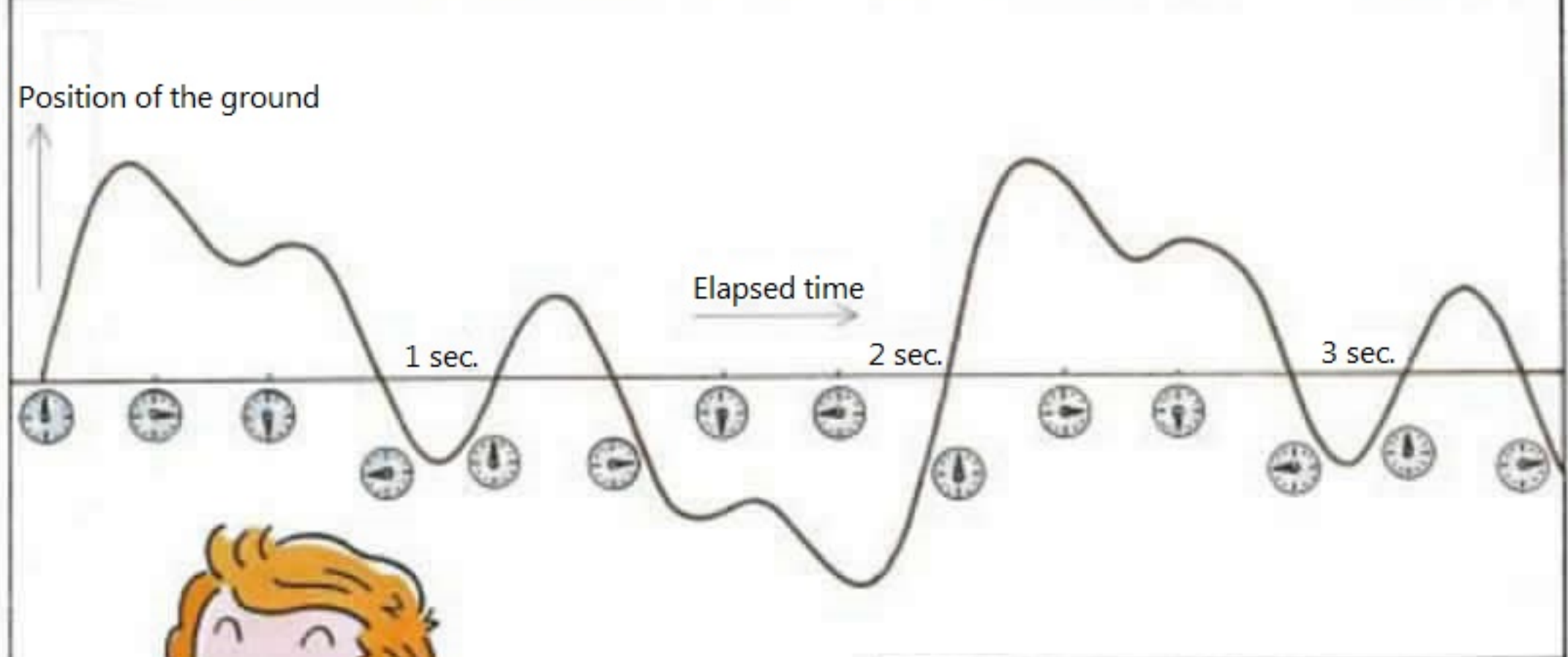
Hey Foury, If you see the ground shaking in slow motion,



it is the repetition of raising and falling of the ground surface.



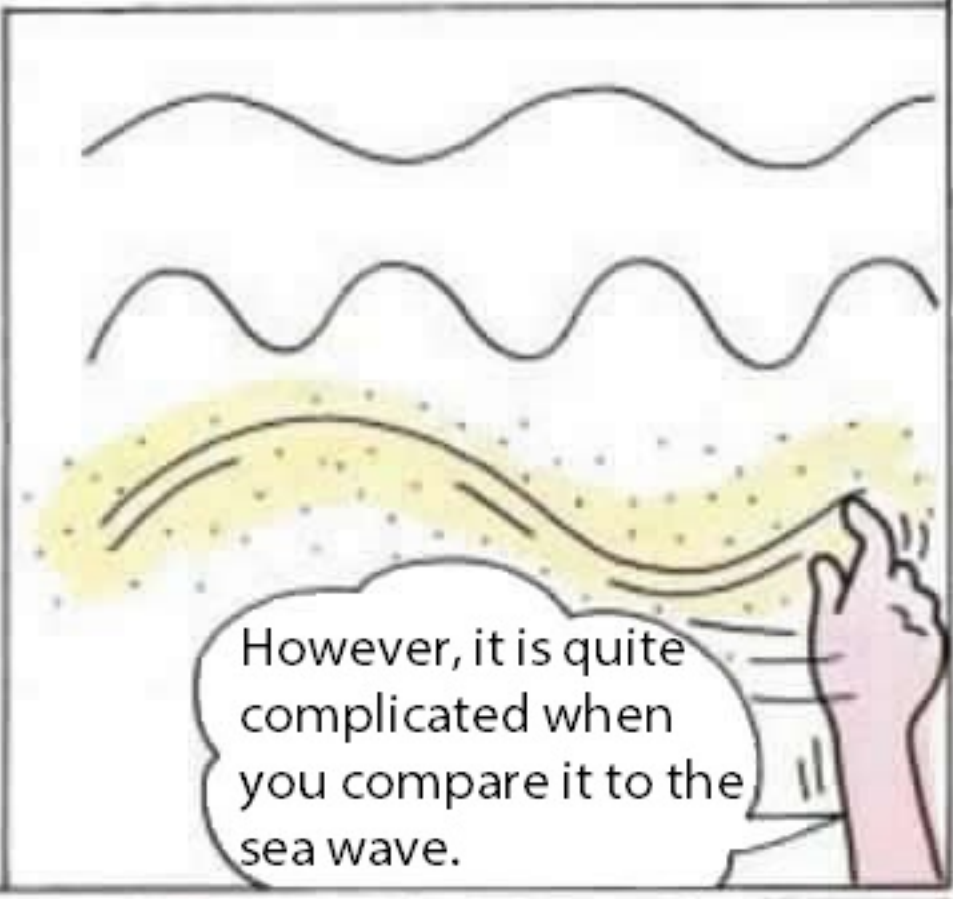
Let's draw this repeating action with the passage of time.



Look, an earthquake can be drawn like a waveform.



However, it is quite complicated when you compare it to the sea wave.

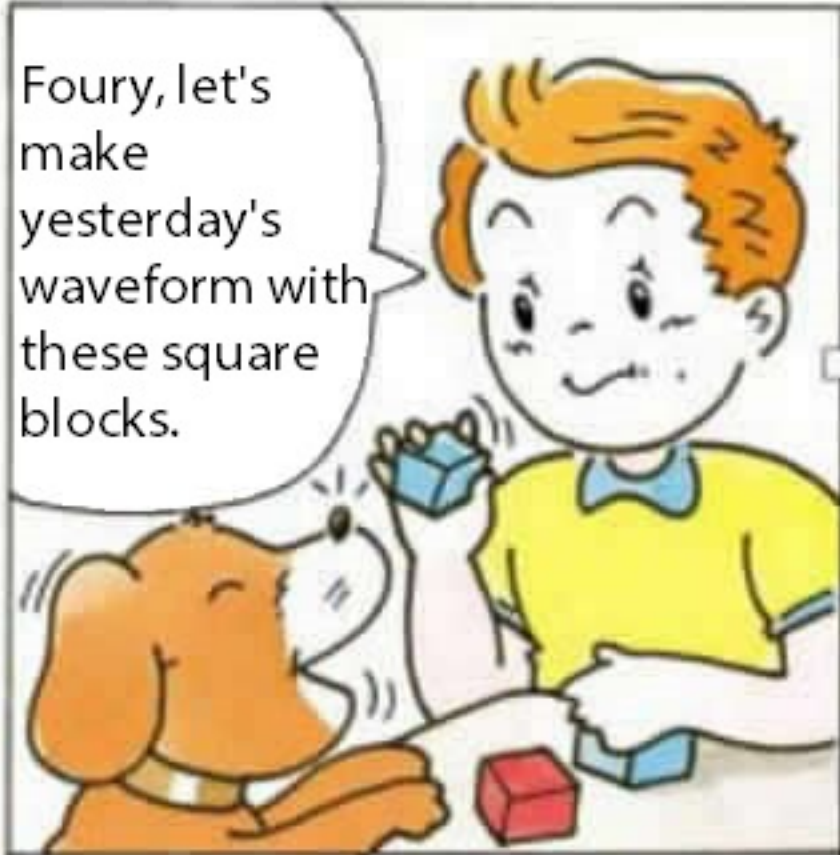


Oh, god!

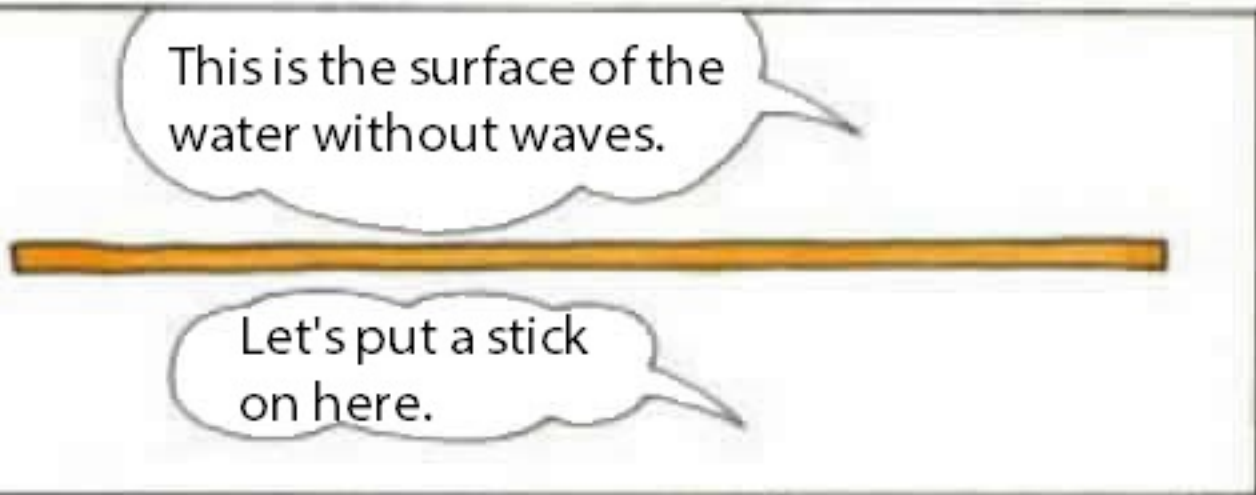


Run Foury! A tsunami may come.





Foury, let's make yesterday's waveform with these square blocks.

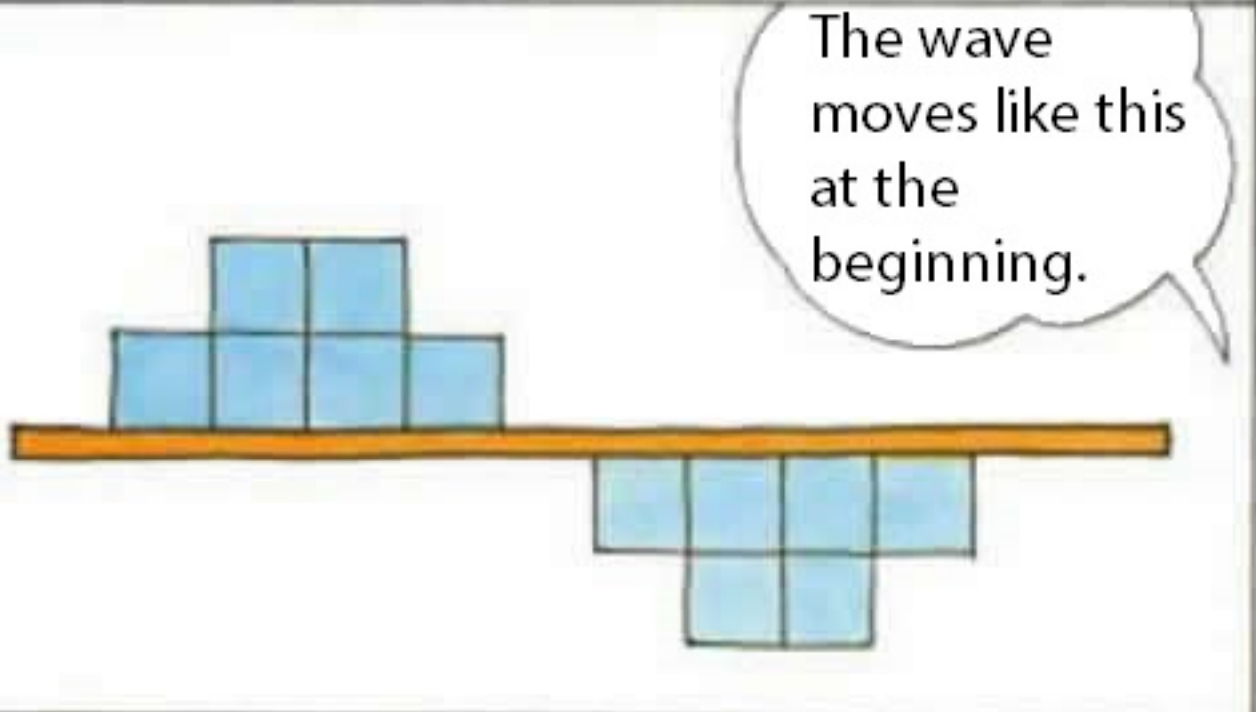


This is the surface of the water without waves.

Let's put a stick on here.



This wave is too rough to understand.

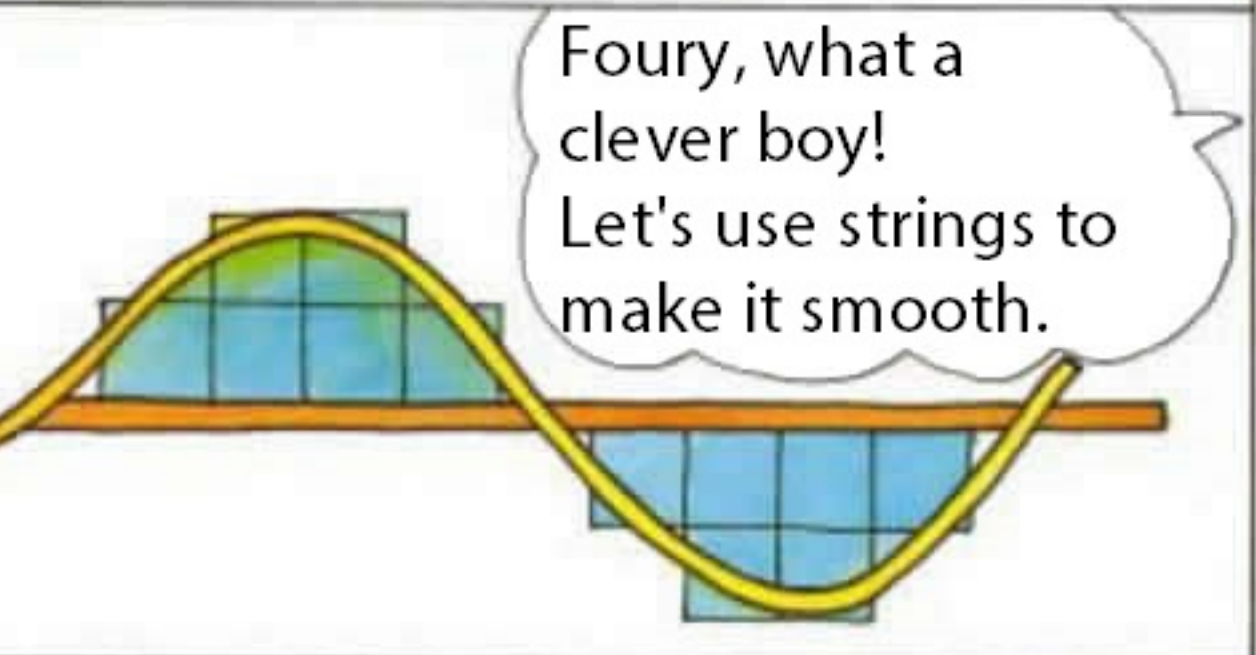


The wave moves like this at the beginning.

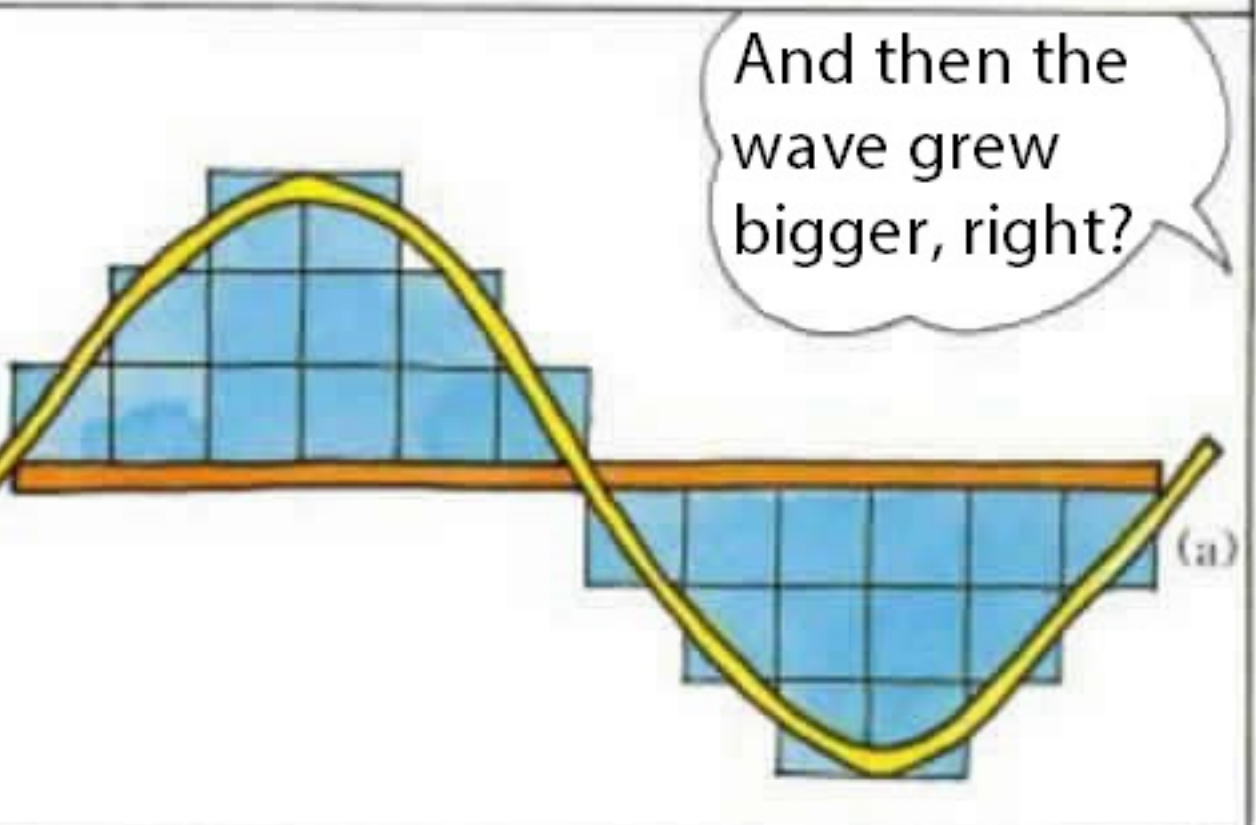


Oh, I see. It is a repetition action of up and down from the original water surface and returning to the original position.

It seems same motion as an earthquake.



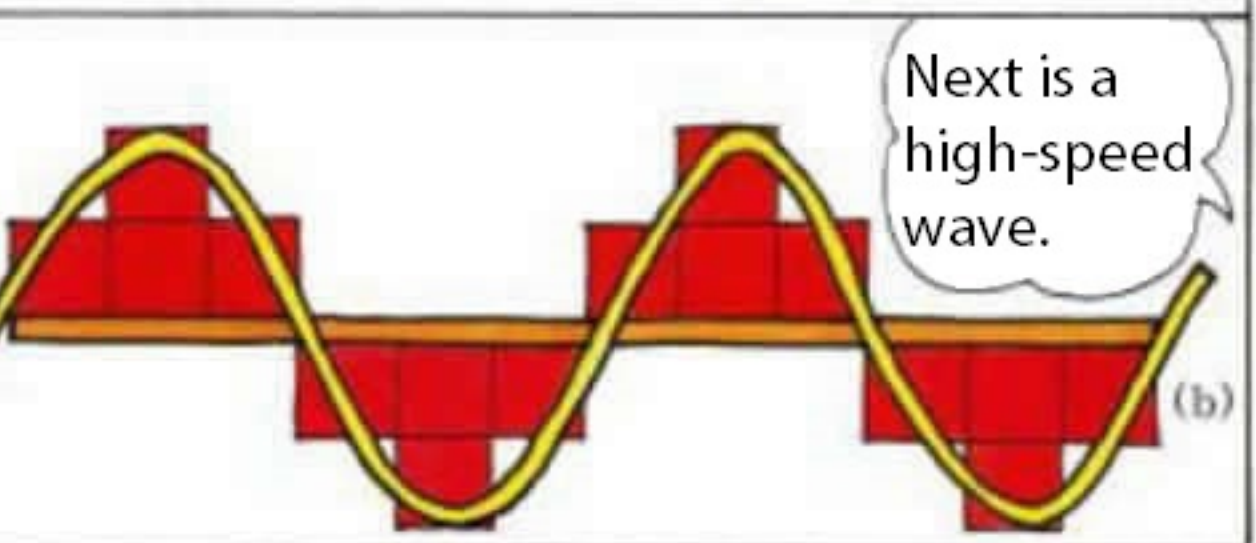
Foury, what a clever boy! Let's use strings to make it smooth.



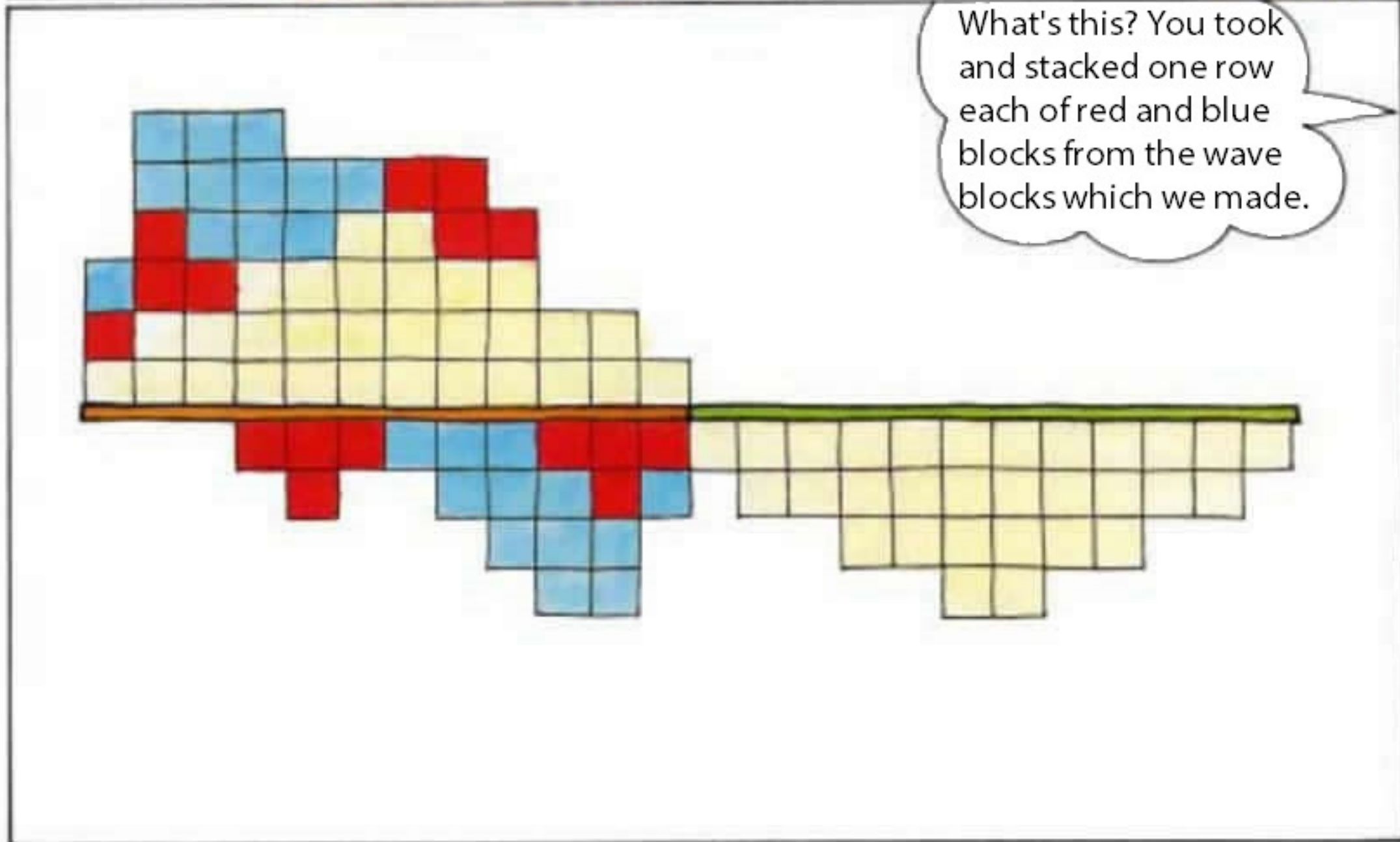
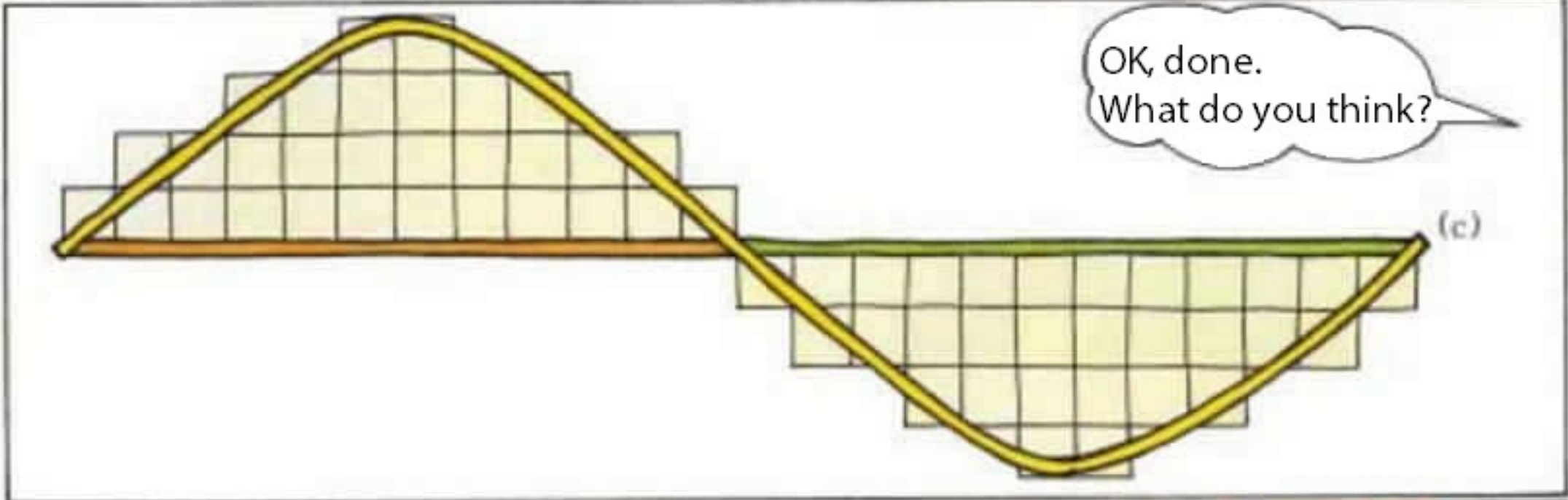
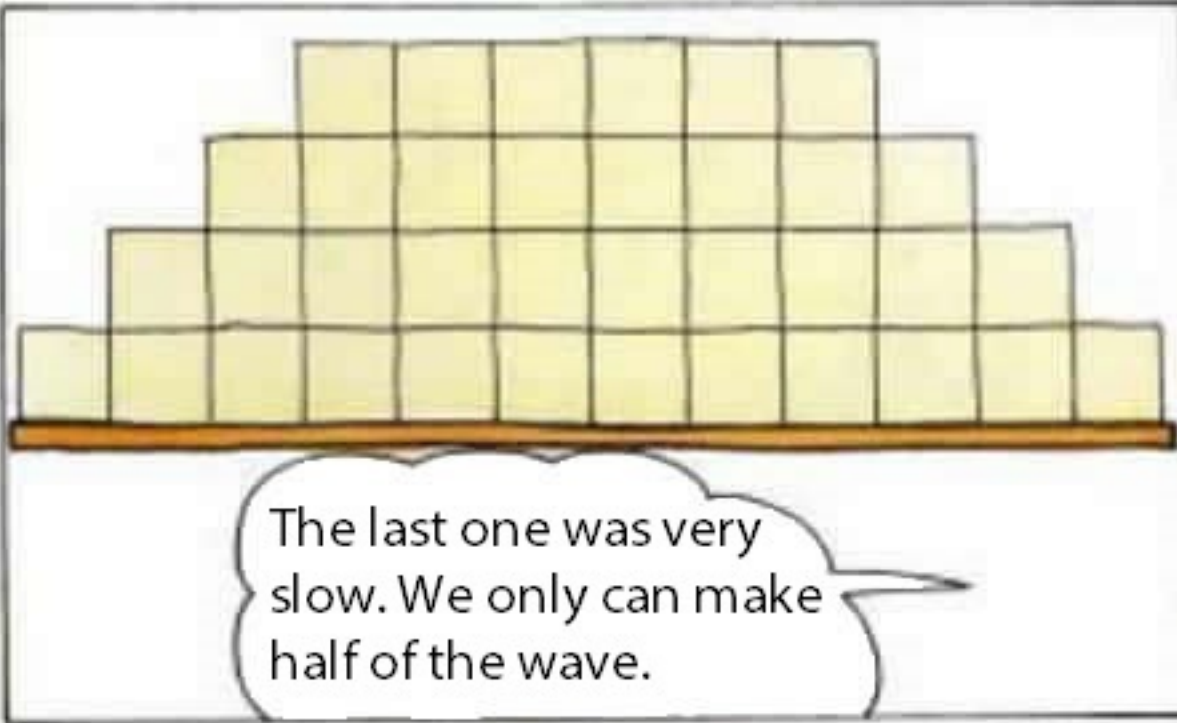
And then the wave grew bigger, right?

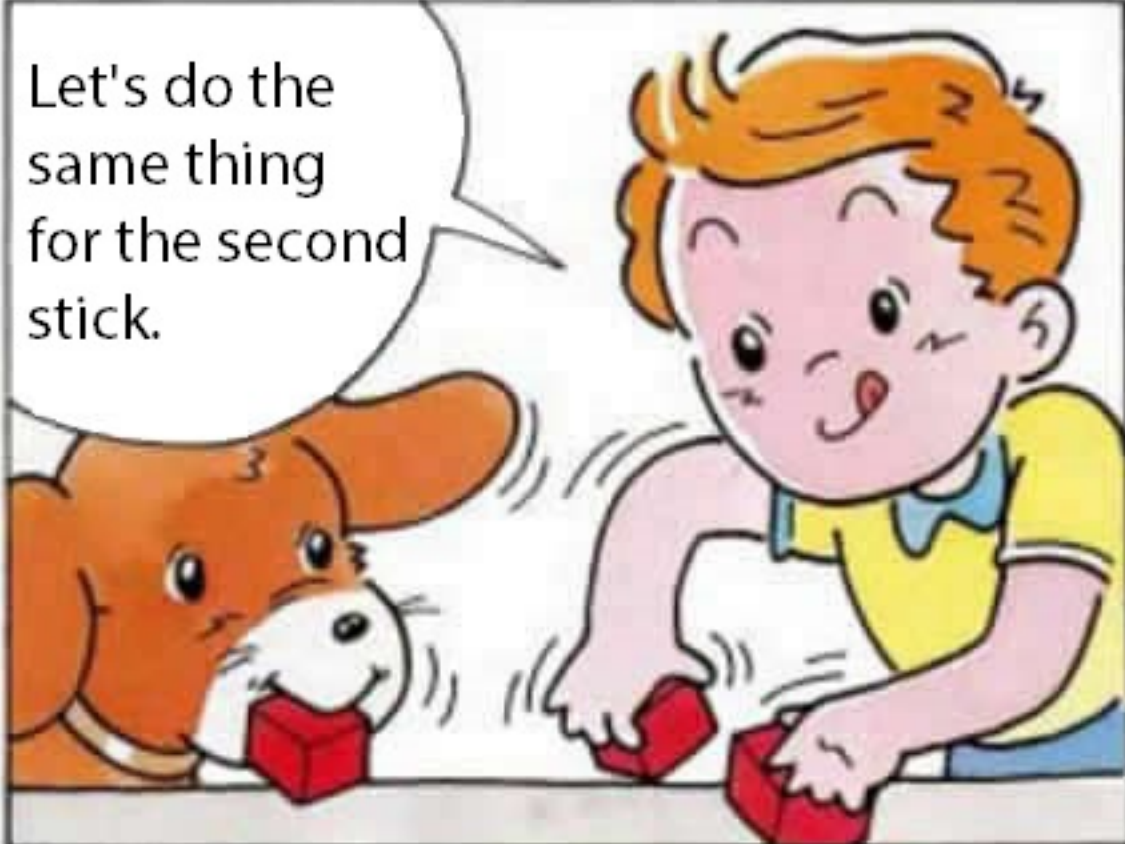


At that time, the wave came every other second, so one waveform (one stick) shows one second in length.

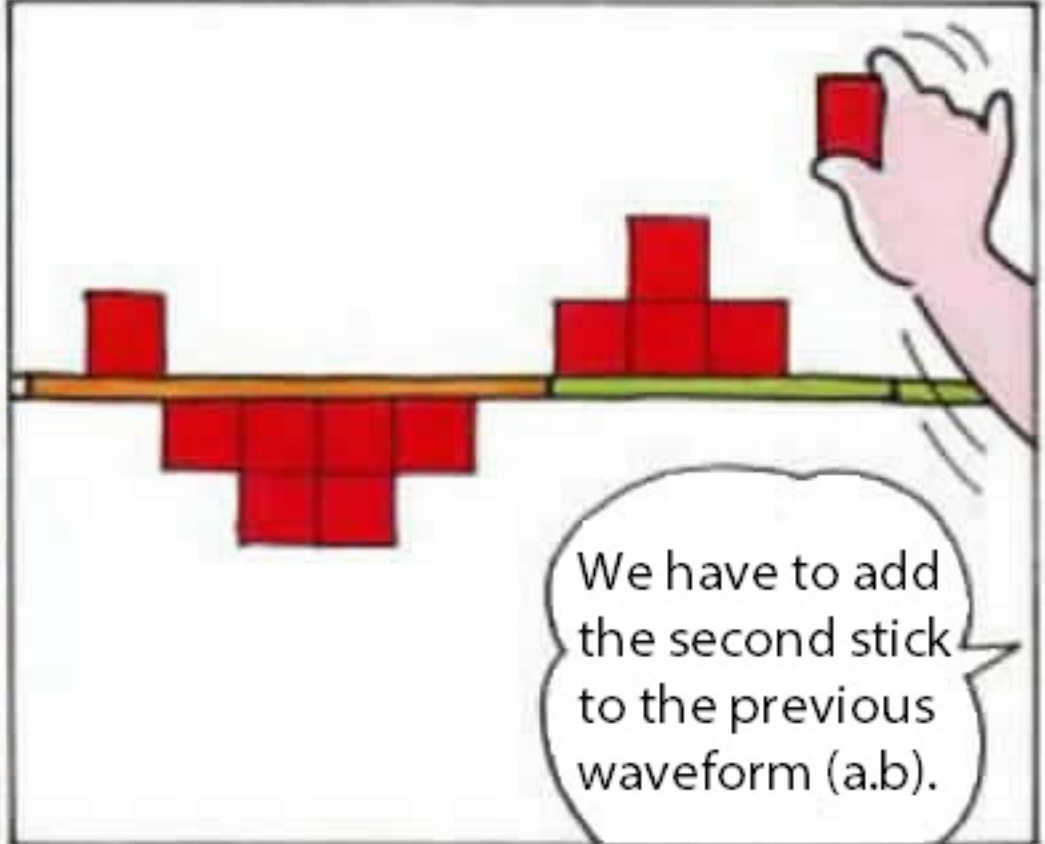


Next is a high-speed wave.

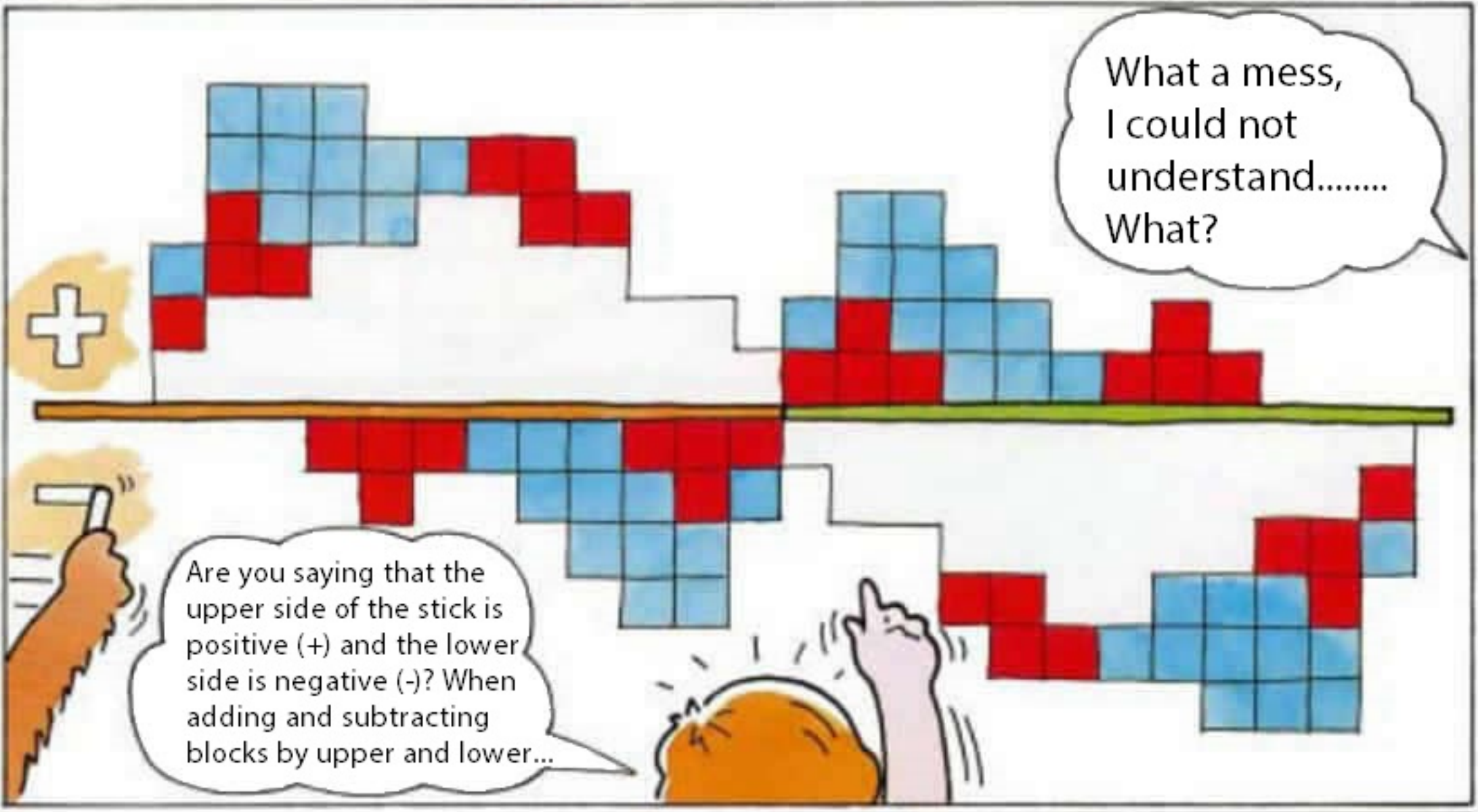




Let's do the same thing for the second stick.

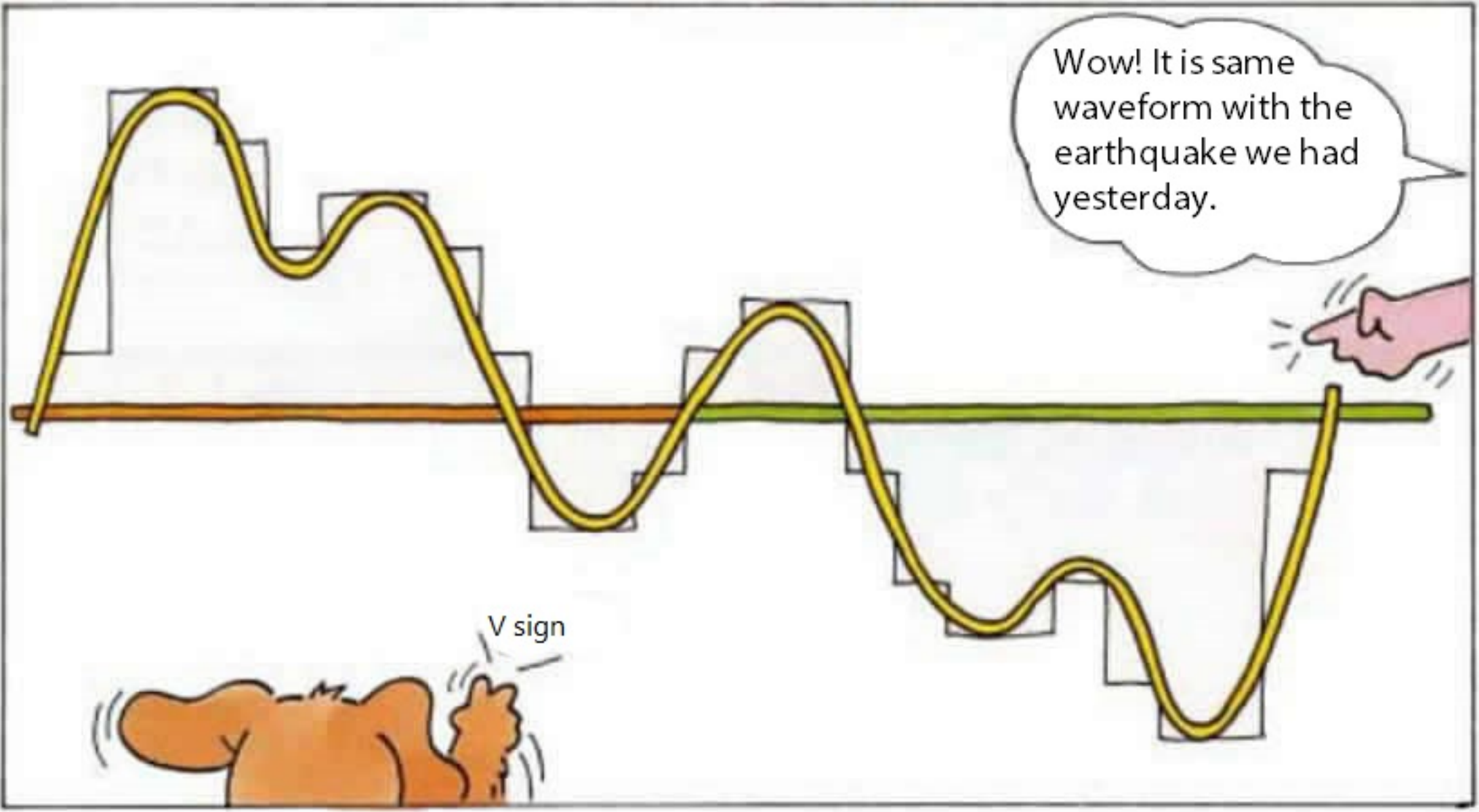


We have to add the second stick to the previous waveform (a.b).



What a mess, I could not understand..... What?

Are you saying that the upper side of the stick is positive (+) and the lower side is negative (-)? When adding and subtracting blocks by upper and lower...



Wow! It is same waveform with the earthquake we had yesterday.

V sign

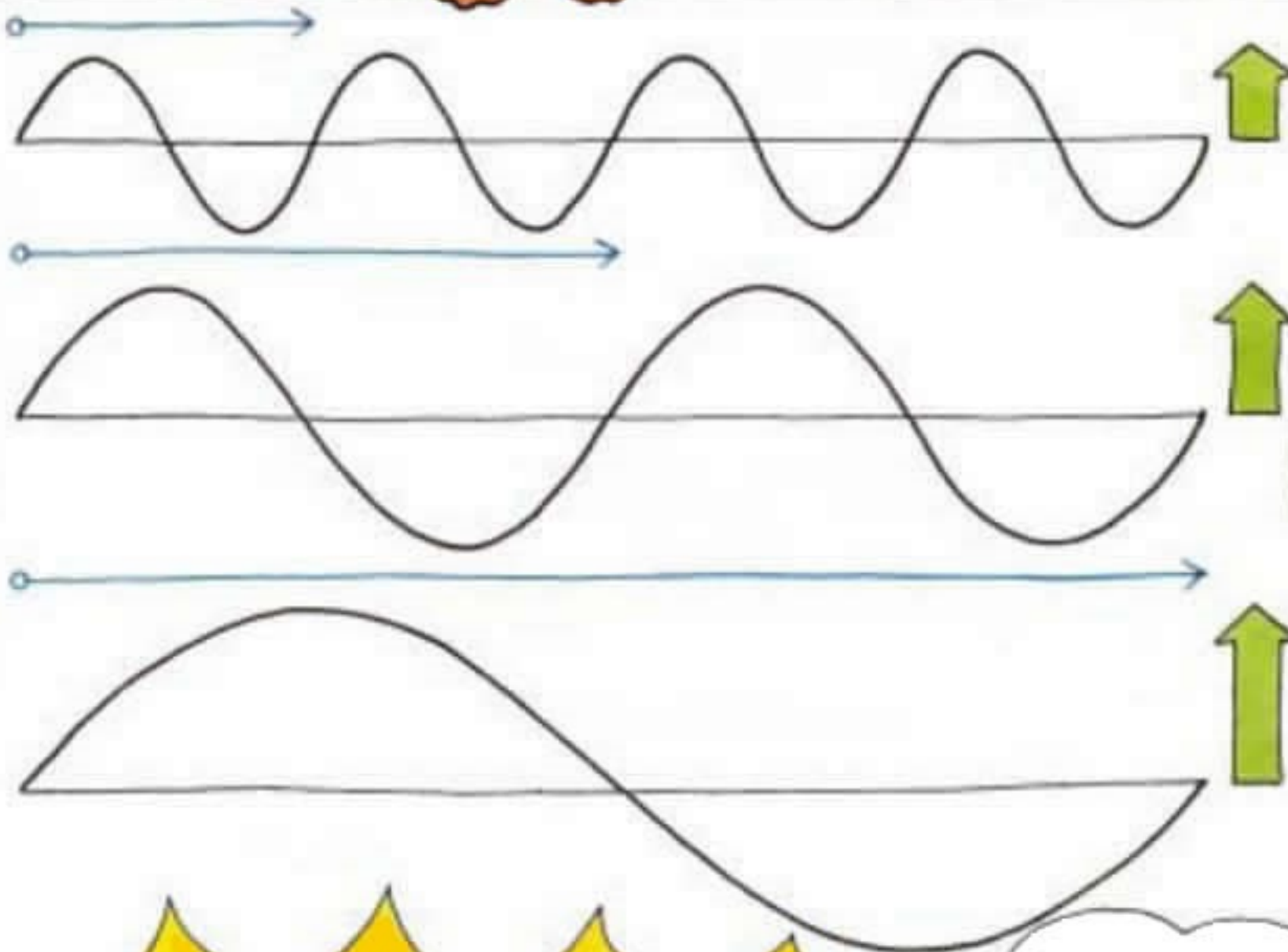
Ok, so, this weird shaped waveform is....



Bow wow!



An arrangement of various simple shaped waveforms.



What's the difference between those three original waveforms? Vibration speed, elapsed time of single wave, and height of the wave are different.

This is called Fourier transform.

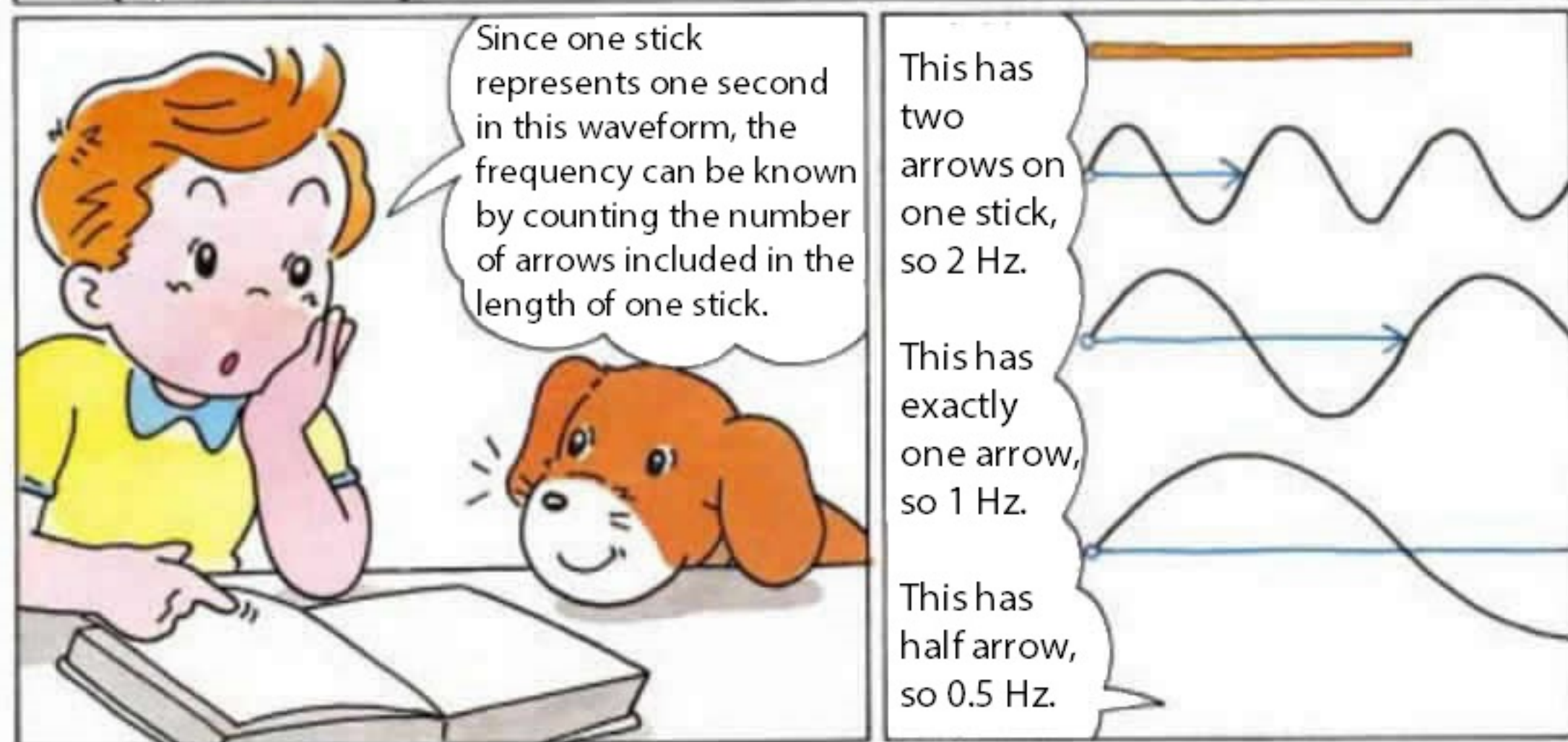
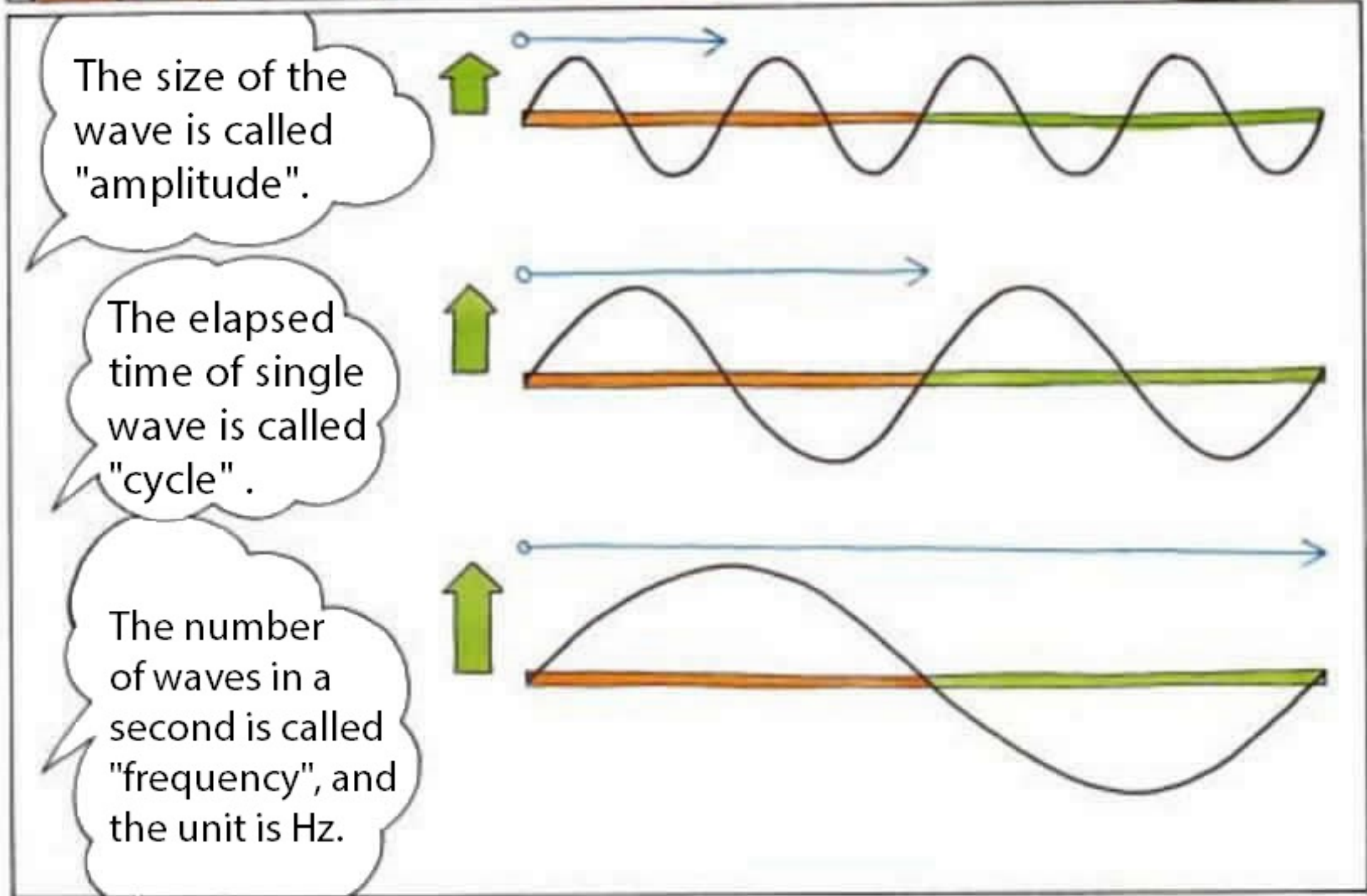
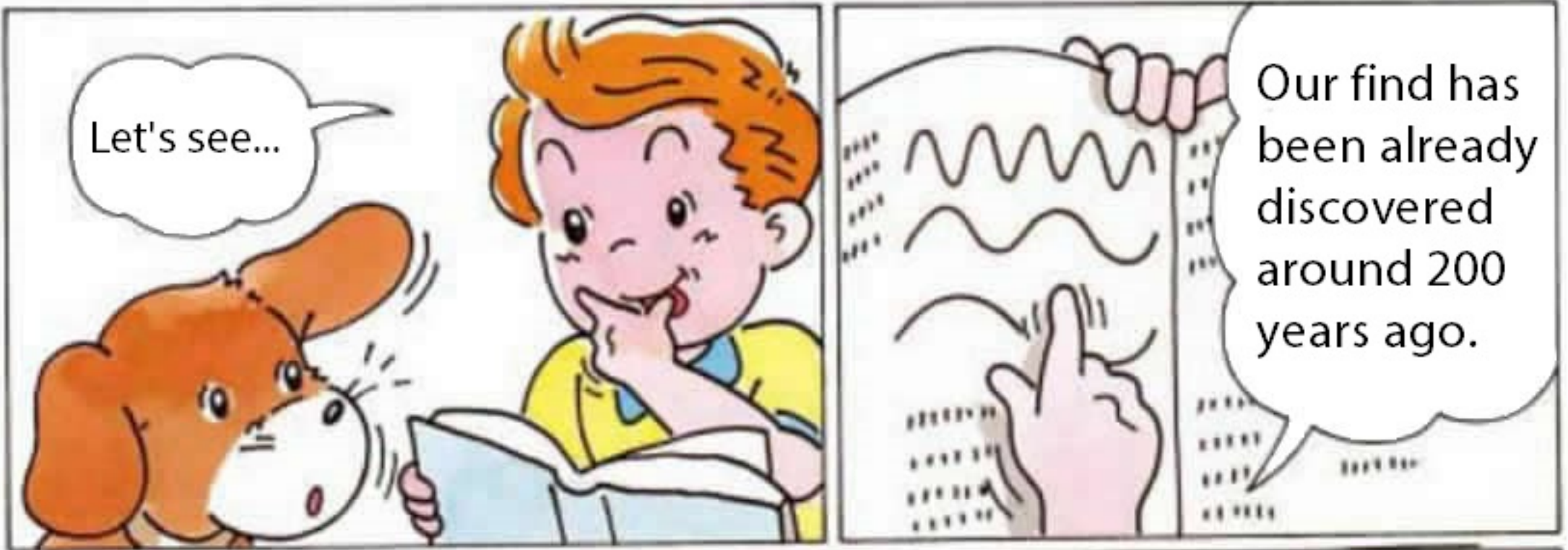
The waveform that we have made consists of those three waveforms.

How come you know about it Foury? Have you noticed by yourself?

I see! You have read my dad's book. My dad gave you your name, Foury.

PHYSICS





The frequency is defined by the length of a cycle (arrow).  
When it is short, the frequency is large. It is in an inverse proportion.

0.5 sec. 2Hz  
1 sec. 1Hz  
2 sec. 0.5Hz

0.5 sec. x 2Hz =  $\frac{1}{2} \times 2 = 1$   
1 sec. x 1Hz = 1  
2 sec. x 0.5Hz =  $2 \times \frac{1}{2} = 1$

Moreover, frequency and cycle are in an inverse relationship. When the frequency is multiplied by cycle, it becomes 1.

Cycle x Frequency = 1  
Cycle = 1/Frequency  
Frequency = 1/Cycle

OK, I got it.

Good boy!

Thanks!

Amplitud

2Hz  
1Hz  
0.5Hz

0.5Hz 1Hz 2Hz Frequency

Now, let's look at this vertical arrow.

Arrange them side by side in ascending order of frequencies.

You can tell what size of what speed wave is in this waveform.

## 2. A tale of sound



Foury, we learned a lot yesterday, aren't we?

BOW-WOW

What is that gentleman doing there?

Hi Mister, what are you doing here?

Hello boy, what a great timing. Would you like to see my invention box?

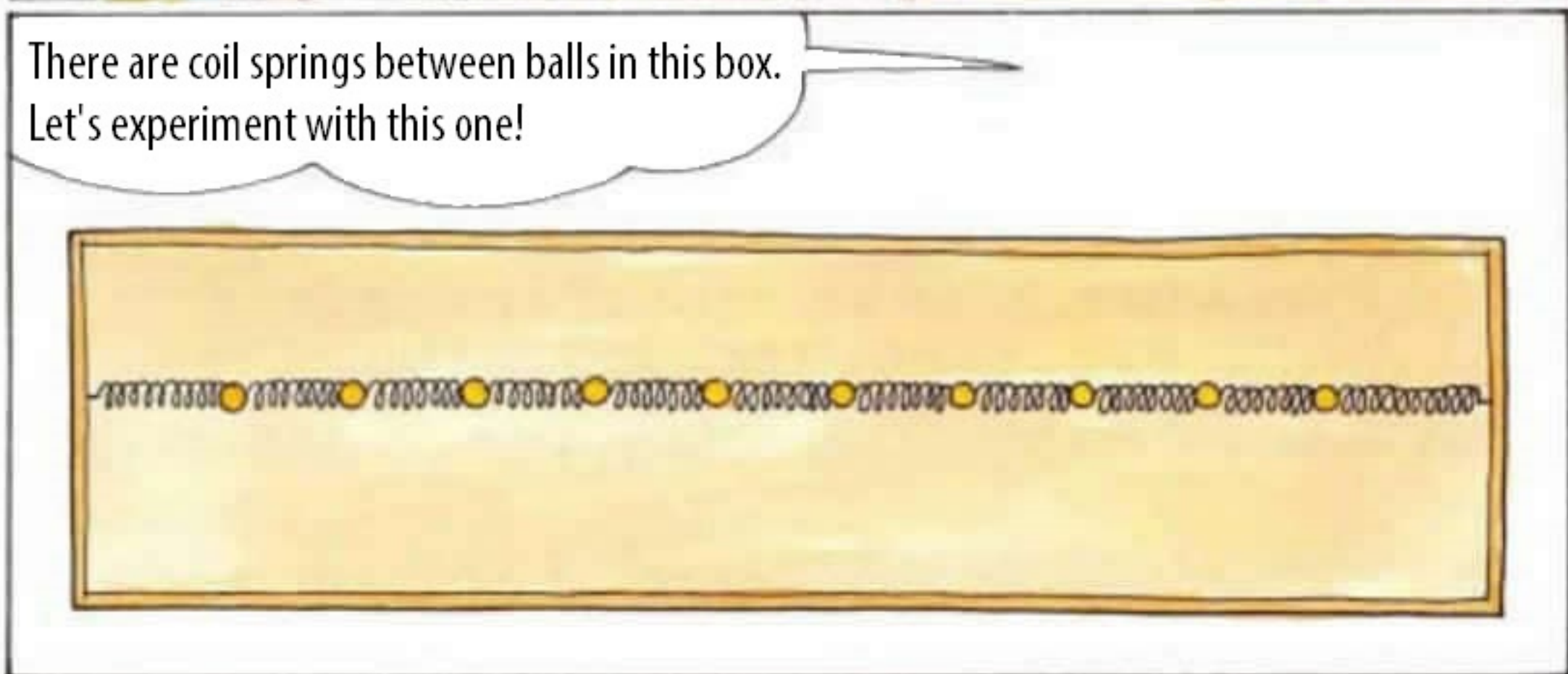
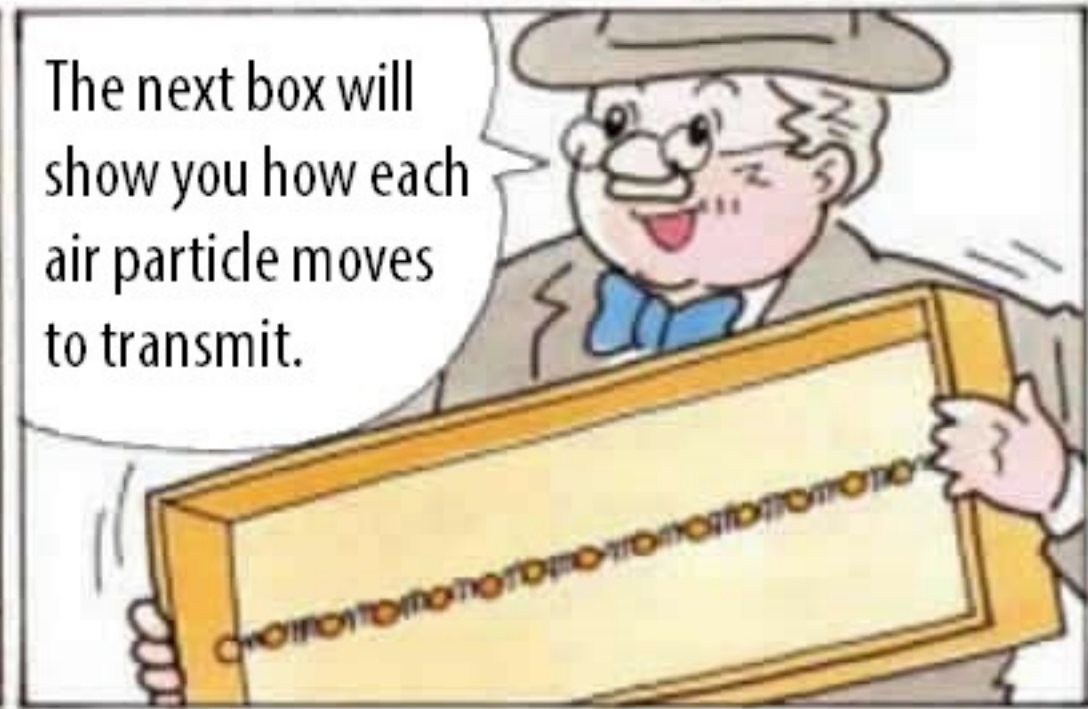
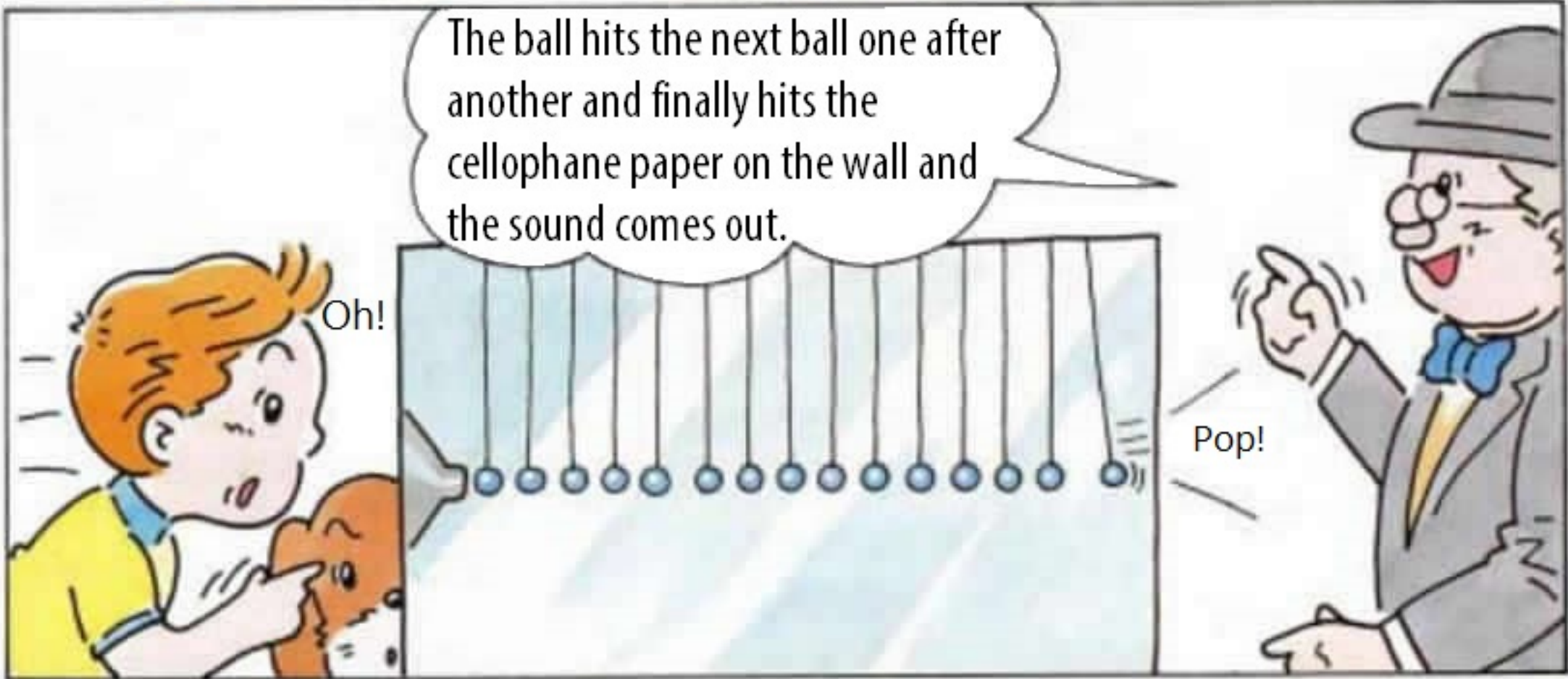
Invention box? What is it?

This is the box which can visualize the sound.

Really? I think sound cannot be seen.

Isn't it great, if you can see the sound?

In this box, there are very light balls hanging in line with a very short distance.



The spring shrinks when pressed it down.

However, it has a restoring force to return to an original shape.

The air has the same property as a spring. This is why the coil spring is necessary for this box.

You must have experienced the restoring force of going to return to the original shape when you press a piston in air.

Let's look at how the sound travels in this box.

The sound is generated.

The piston of the ball is pushed on the right side.

The ball moves too far and it tries to return to its original position.

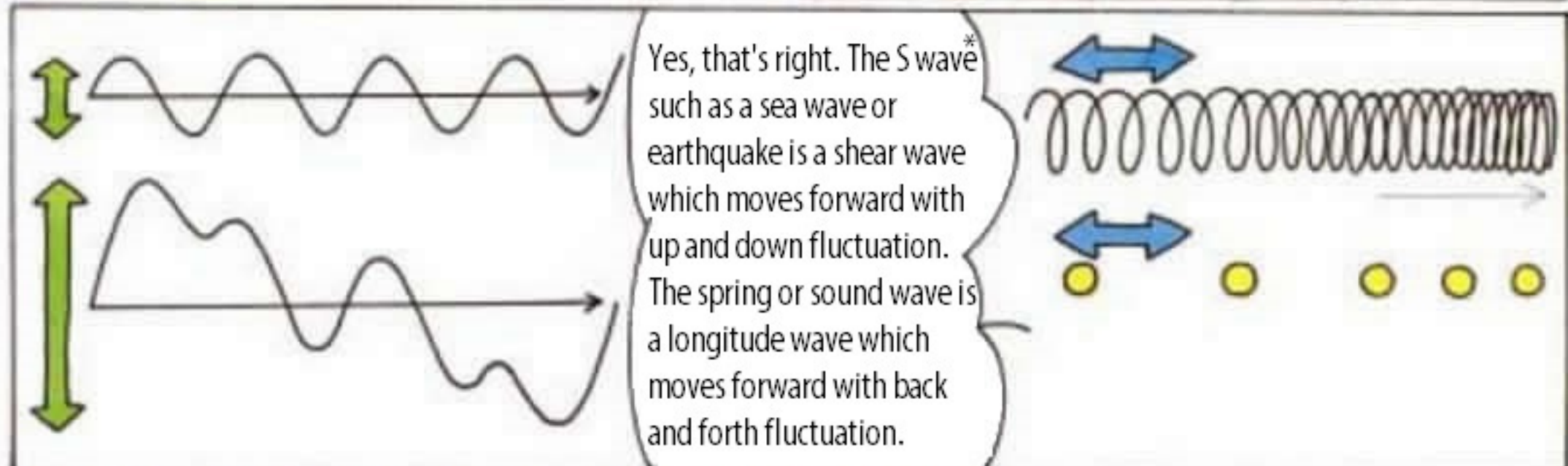
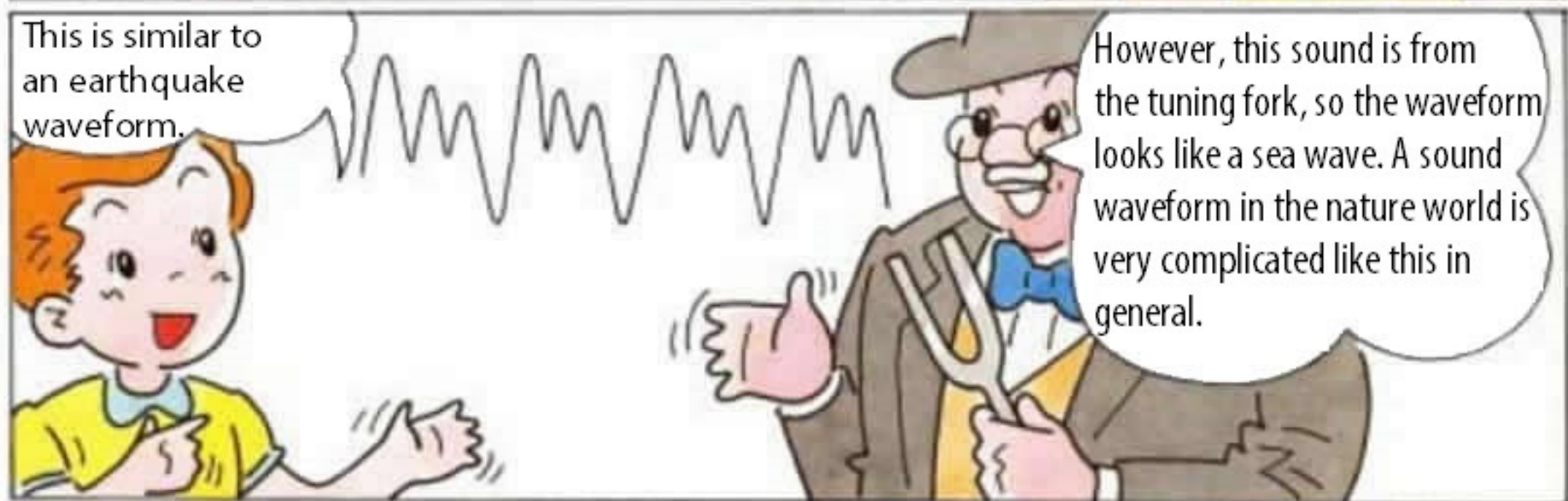
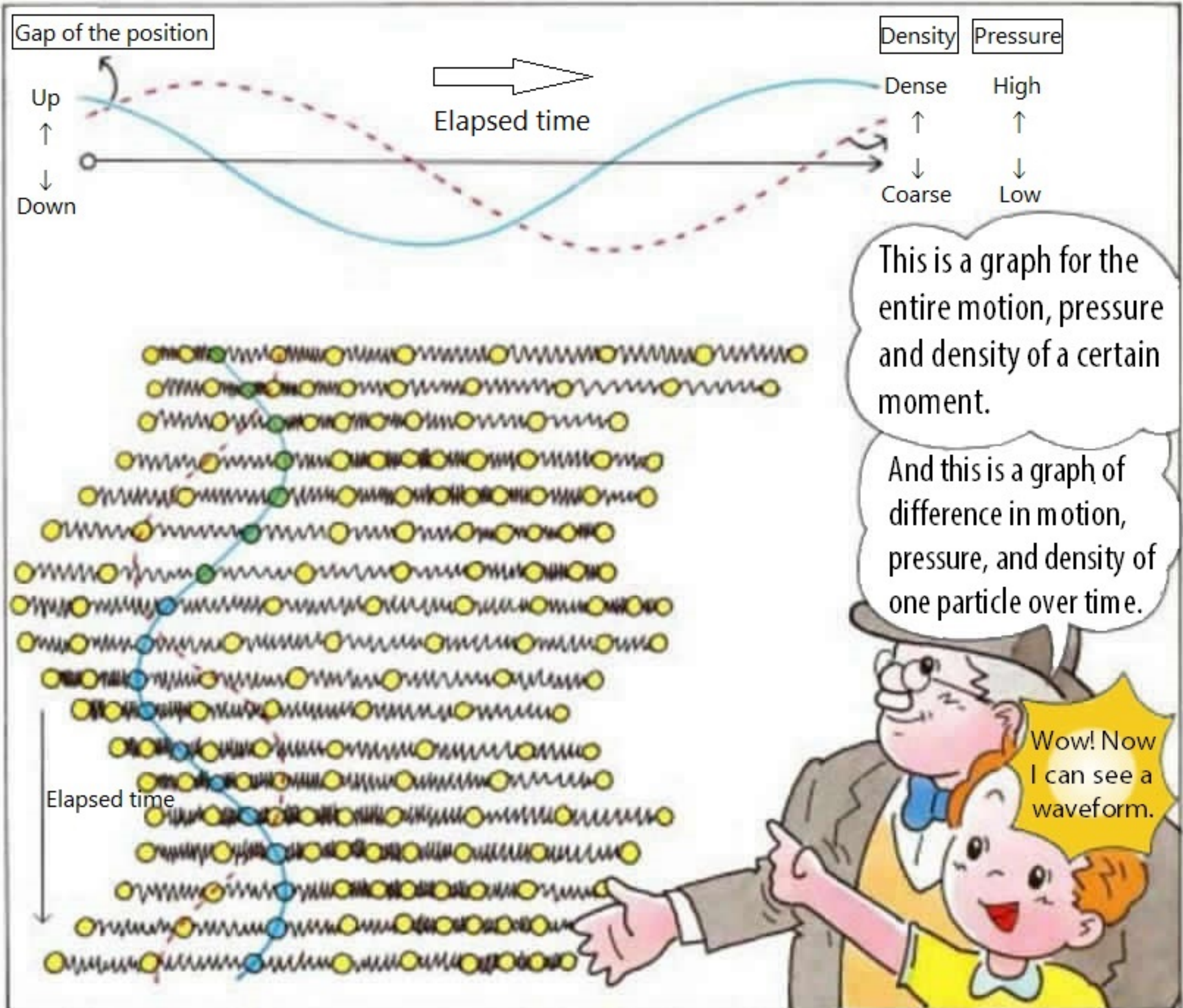
However, the ball returns too much and it comes back again.

As you can see from this, each particle moves back and forth (right and left) repeatedly. This motion transmits to the particle one after another.

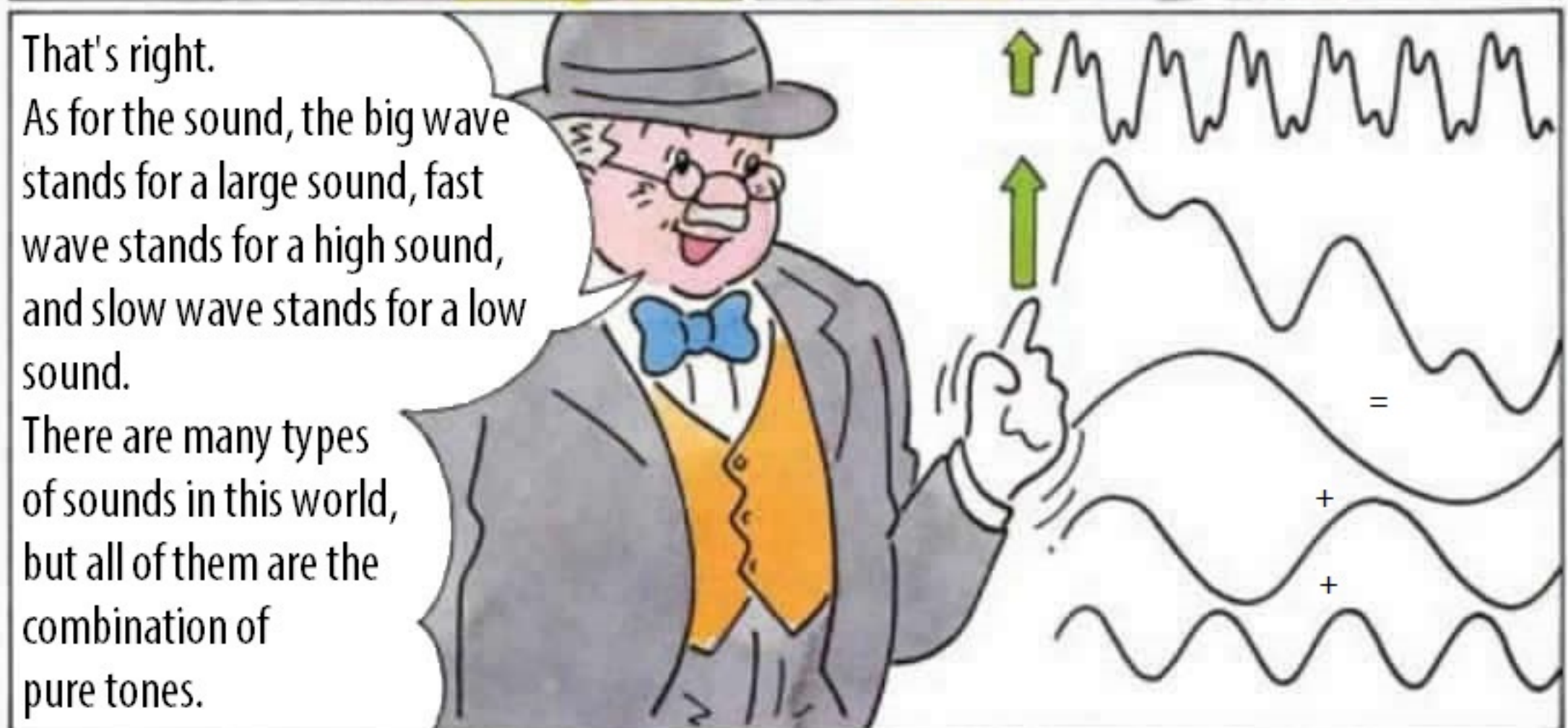
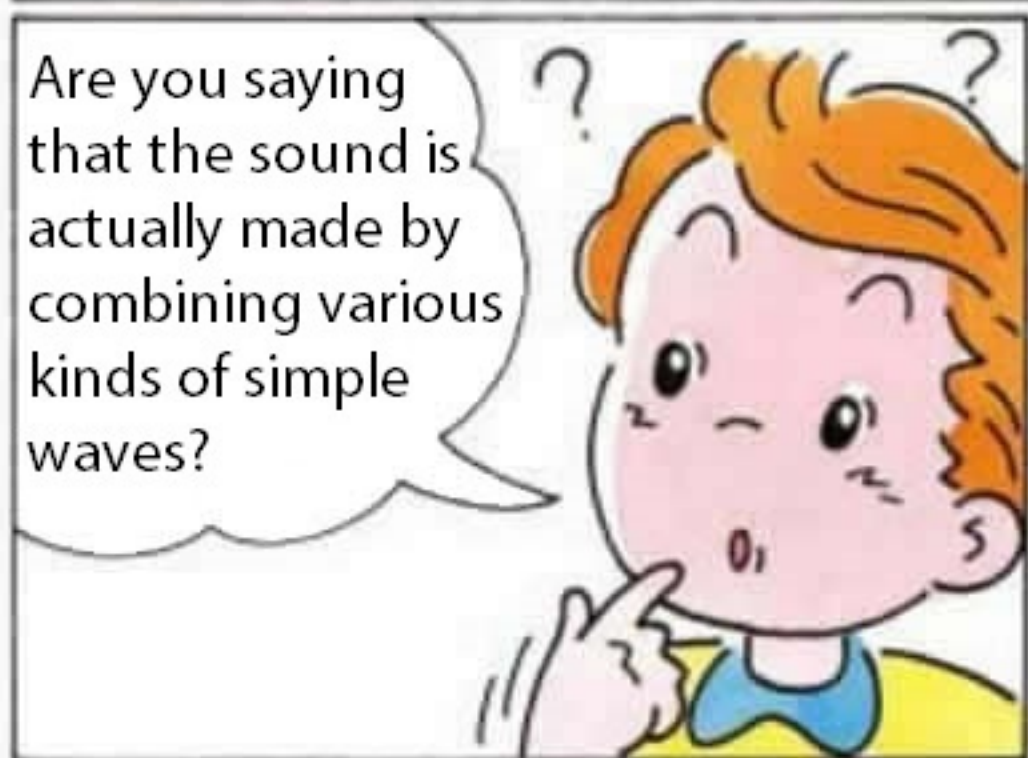
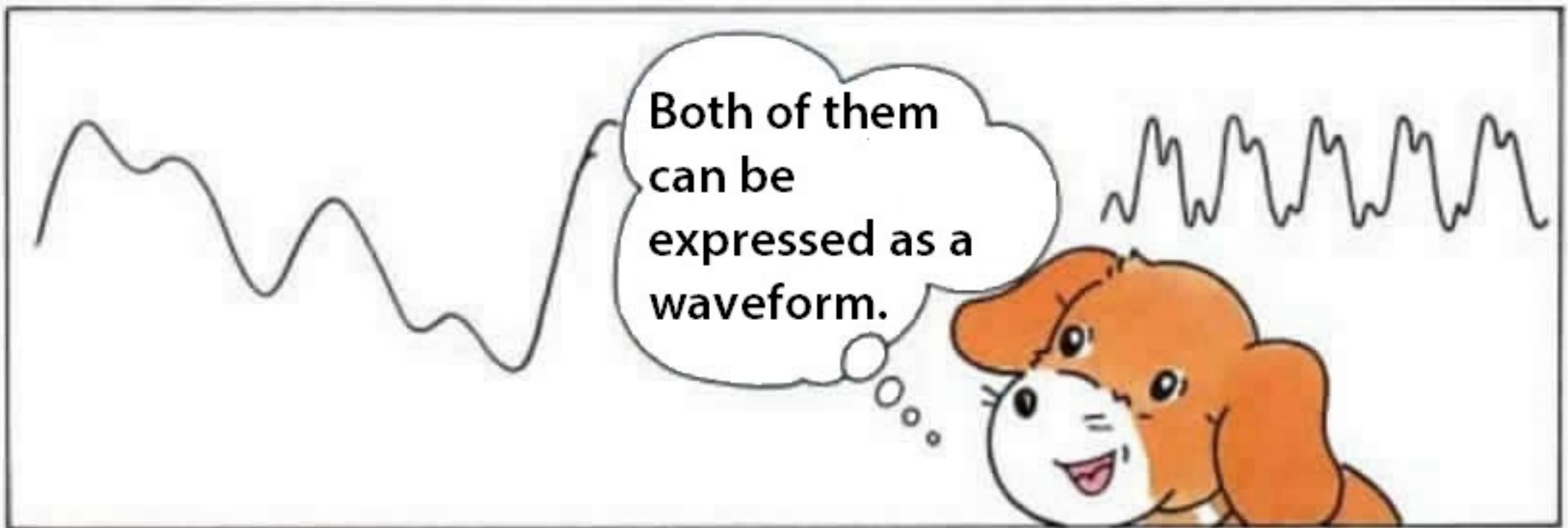
The air pressure is high when the air is compressed. And the air pressure is low when the air is expanded.

So, when you see the whole structure at a certain moment, there are dense and coarse parts of the particles in the air.

The sound wave is the repetition of this structure which transmits the compressional wave. It means that the air repeats pressure fluctuation.

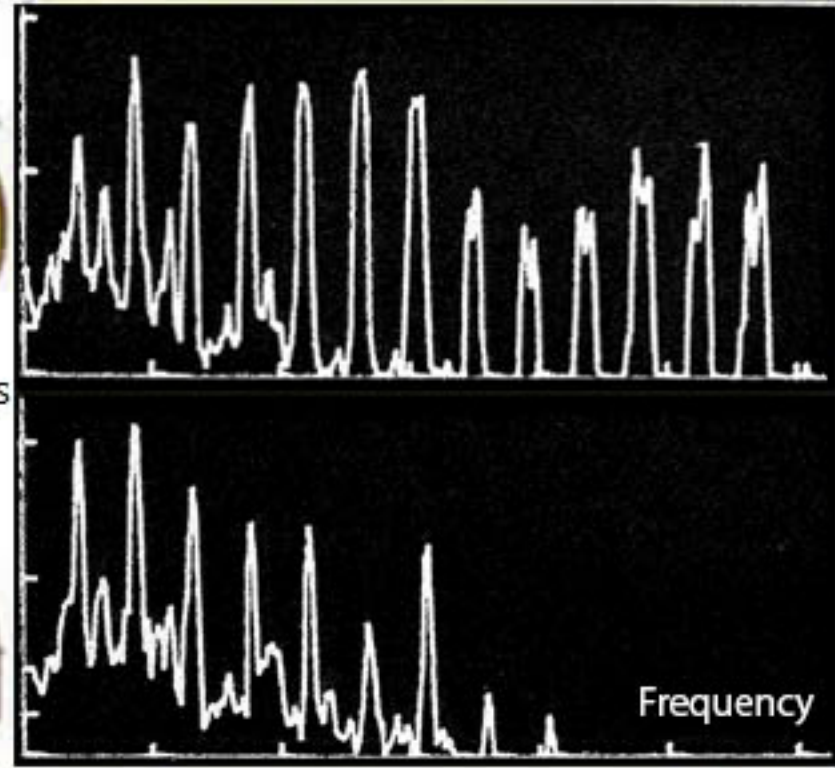


\*Earthquake also has a P wave which is a longitude wave moving back and forth.

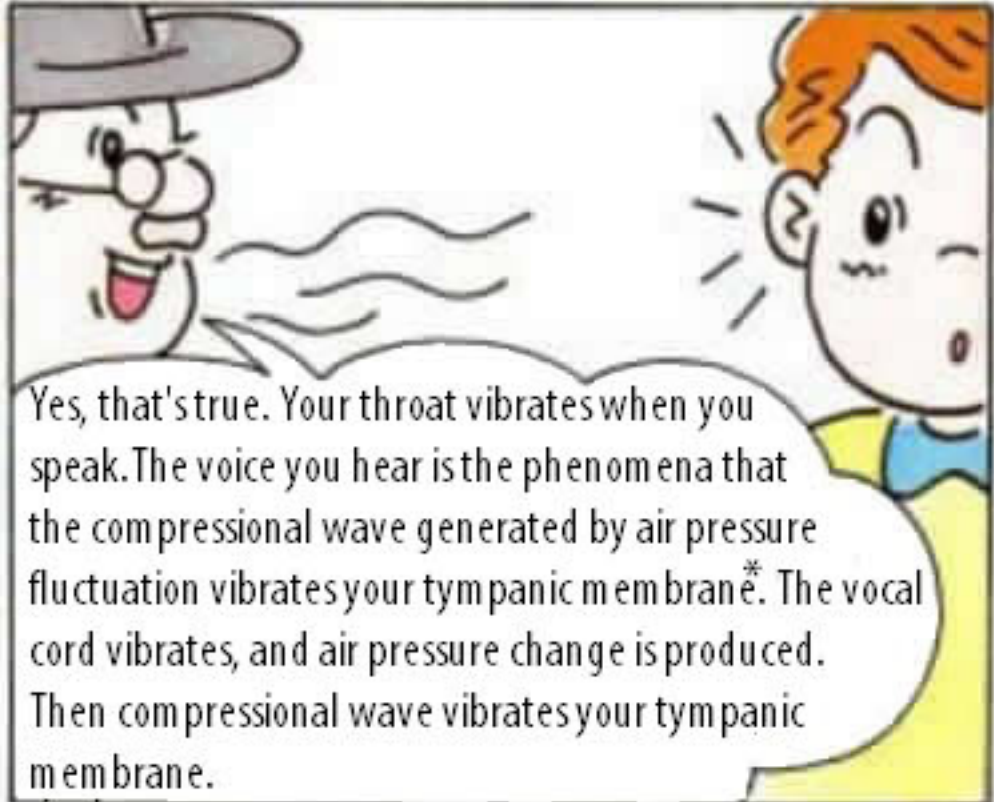


\* Pure tone= Simple waveform

For example, an orchestra tunes with the 440 Hz of c major "la" sound. Sounds from different instruments are heard differently even though the pitch of the sound is the same. This is the difference of the number of frequencies and those amount included in the sound. The character of each hearing sound depends on the frequencies contained.



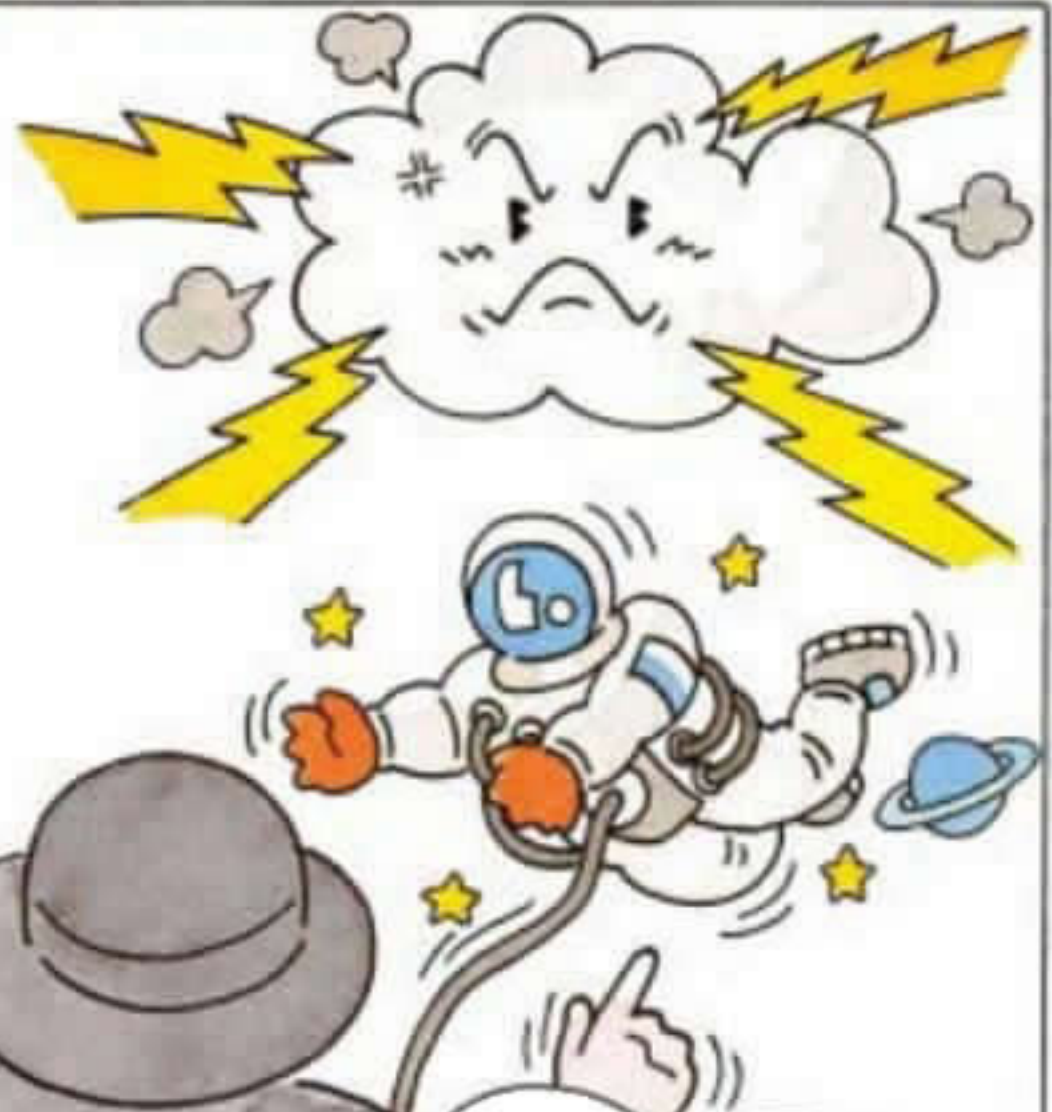
Hmm, interesting. Both the sound and vibration have the same property. Well, the guitar string vibrates while the sound comes out, but when I pinch it up with a finger, the sound stops.



Yes, that's true. Your throat vibrates when you speak. The voice you hear is the phenomena that the compressional wave generated by air pressure fluctuation vibrates your tympanic membrane\*. The vocal cord vibrates, and air pressure change is produced. Then compressional wave vibrates your tympanic membrane.

Does the vibration always produces the sound?

You cannot necessarily say that. For example, if you think about thunder, you don't see anything in the sky even though you hear the sound of thunder. Sudden expansion of air by an electric discharge causes a sudden pressure change, and a sound is generated. When air causes a pressure change, a compressional wave is generated and it travels to generate a sound.



In the universe without an air, there is nothing to transmit a sound, so no sound is generated.

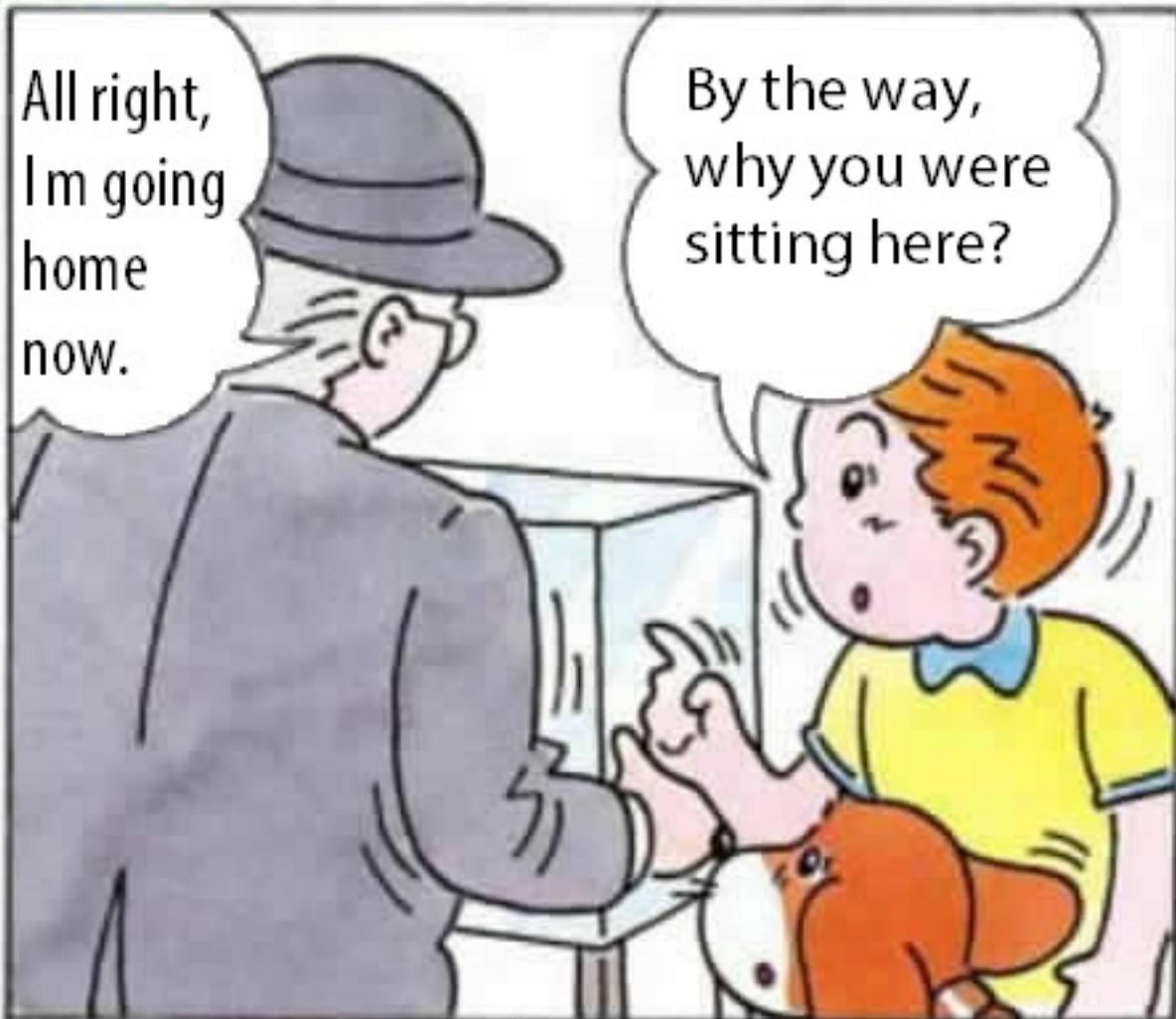
\*The sound generated by vocal cord vibration goes through the vocal tract and mouth, and resonates oral cavity, then heard as a voice.





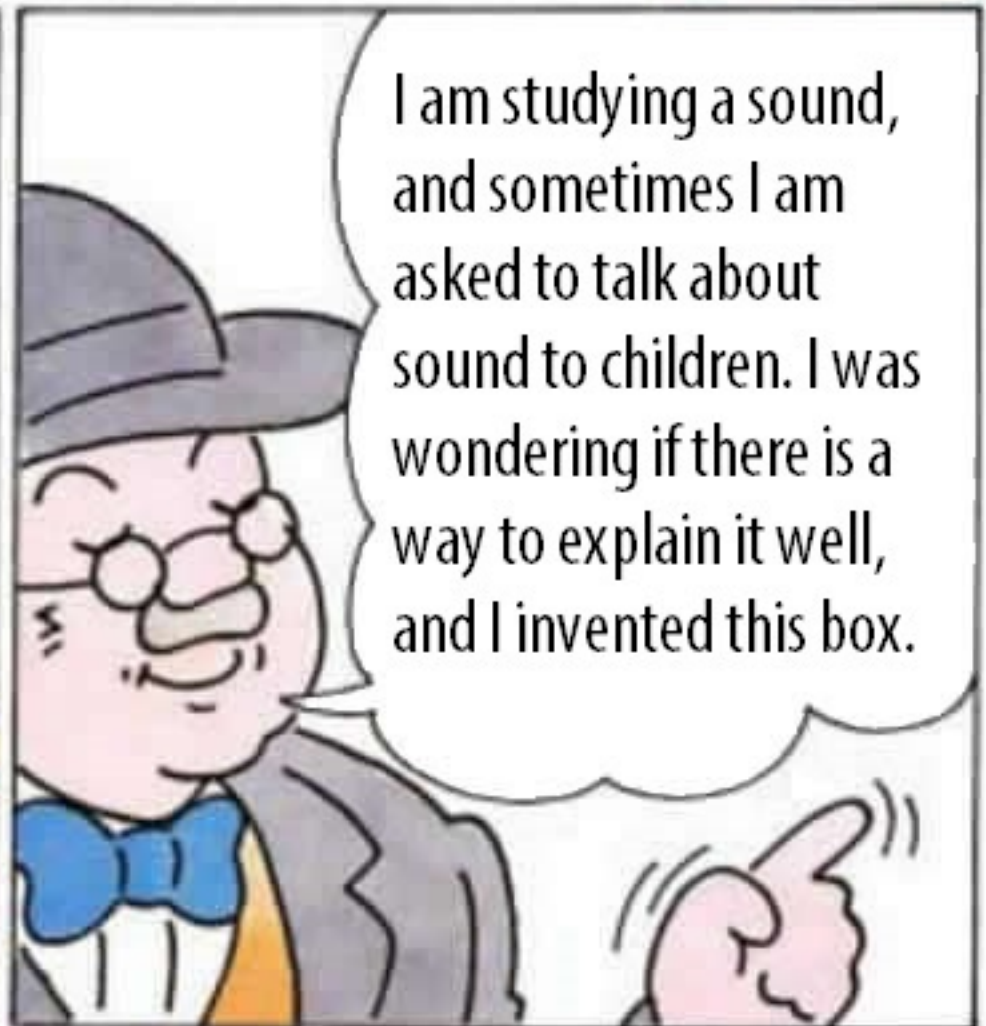
You are very welcome.  
It was a pleasure to meet you.

Thank you very much.  
I feel like I became knowledgeable.



All right,  
I'm going home now.

By the way,  
why you were sitting here?



I am studying a sound,  
and sometimes I am asked to talk about sound to children. I was wondering if there is a way to explain it well, and I invented this box.



When I was looking for someone to try it, you were passing by.

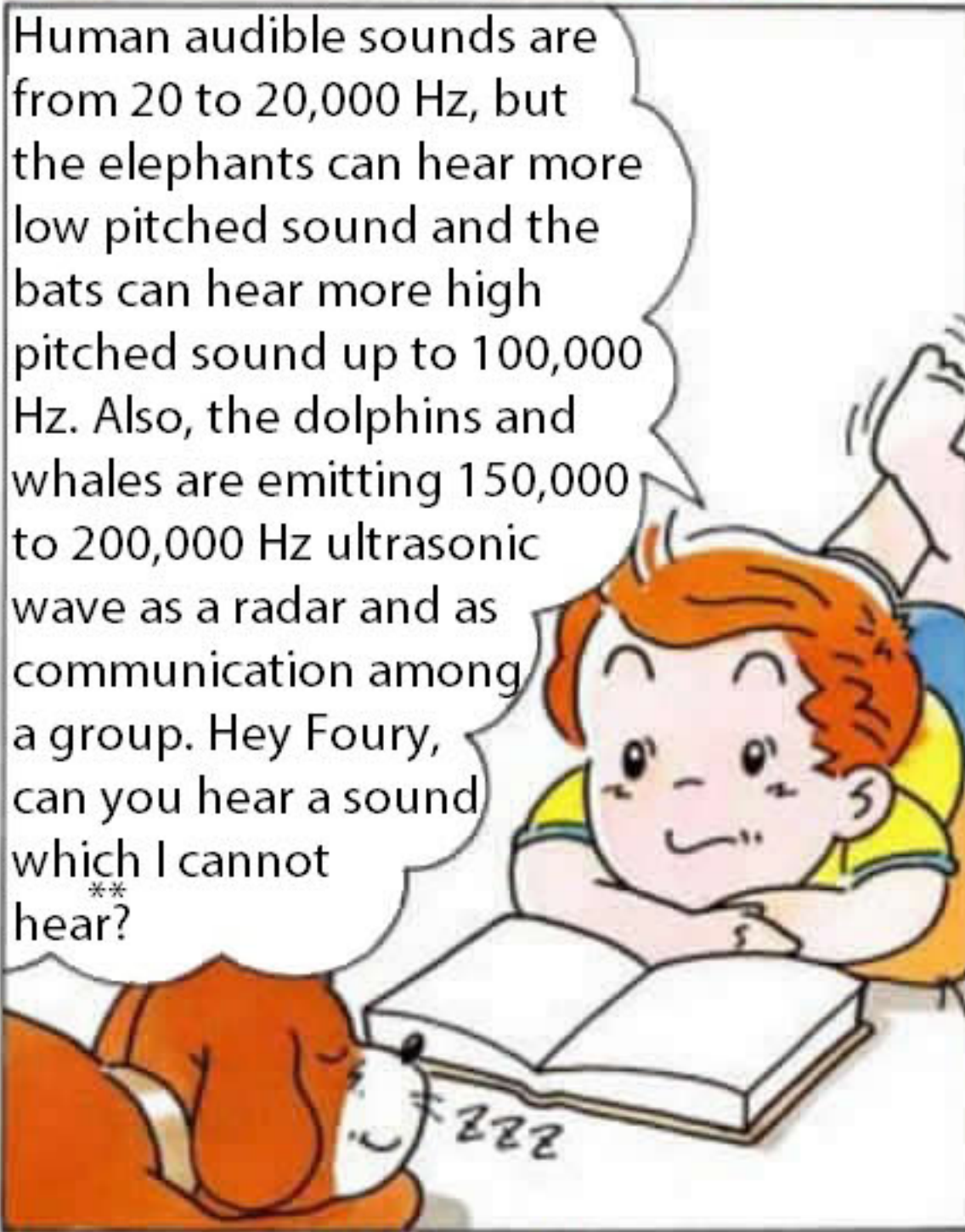
I see.  
Good-bye,  
have a nice day!

### 3. Magical box-FFT Analyzer

FOURY & WAVY ..... A TALE OF SOUND, WAVES and FFT



Hmmm, according to this book, in addition to the sound and vibration, the flow of the electricity, electric wave of TV and radio, infrared radiation, lighting, color, and X-ray can be expressed as a waveform. Waveform seems to be very important.



Human audible sounds are from 20 to 20,000 Hz, but the elephants can hear more low pitched sound and the bats can hear more high pitched sound up to 100,000 Hz. Also, the dolphins and whales are emitting 150,000 to 200,000 Hz ultrasonic wave as a radar and as communication among a group. Hey Foury, can you hear a sound which I cannot hear? \*\*



What's the matter Foury?

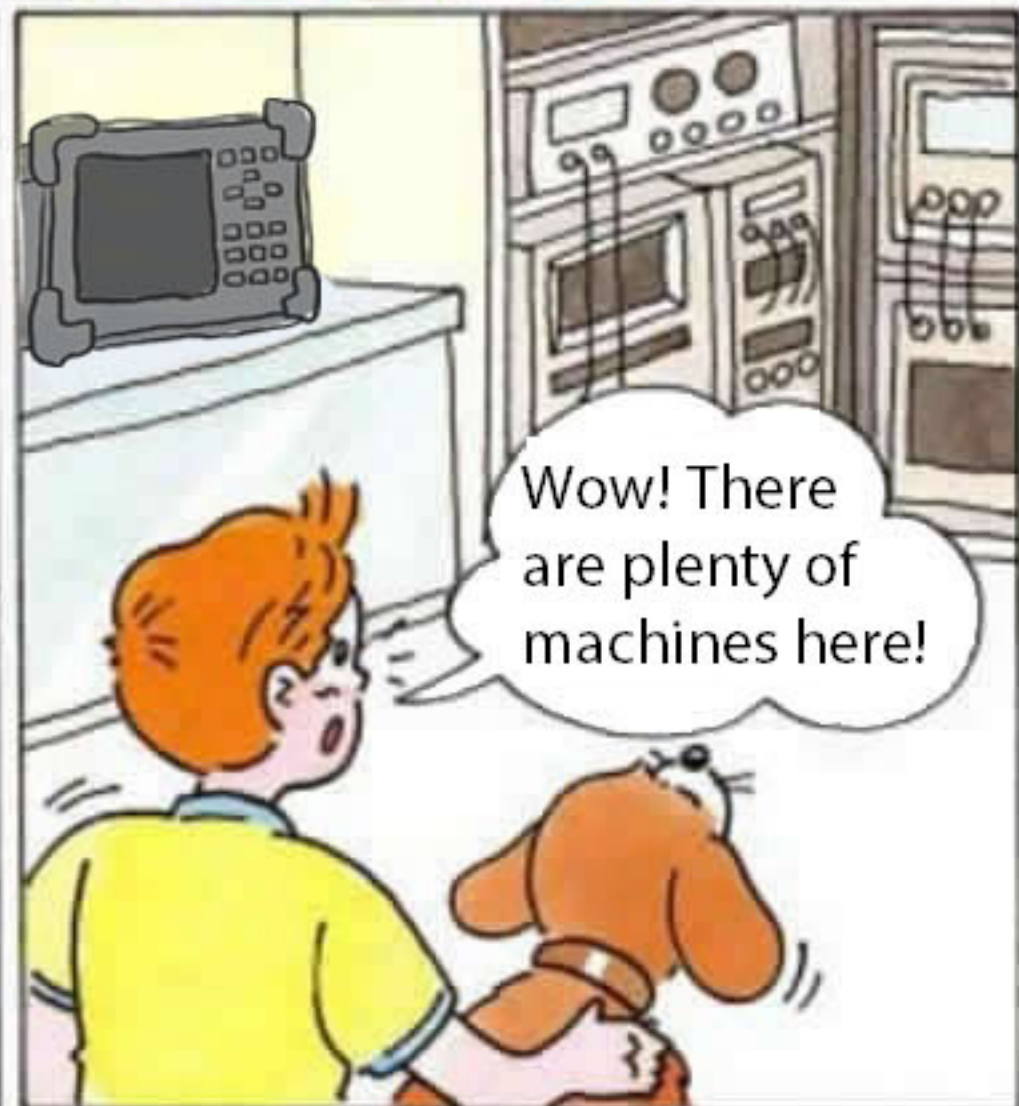
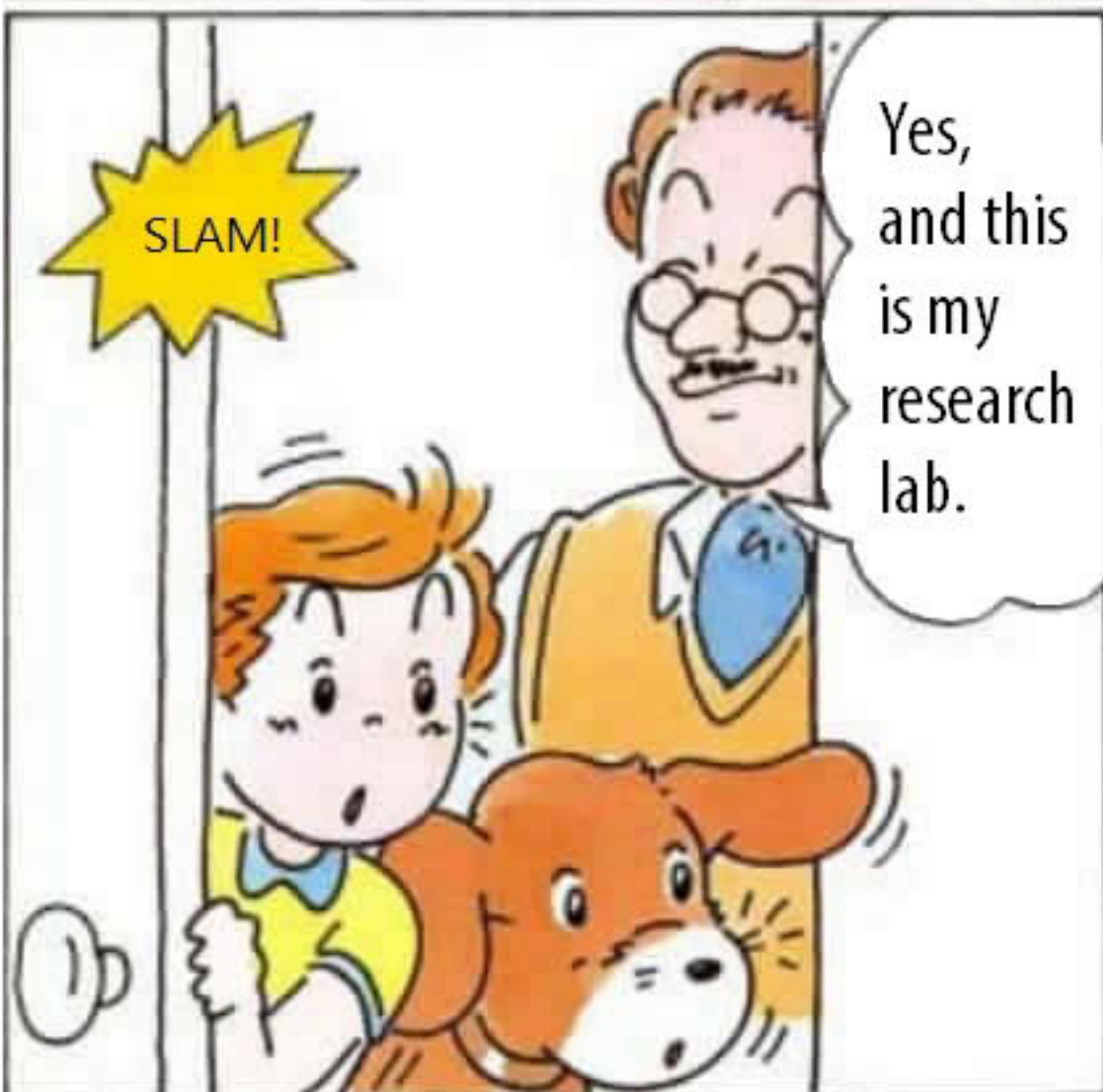
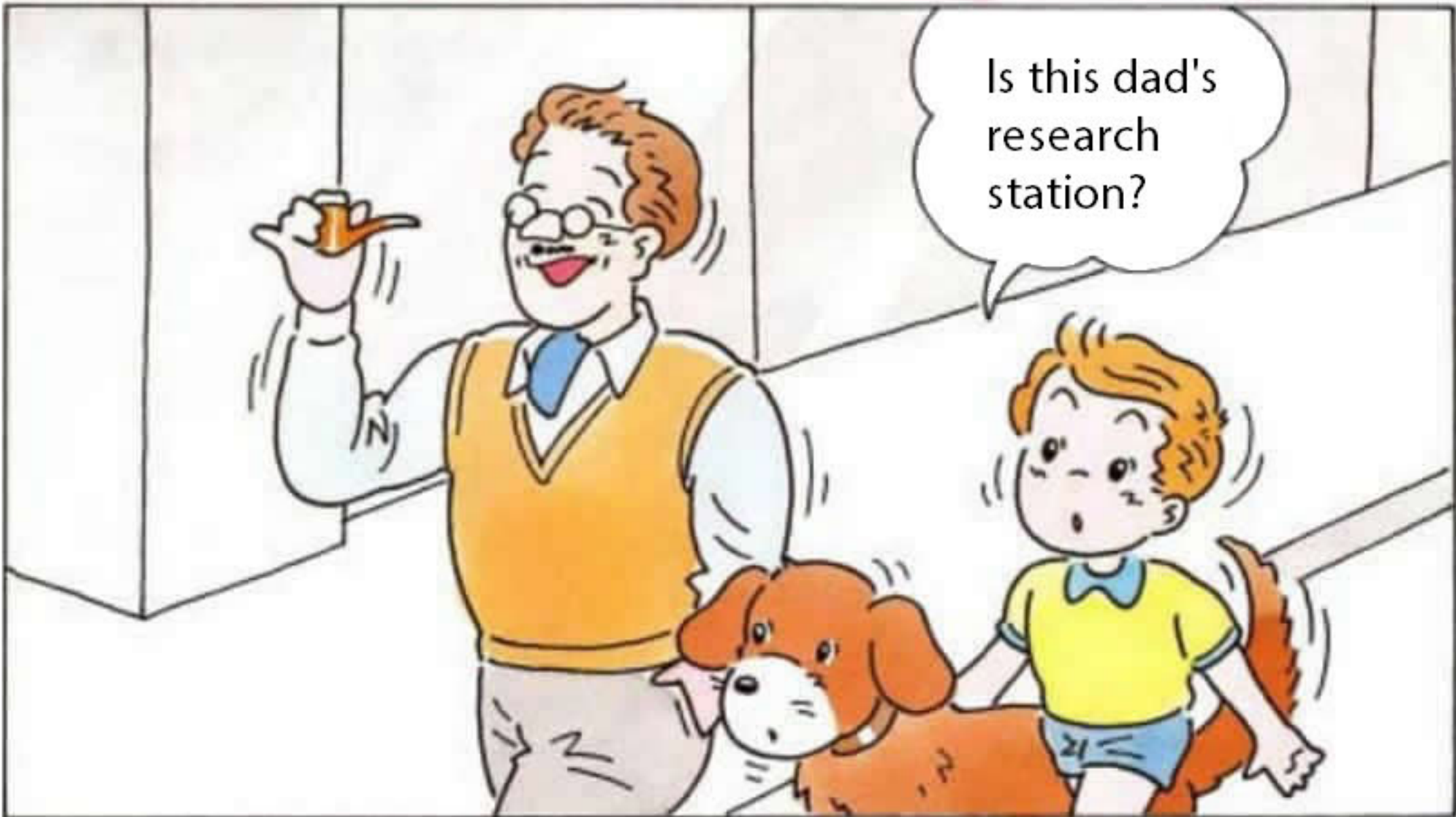


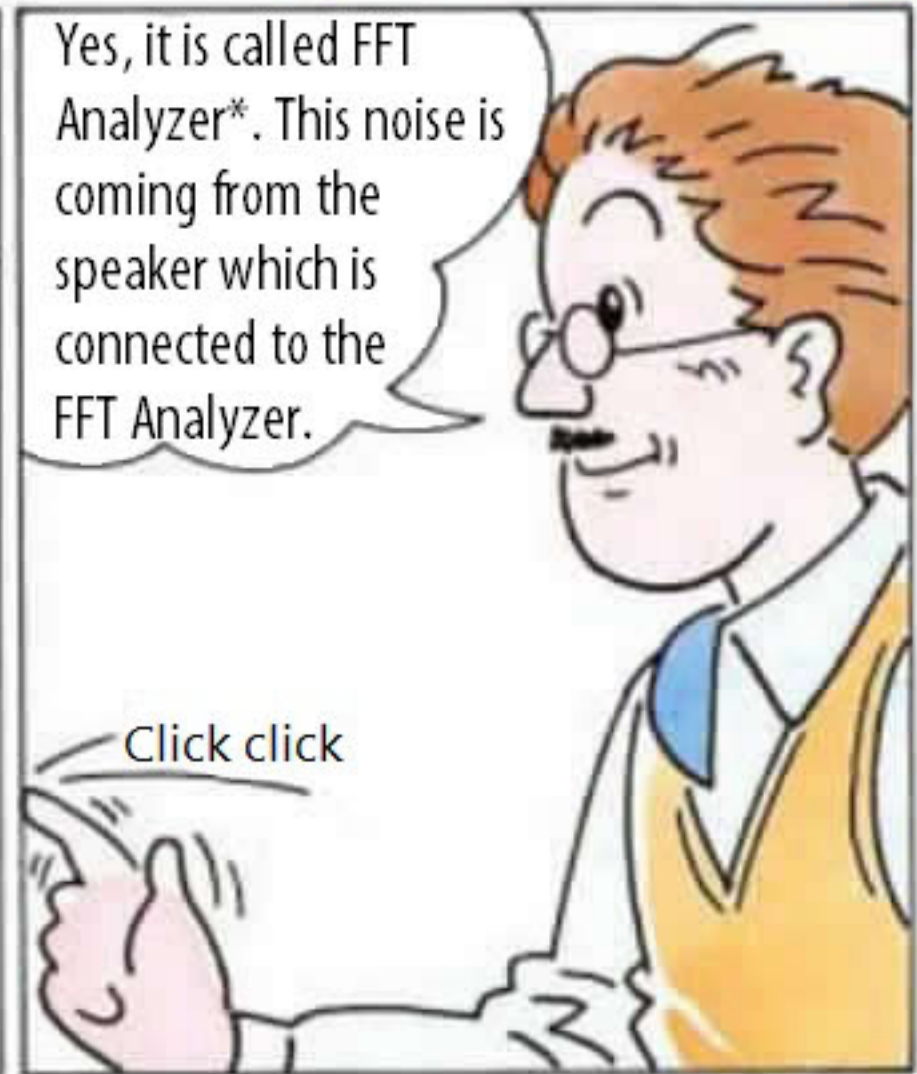
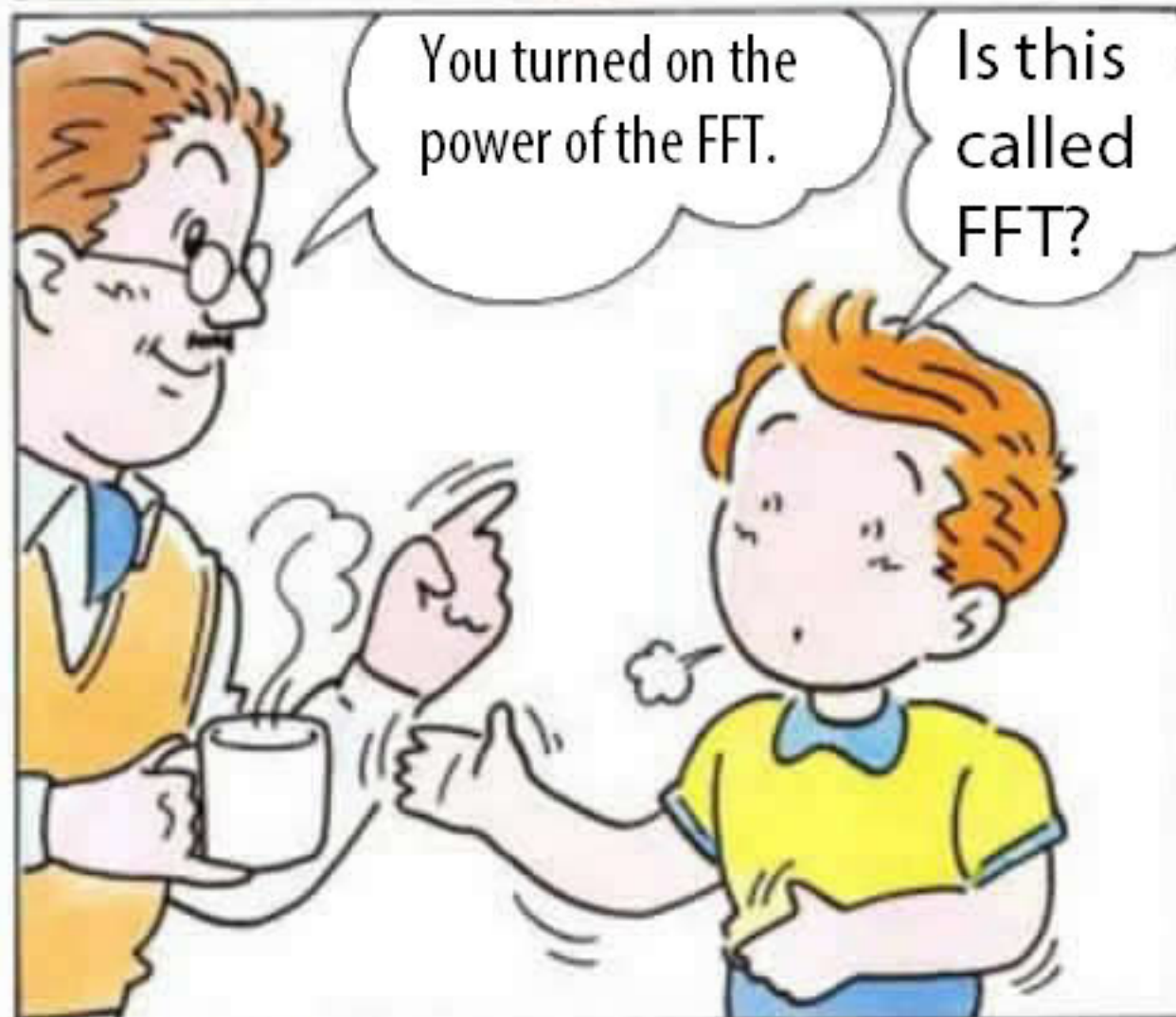
Wavy! It's about a time to leave.

Ok, Daddy!

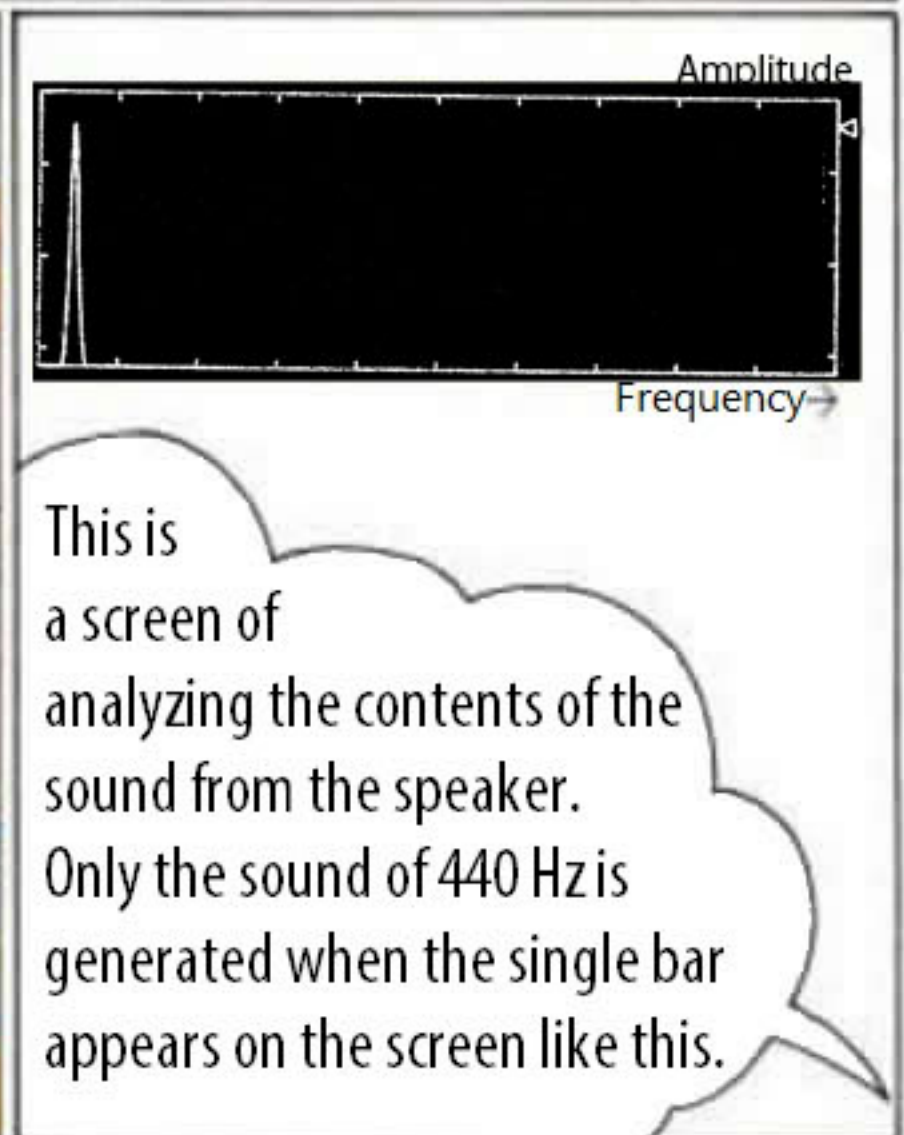
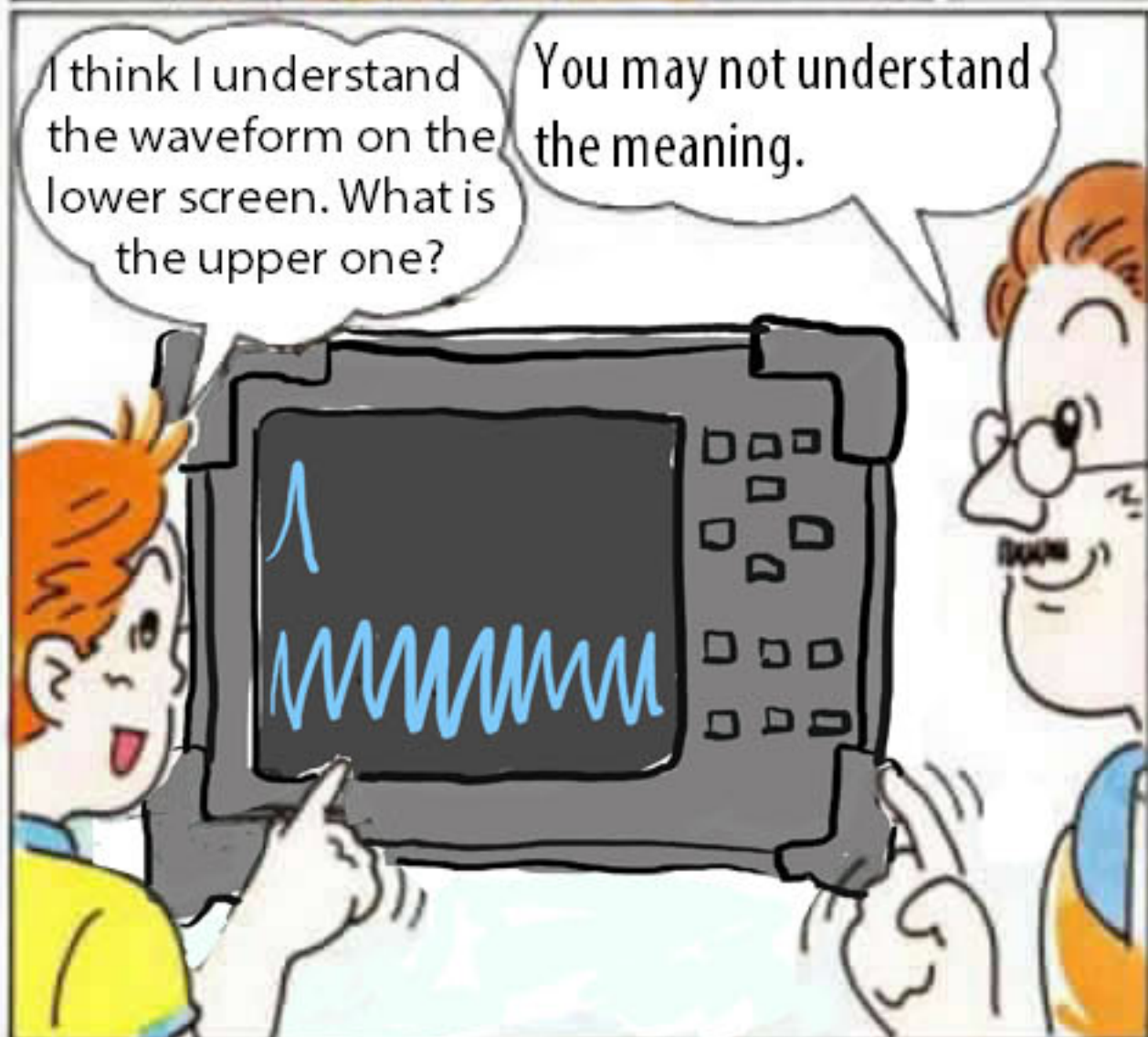
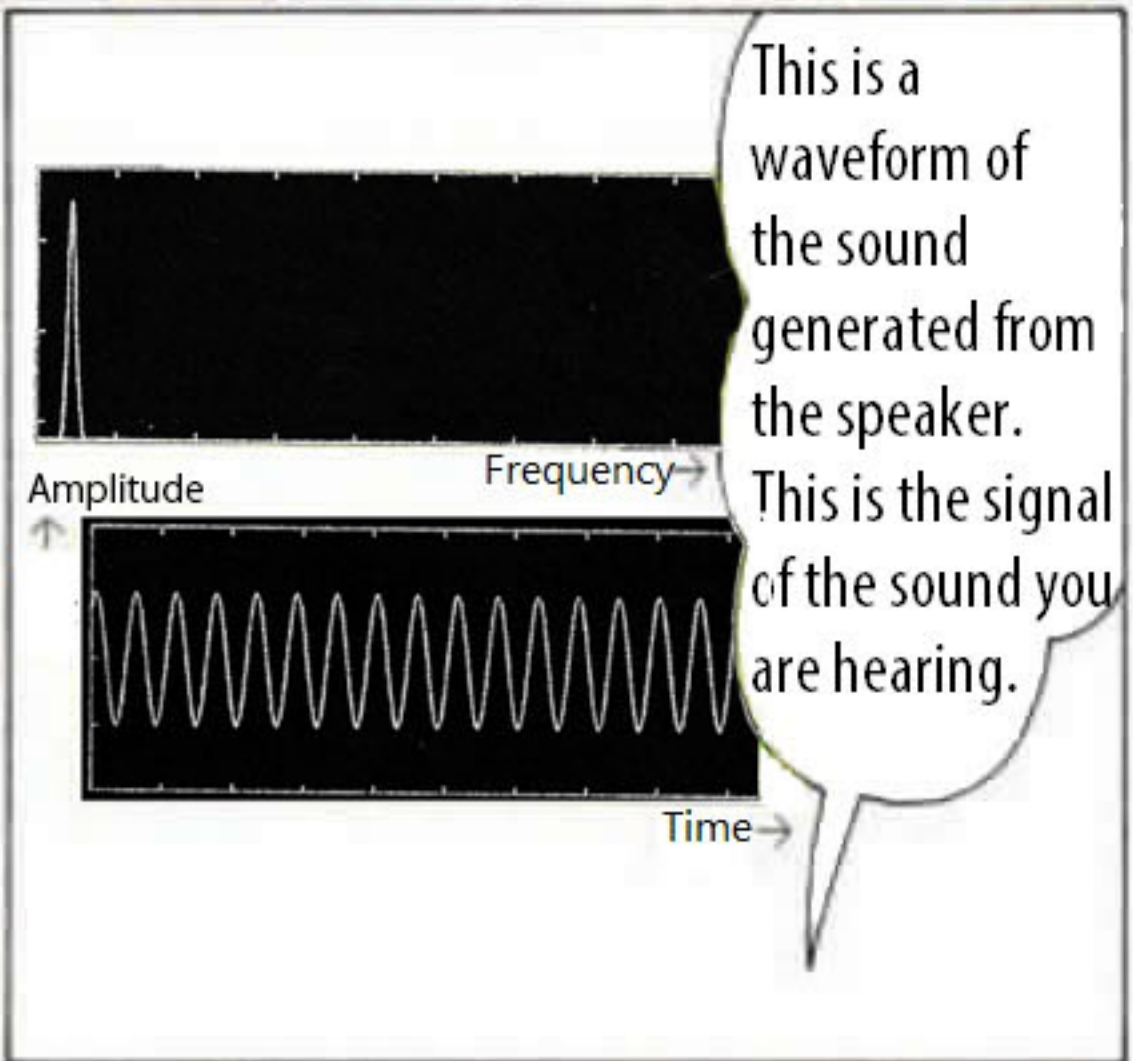
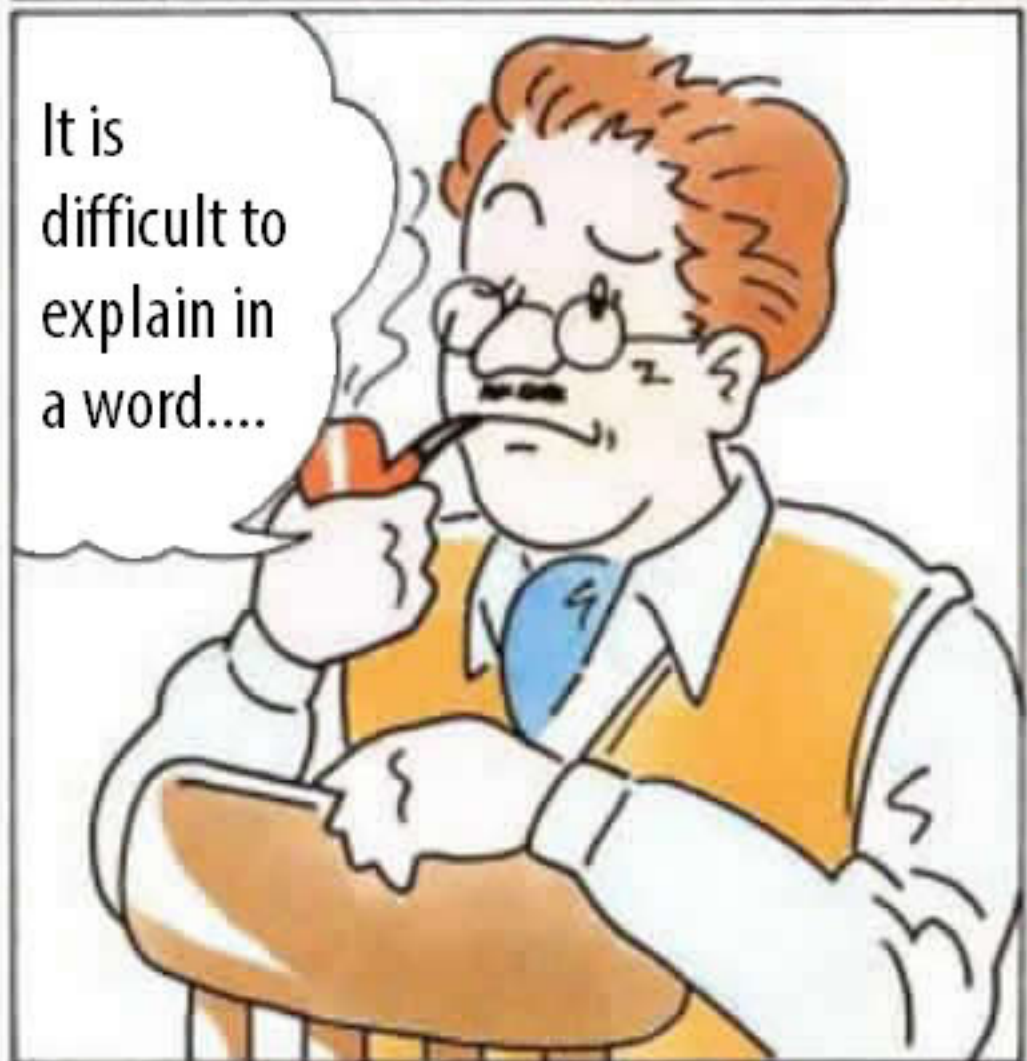
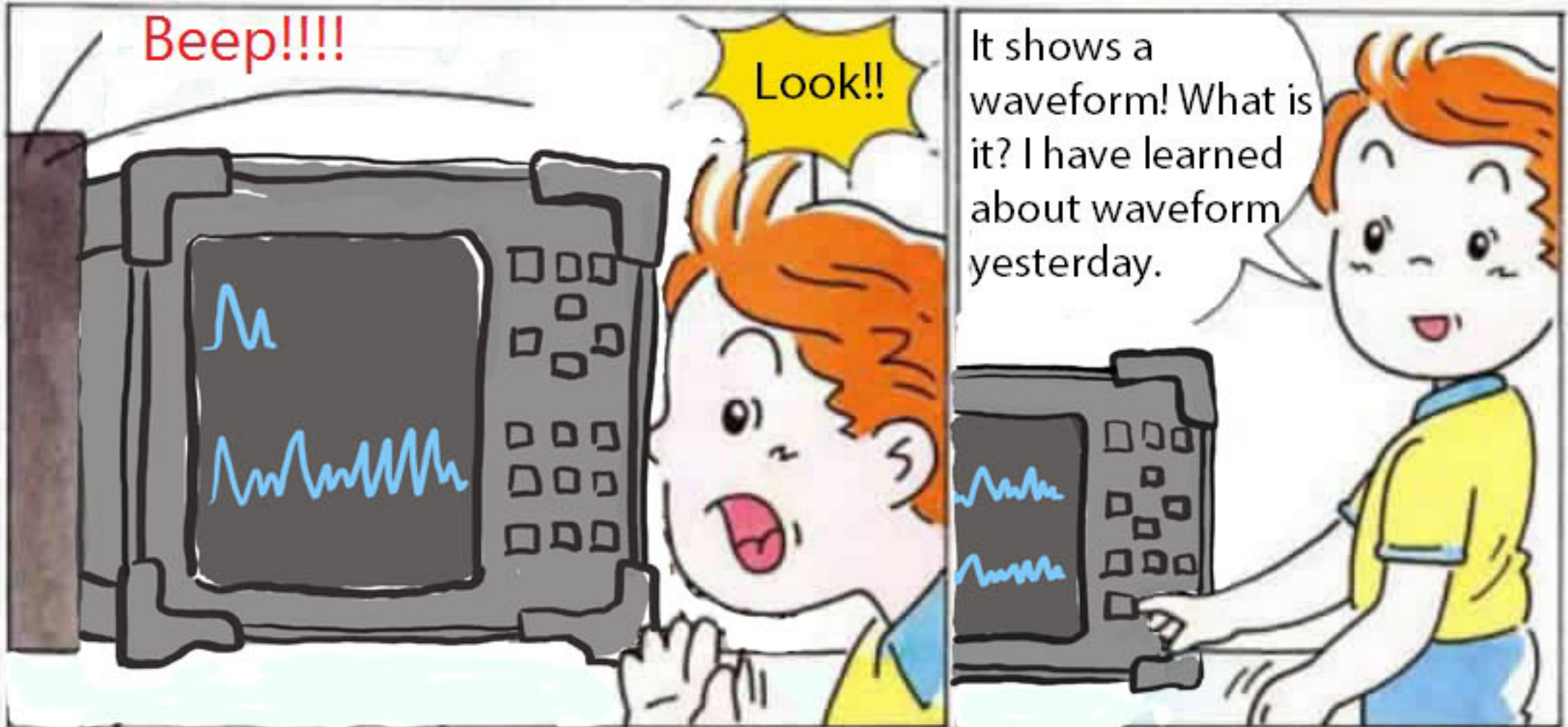
\*\*The dog can hear a higher sound than human.

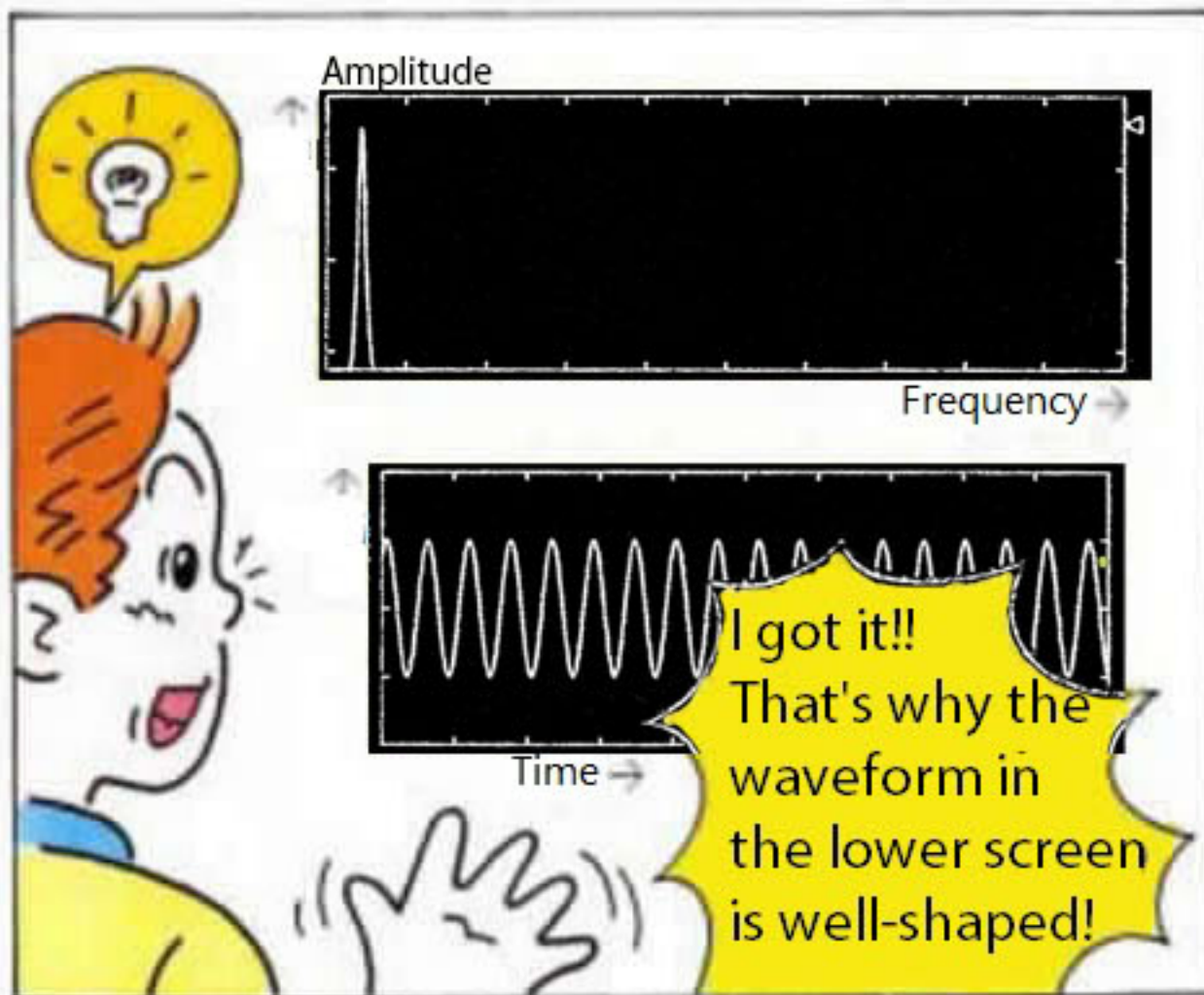
\*Reference of general frequency bands: TV/ Radio MHz=10<sup>6</sup>Hz, Infrared radiation/ Light THz=10<sup>12</sup>Hz, X-ray 10<sup>16</sup>THz=10<sup>18</sup> Hz





\*FFT: Fast Fourier Transform

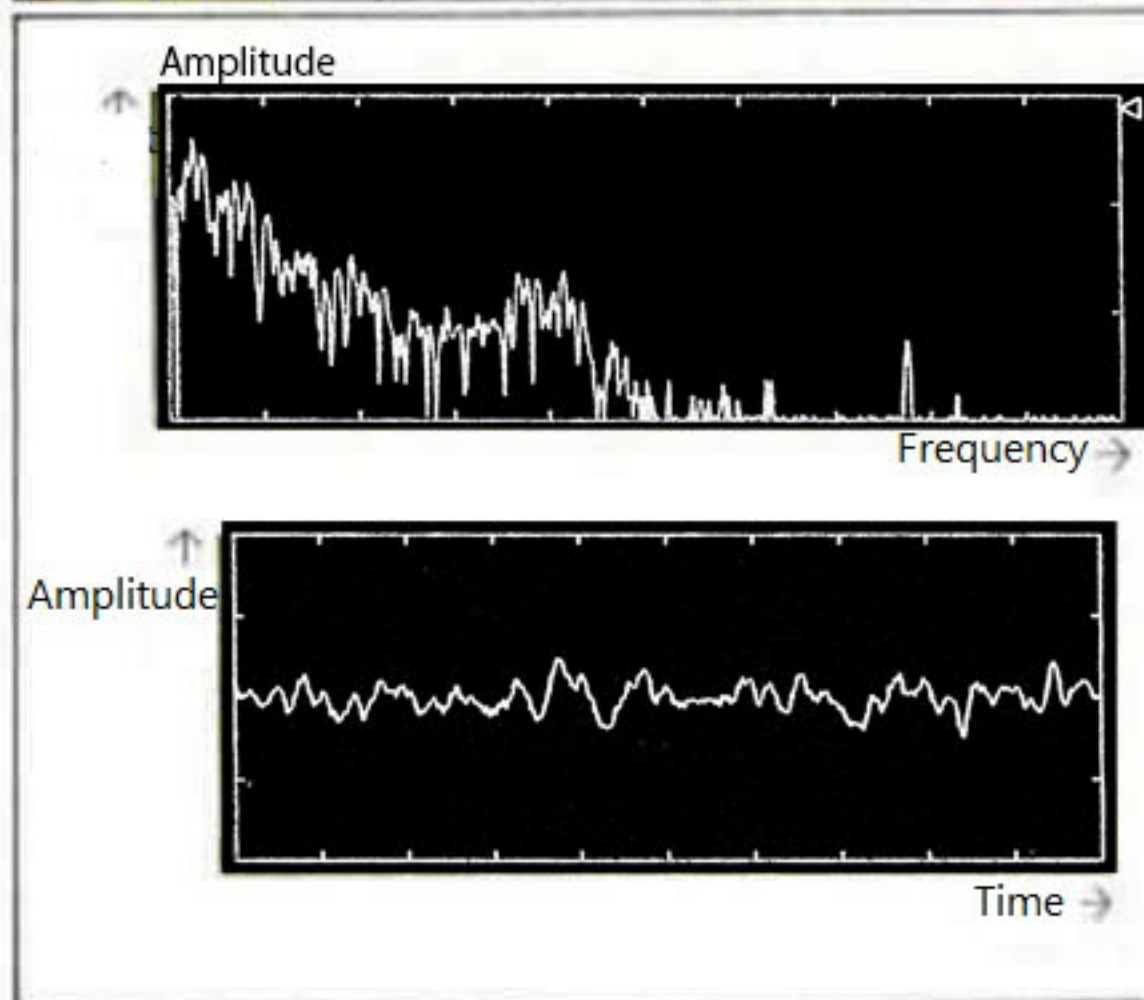




Yes. But this is artificial sound. There is no well-shaped waveform like this in the nature world.

How come you know?

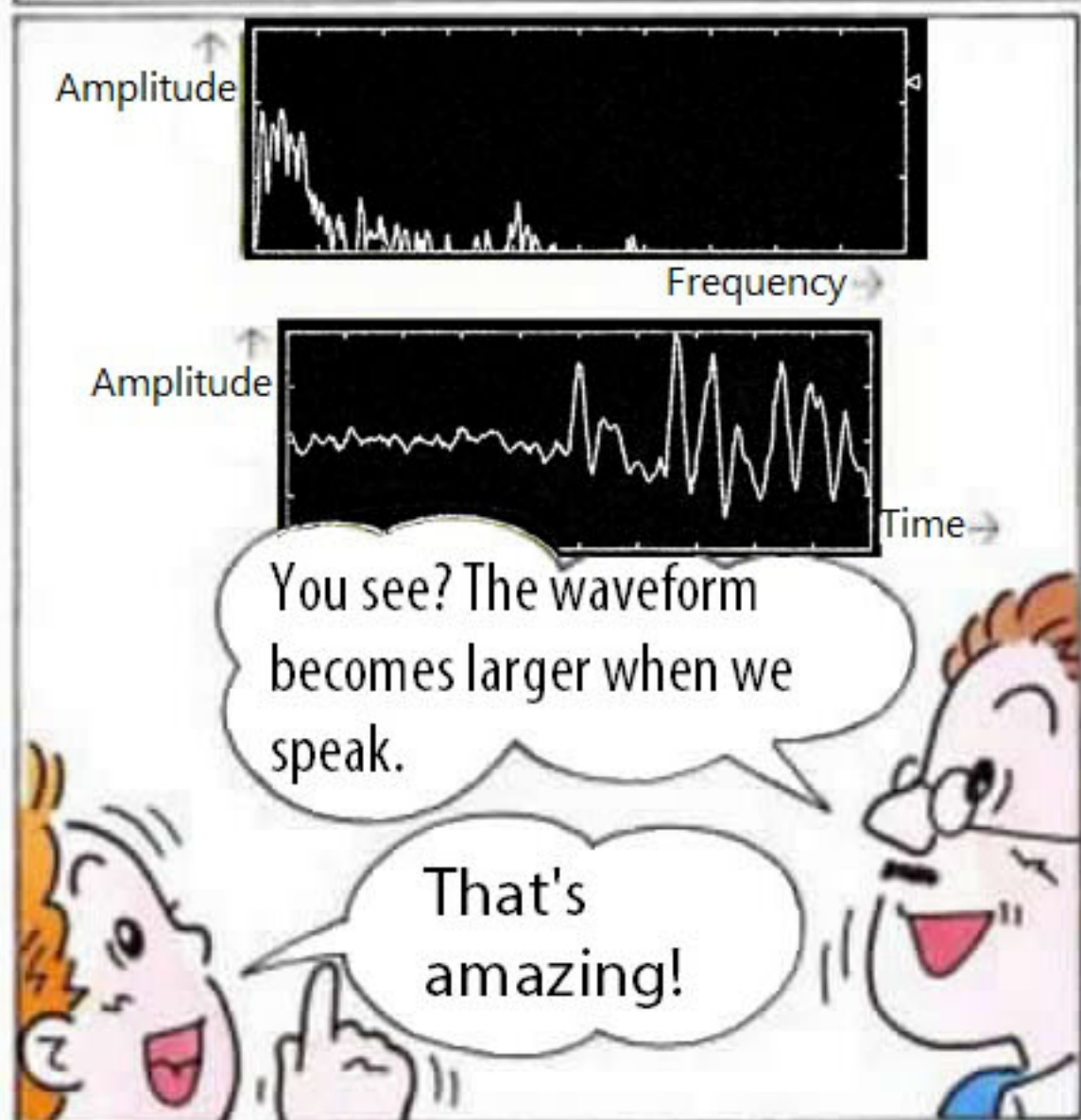
Click!



This is the sound waveform of this room picked up from the microphone.

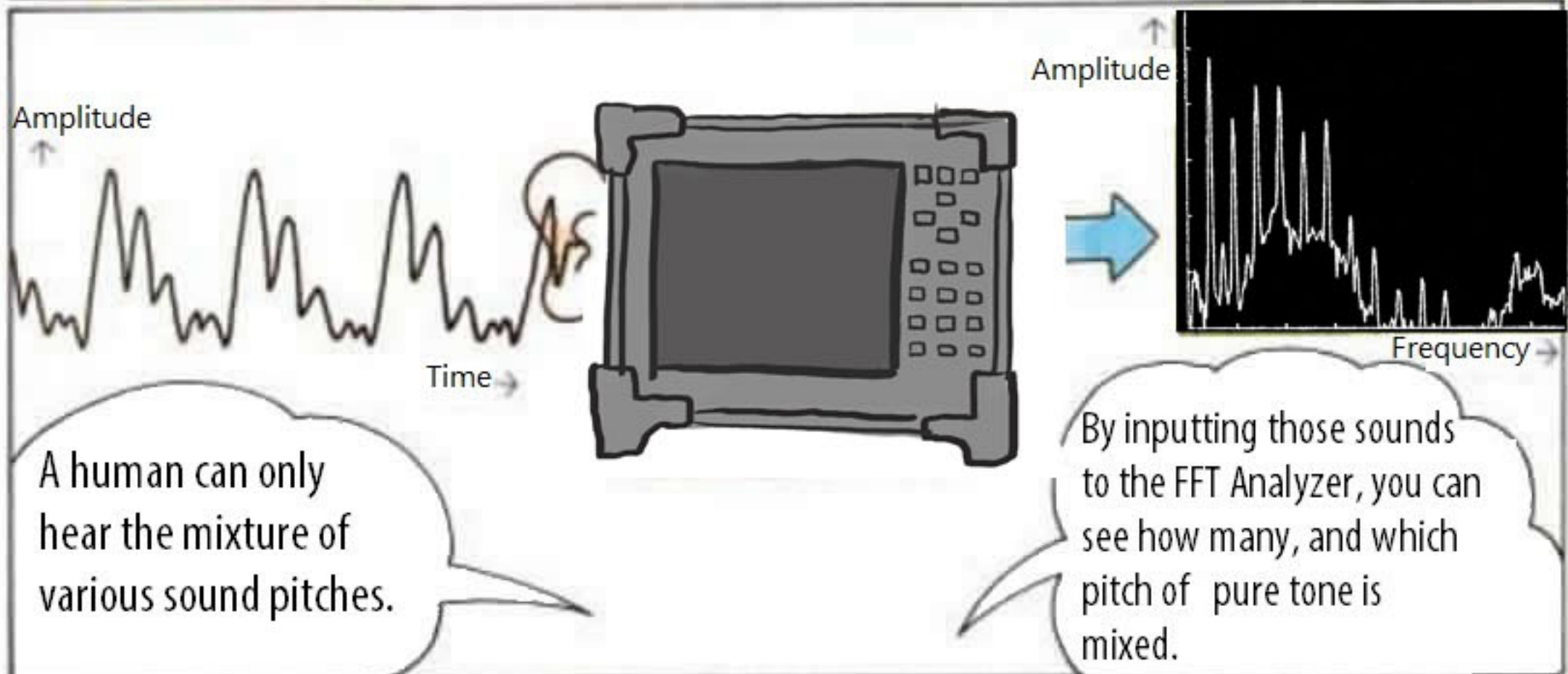
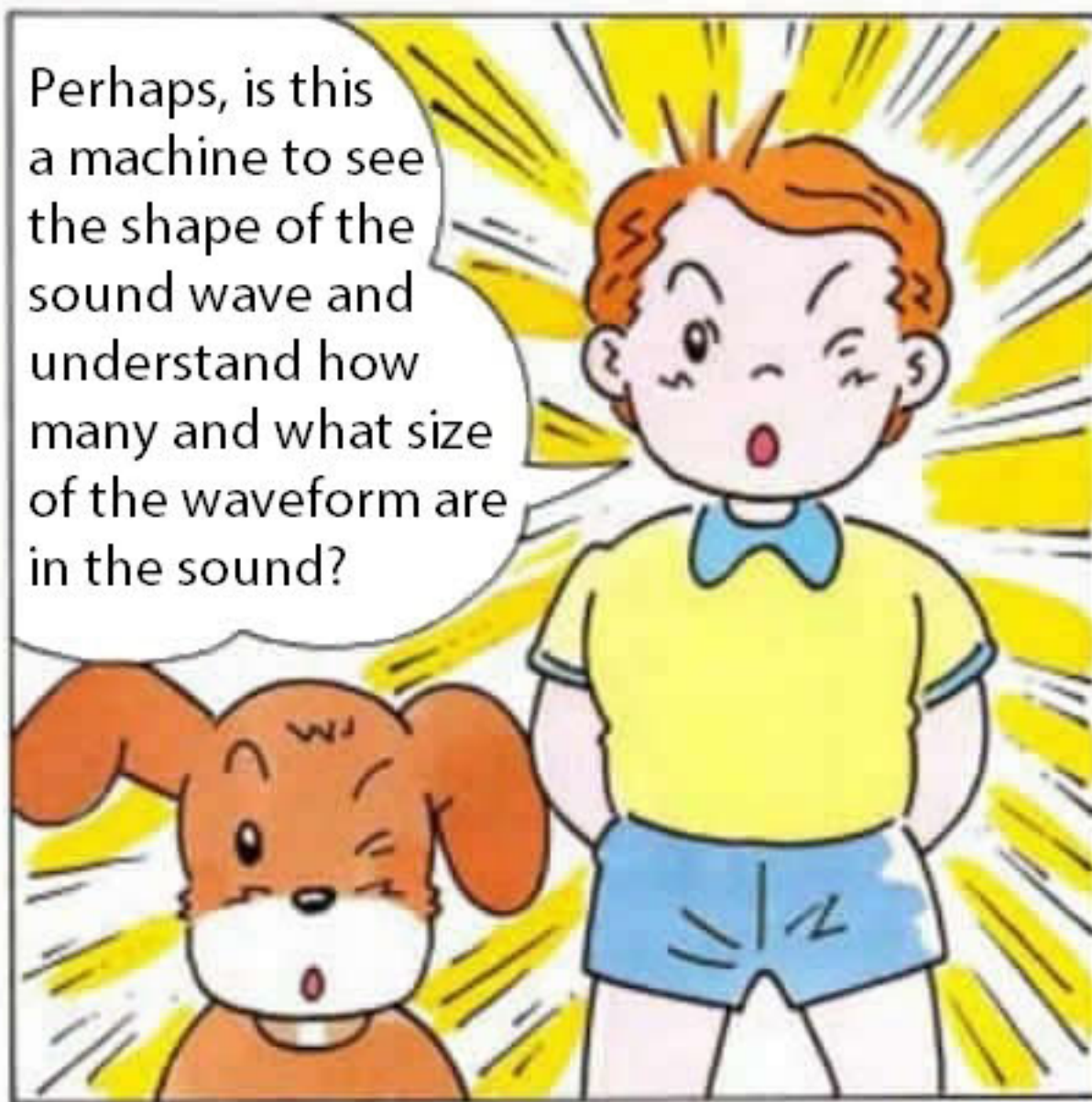
Wow, that's cluttering!

Let me join.



Bow Wow

So that means.....



Amplitude ↑

Frequency →

Amplitude ↑

Frequency →

I see. It is same as the graph we made the other day which the wave magnitude is arranged in speed order. (P.9)

The top panel shows a boy with orange hair pointing at a graph. The graph on the left has a vertical axis labeled 'Amplitude' with an upward arrow and a horizontal axis labeled 'Frequency' with a rightward arrow. It contains three green arrows of decreasing height from left to right. To the right is a spectrogram with a vertical axis labeled 'Amplitude' and a horizontal axis labeled 'Frequency'. It shows a complex waveform with multiple peaks of varying heights.

It is quite interesting that we could see what is inside the sound. What else is there?

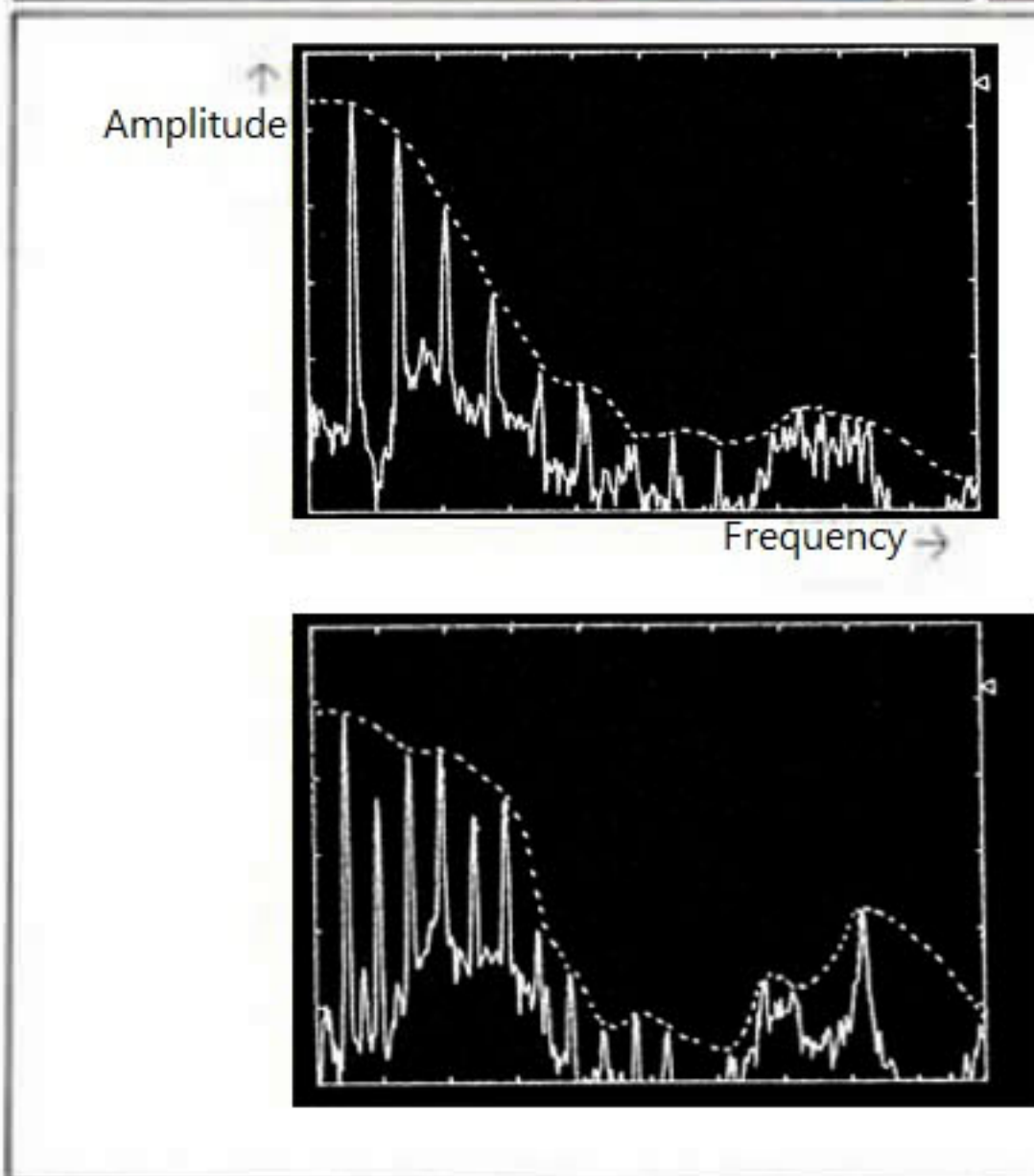
The middle panel shows a man with glasses and a mustache, wearing an orange sweater, looking at a computer monitor. A boy with orange hair and a dog are looking at the monitor with him. The boy has a surprised expression.

Hey Wavy, do you think I am working hard just only for that reason?

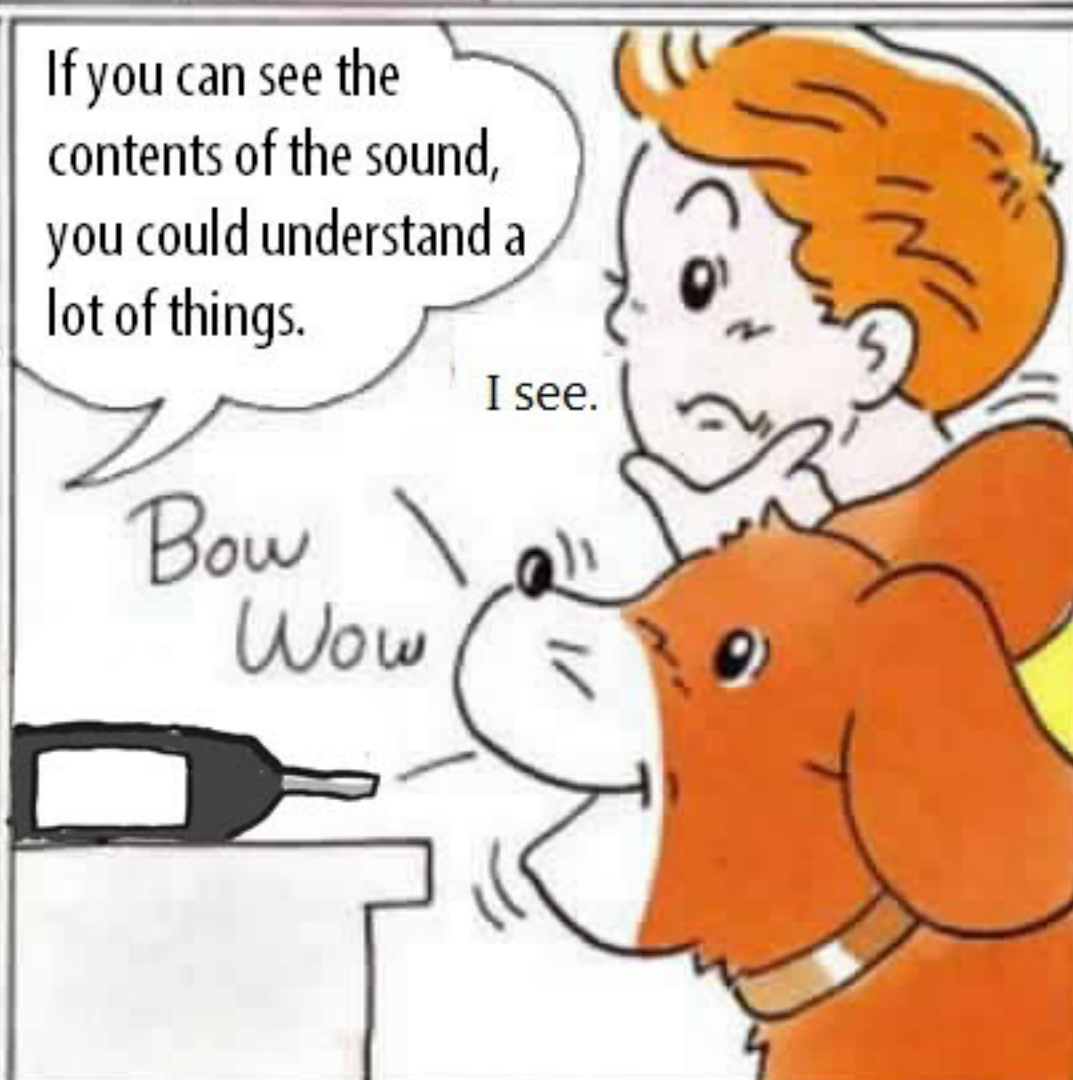
Wavy, say something to this microphone.

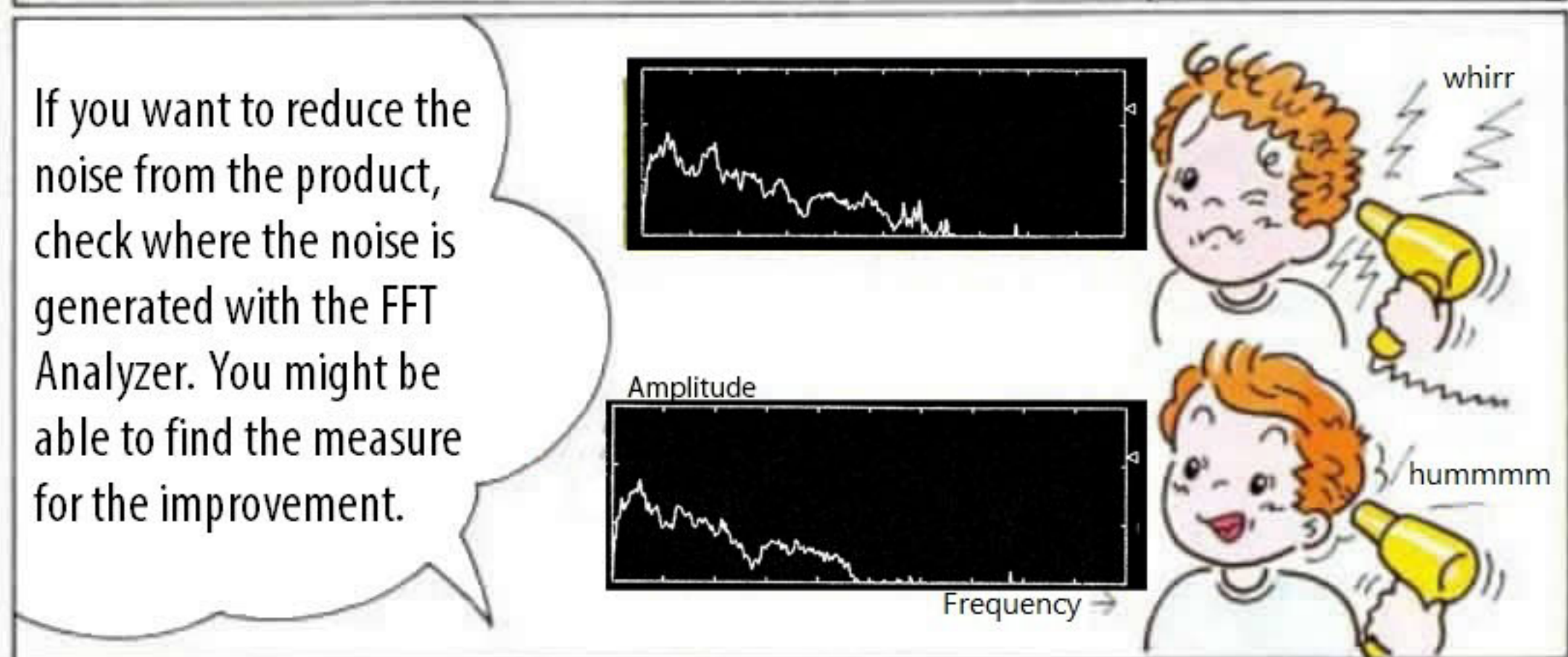
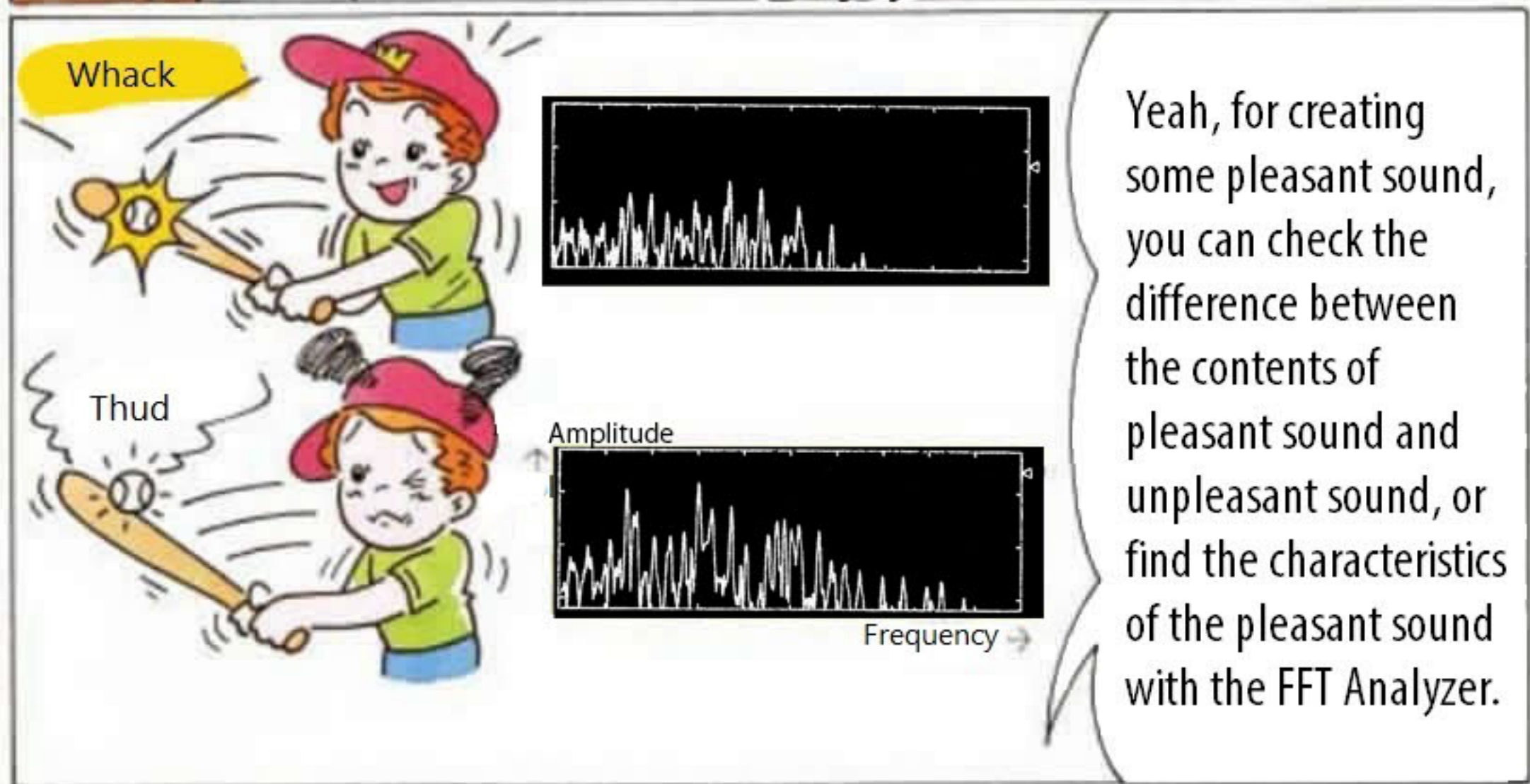
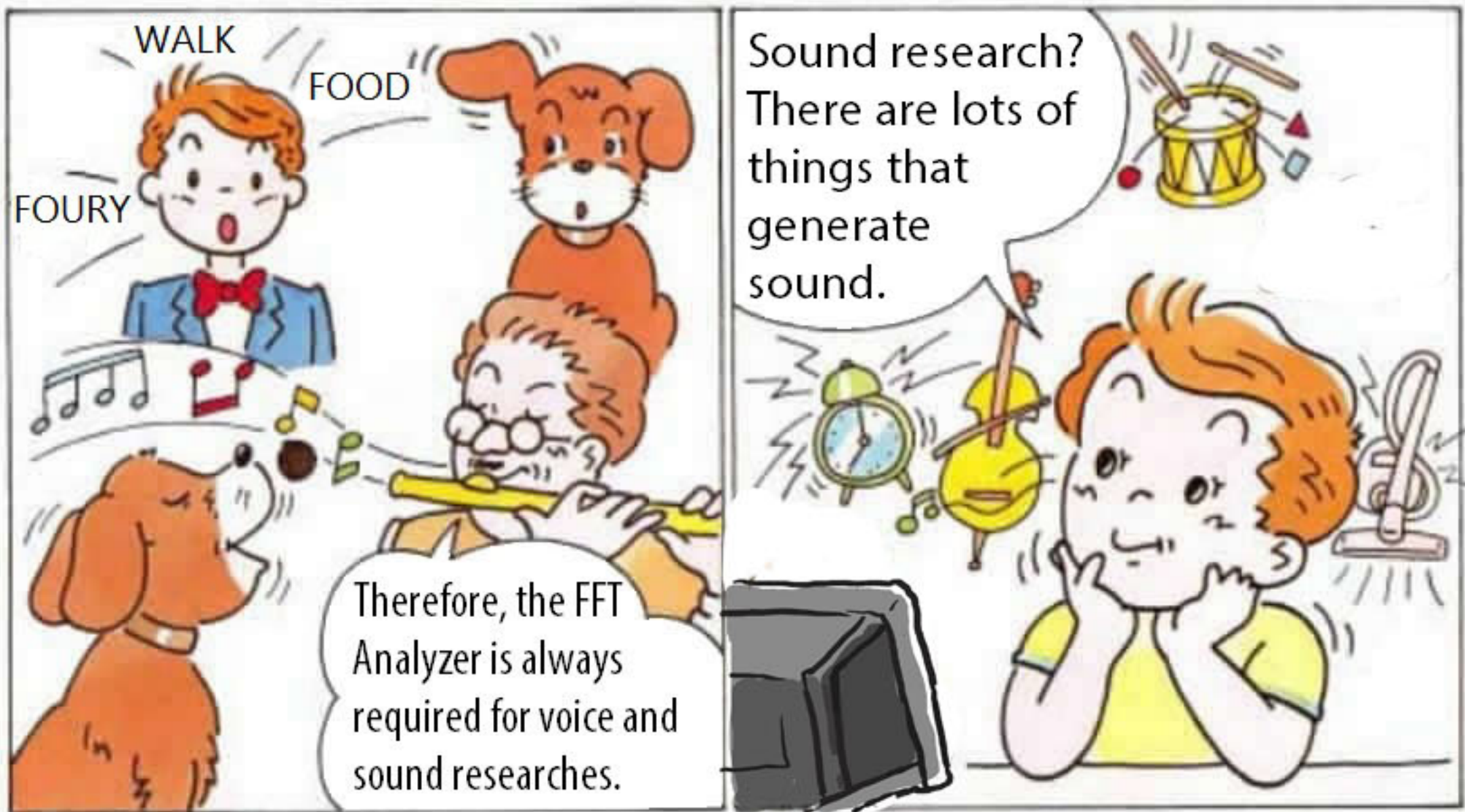
The bottom panel is split into two parts. On the left, the man with glasses is speaking. On the right, a hand is holding a black microphone. The boy with orange hair is looking at the microphone.

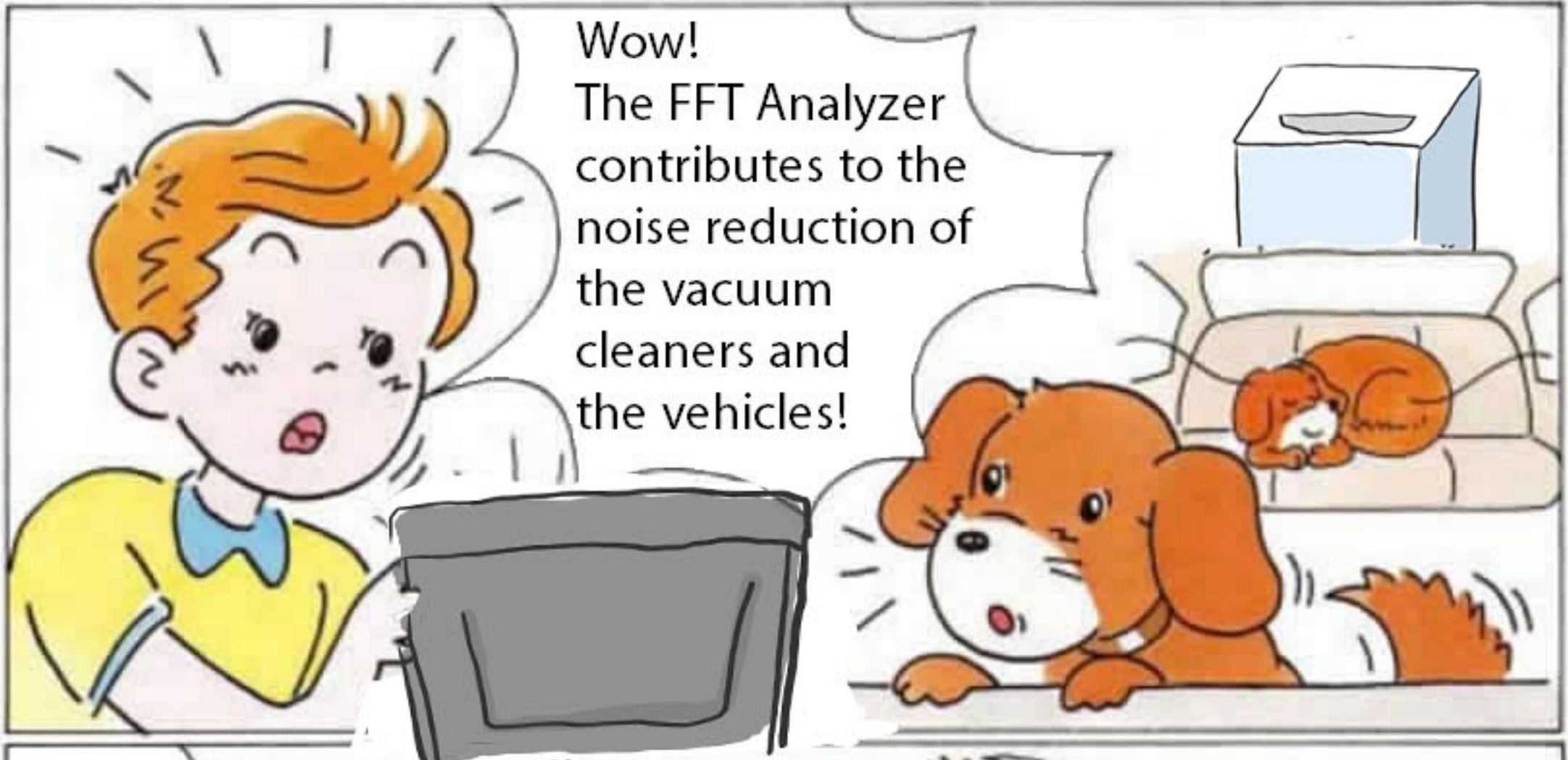




Look Wavy, upper waveform is Wavy's voice and the lower one is mine. We spoke same words so the waveform looks similar. However, you shouted, so the ridge of your waveform is higher than mine. Also, the whole ridge of your waveform is located on the right side.







Wow!  
The FFT Analyzer  
contributes to the  
noise reduction of  
the vacuum  
cleaners and  
the vehicles!



Also, the FFT  
Analyzer can  
use for other  
things.



Ah  
Ahh

For example, even  
if you and I speak  
exactly the same  
volume, my voice  
may be heard  
smaller when it  
passes the speaker.

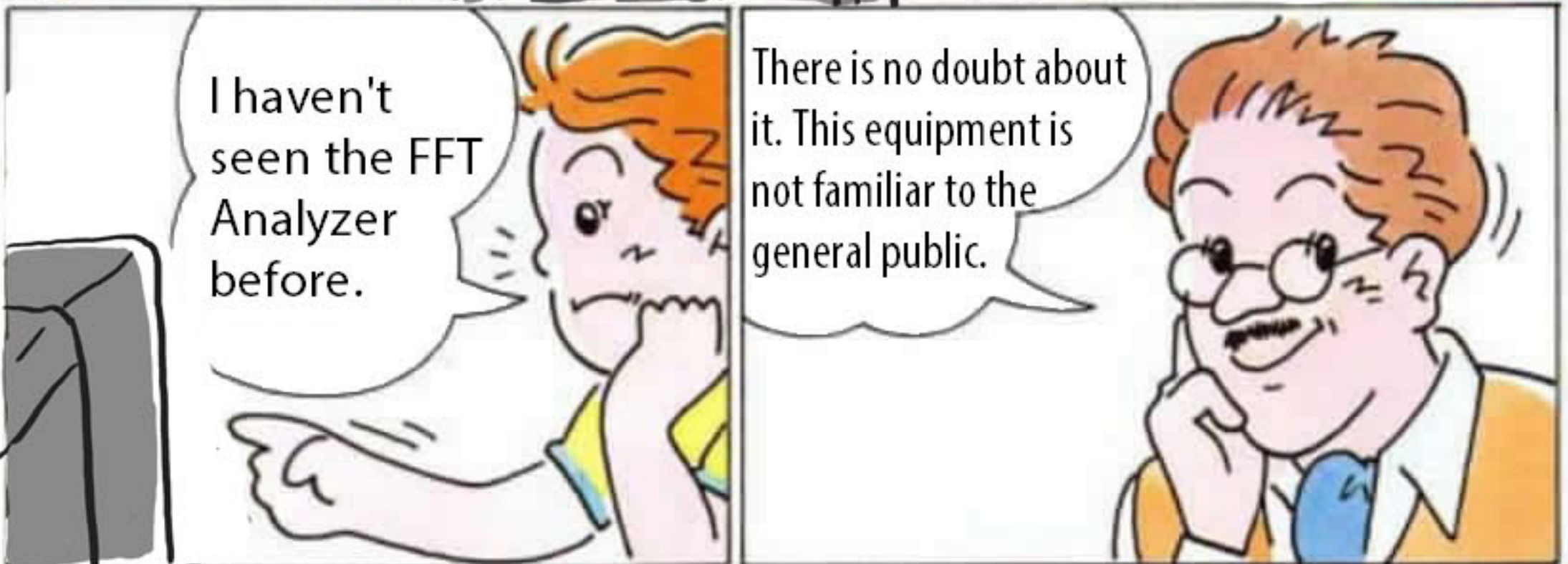
Ah  
Ahh

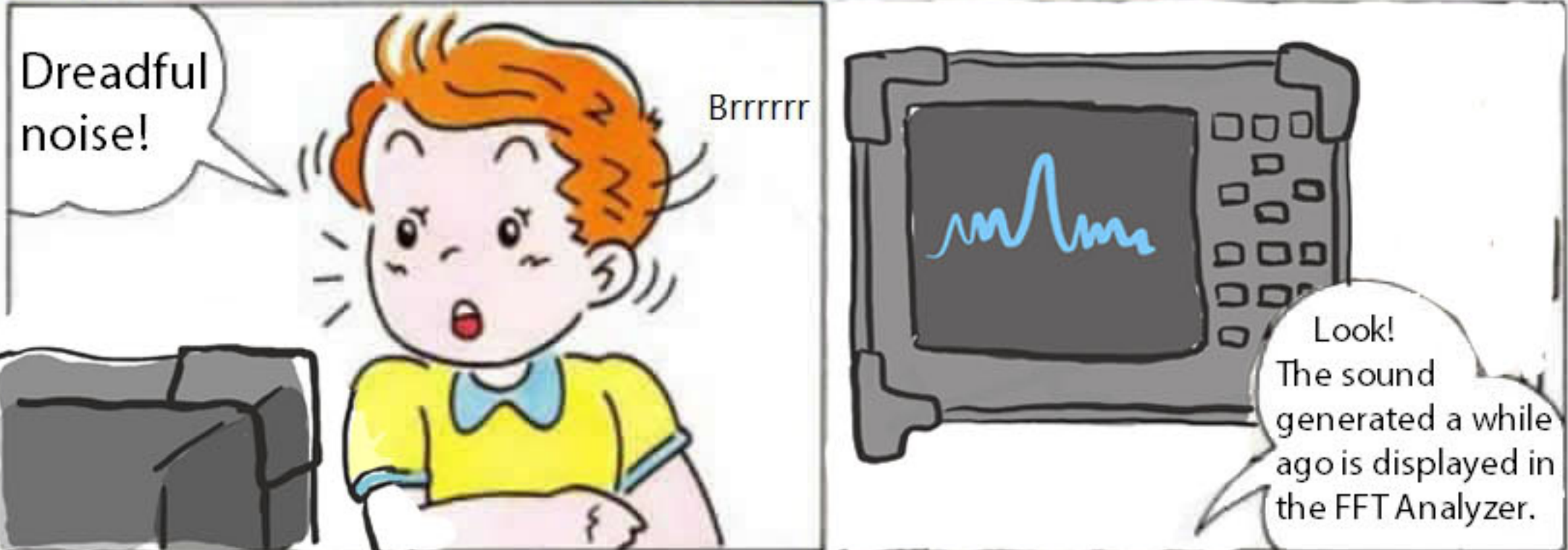
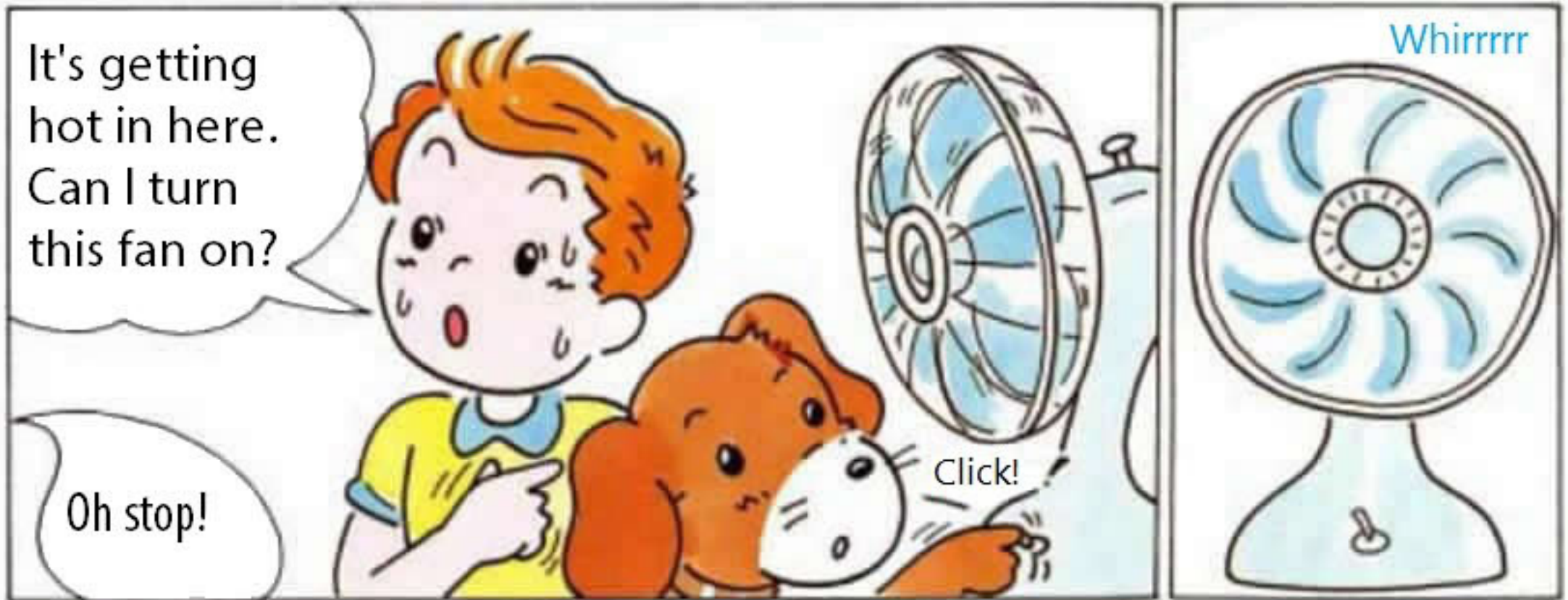


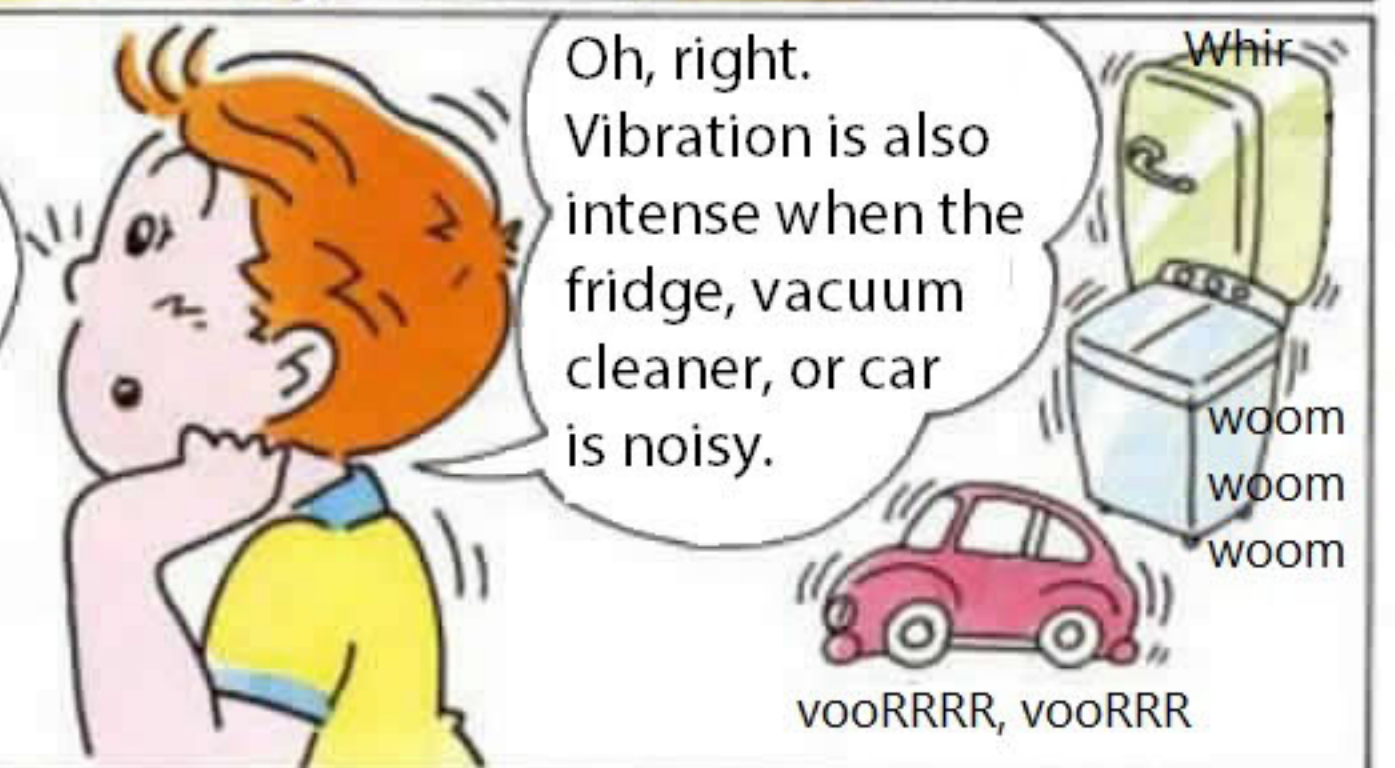
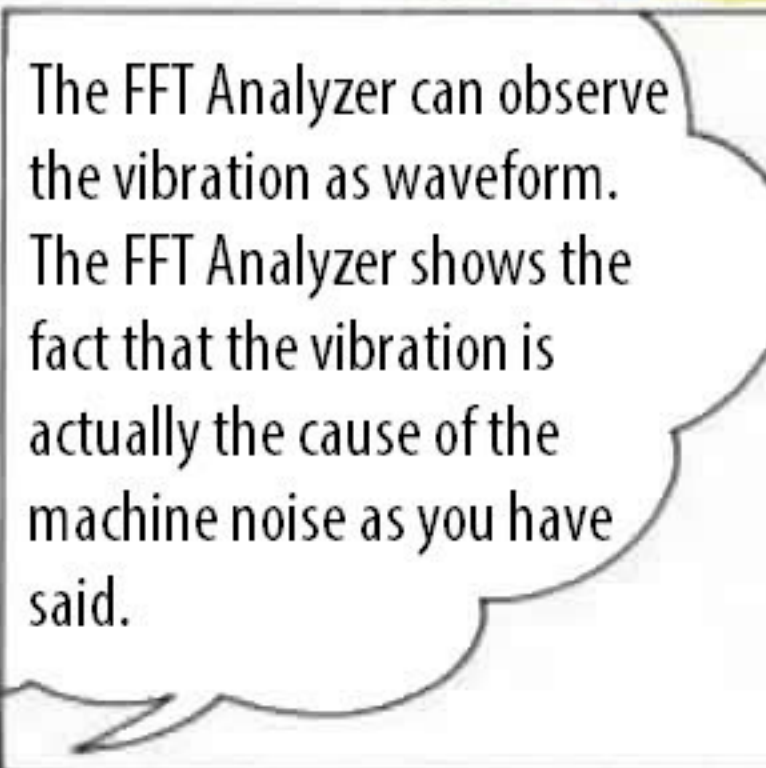
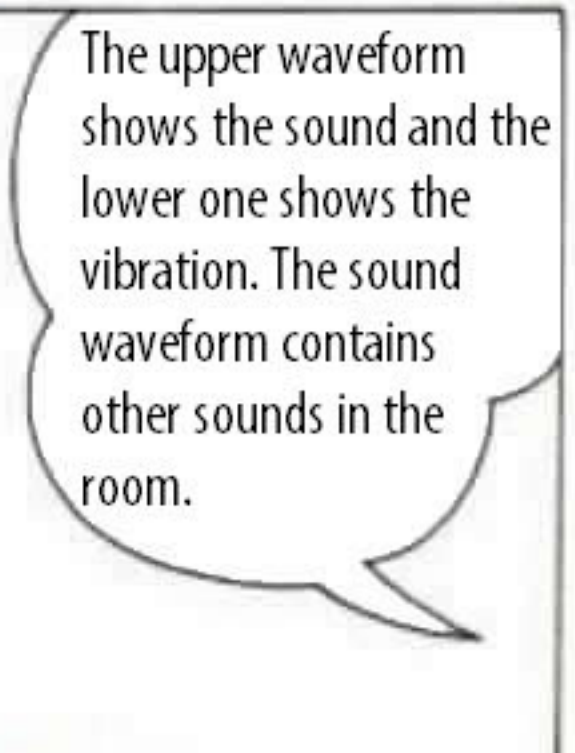
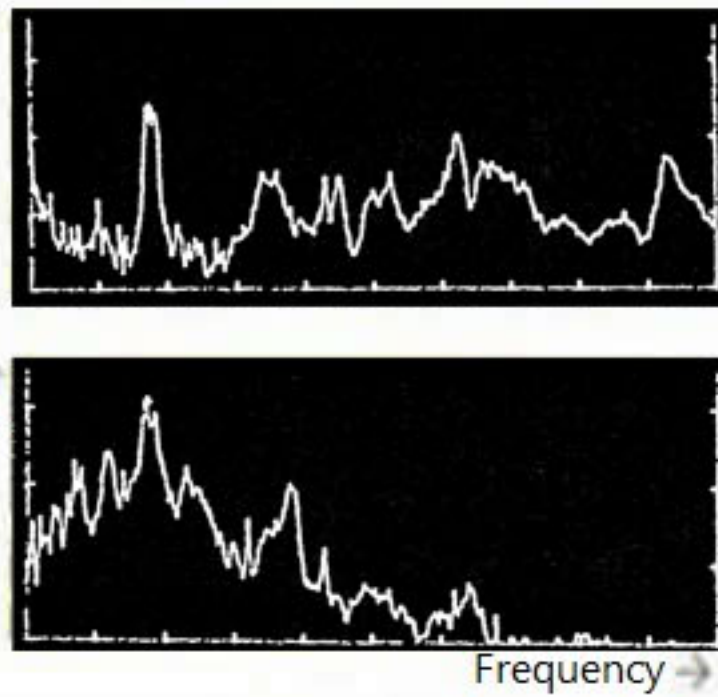
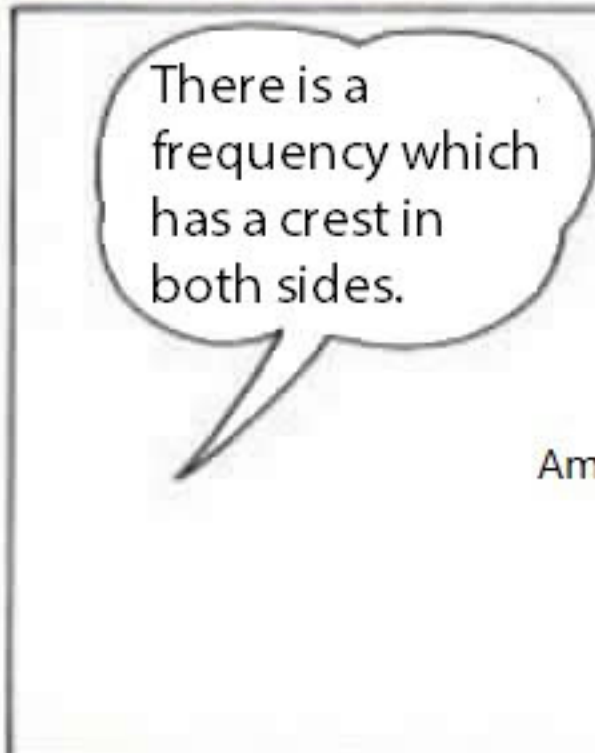
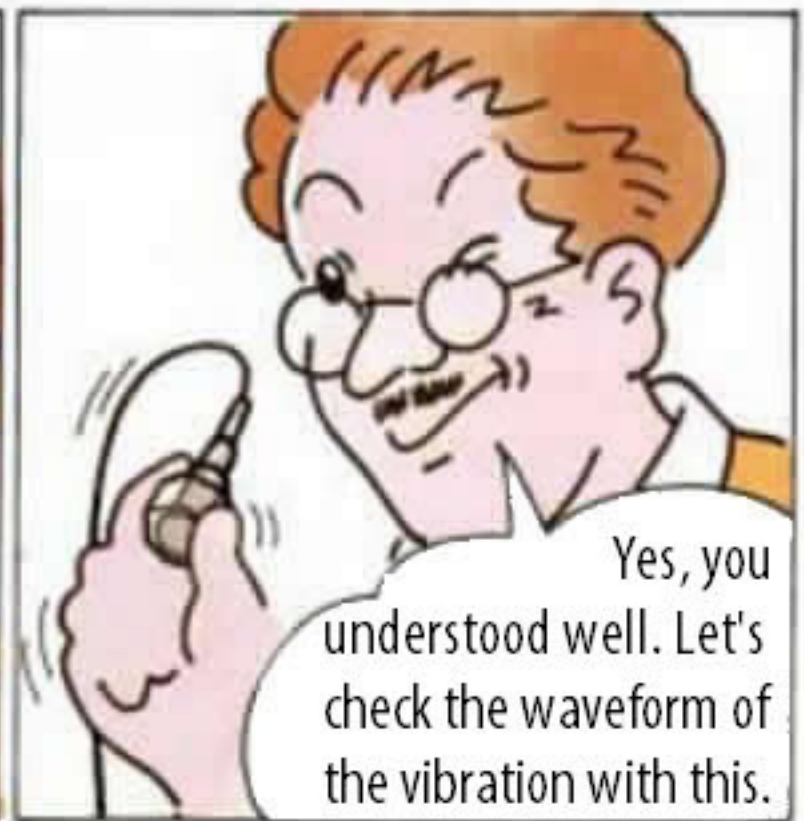
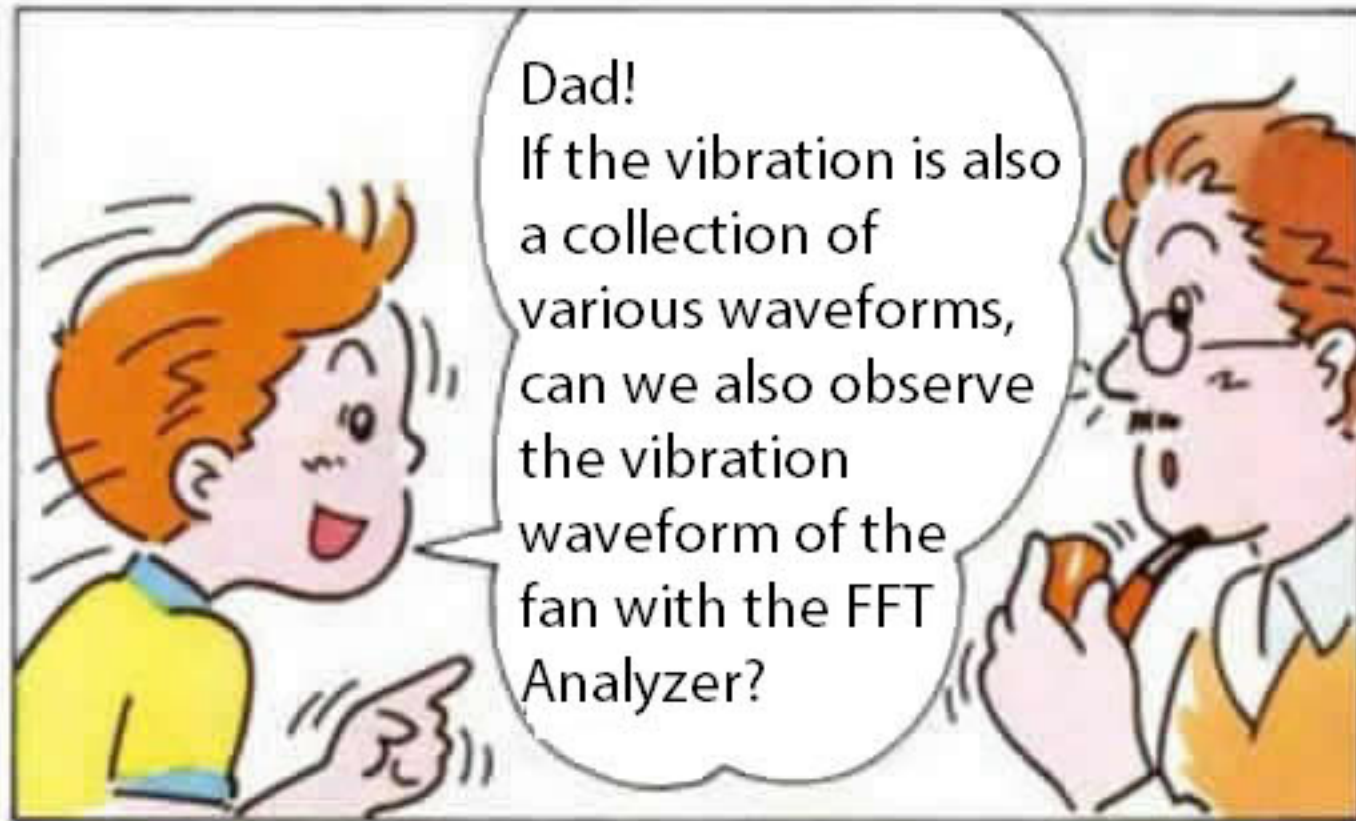
The FFT Analyzer can be used to research  
the characteristics of a speaker, such as  
being good at high-pitched sound or  
being good at low-pitched sound.

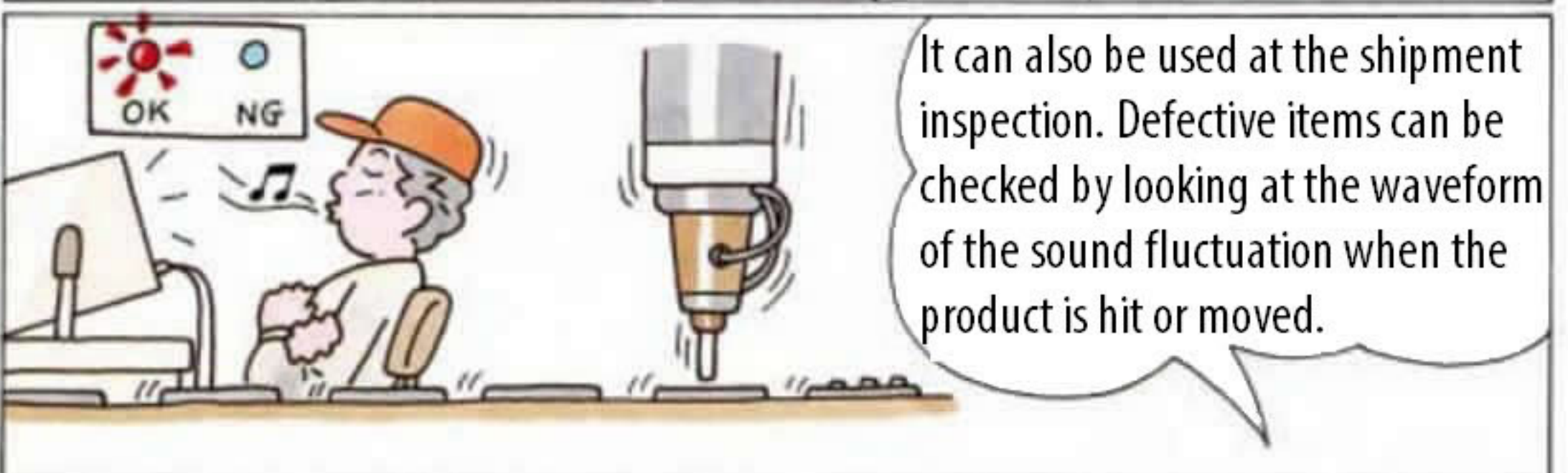
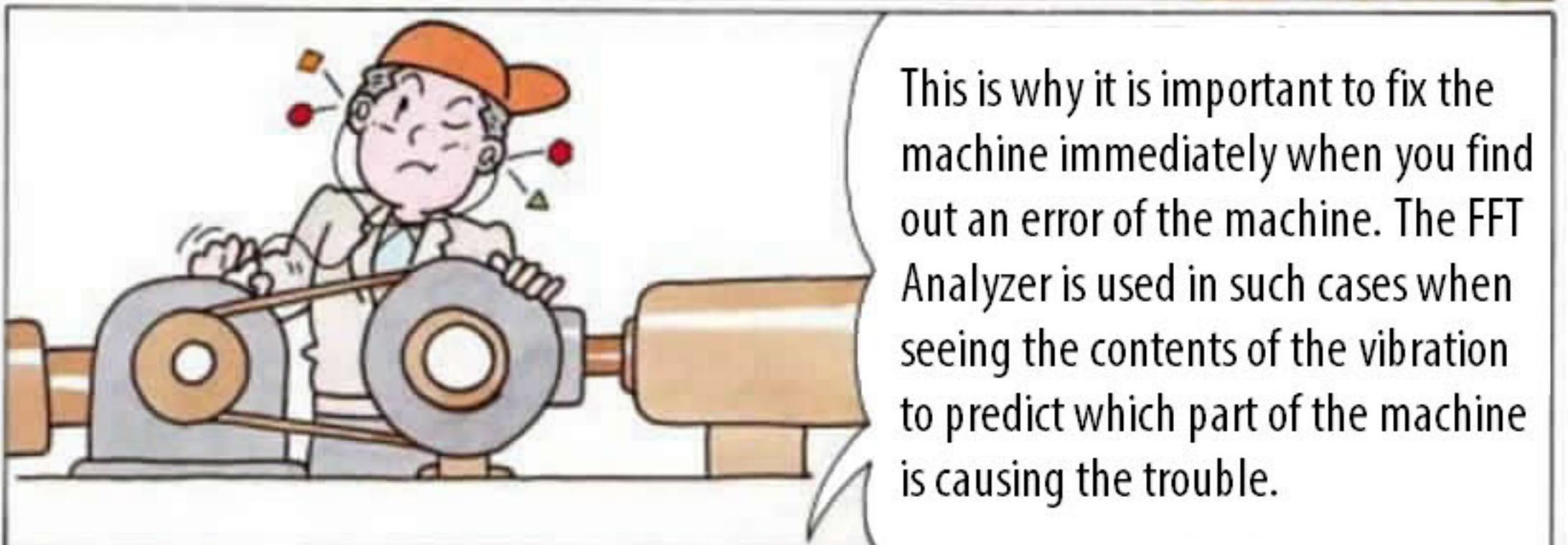
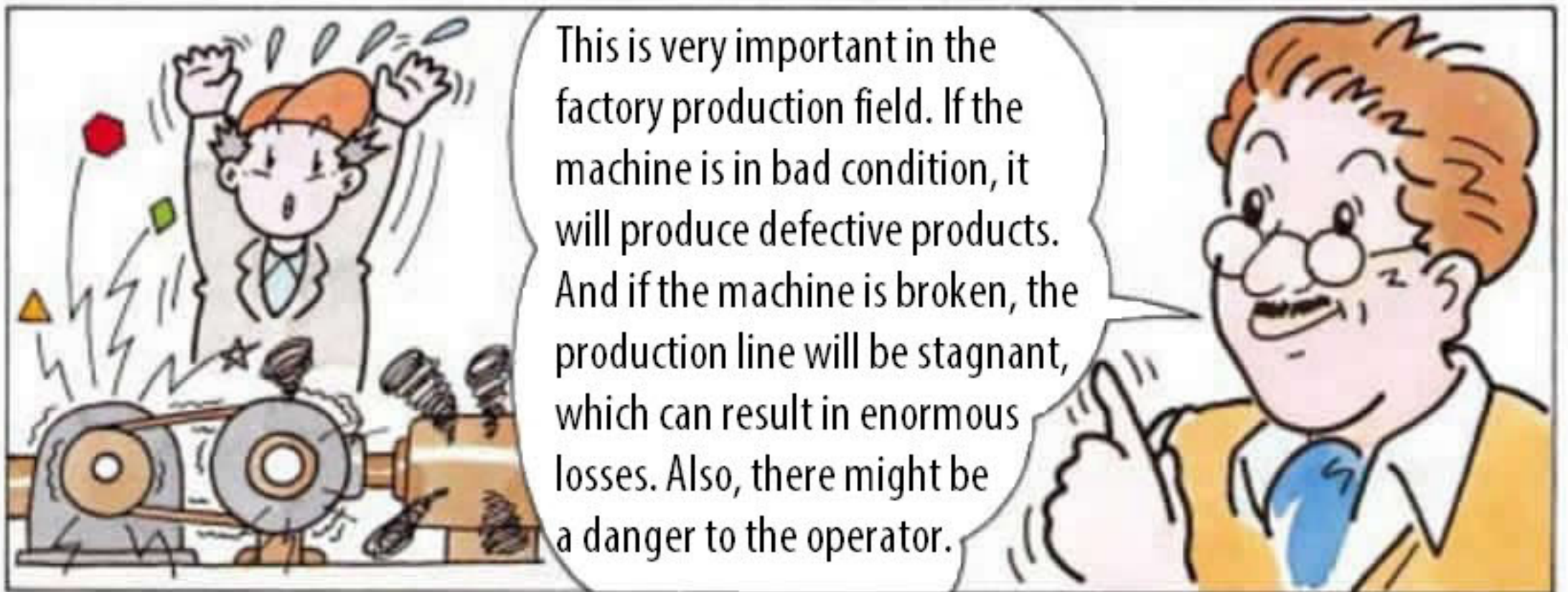
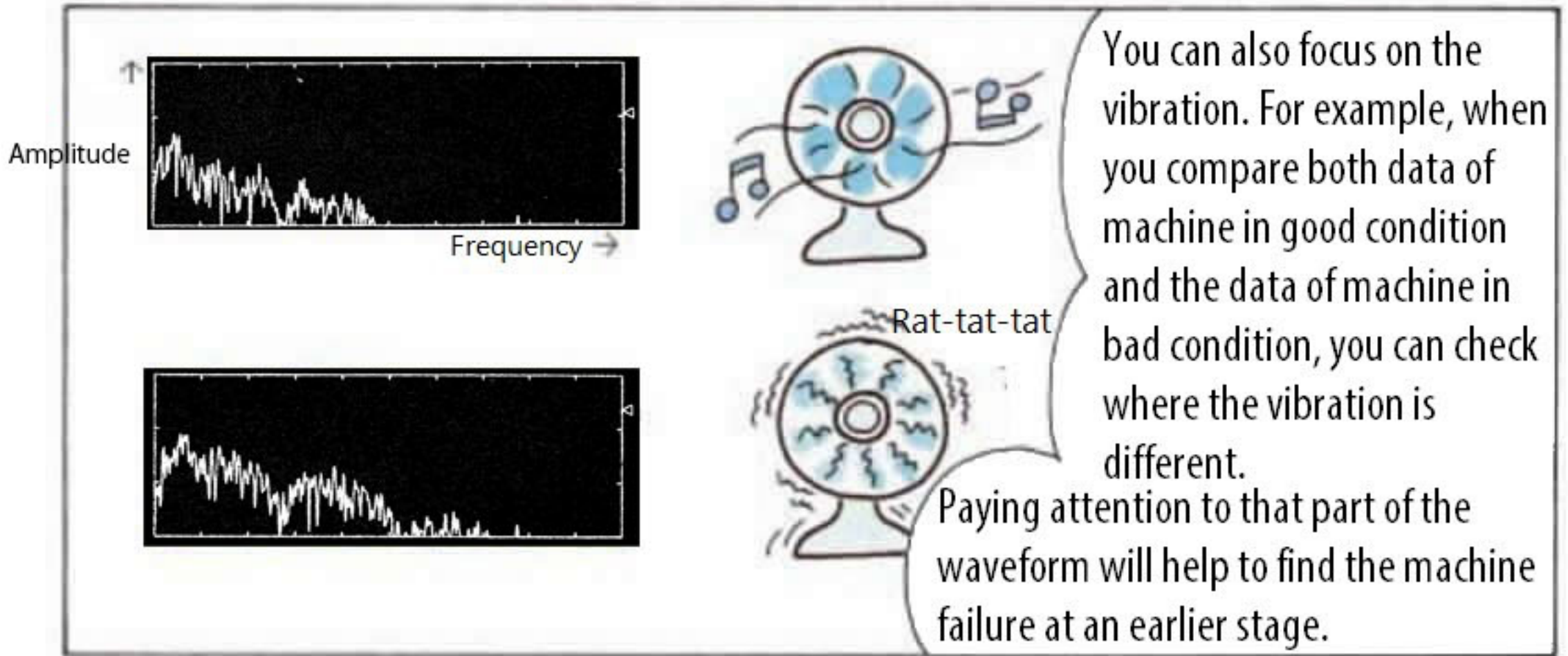
It is also used for the  
research of the  
effectiveness of the  
soundproof material for  
houses.







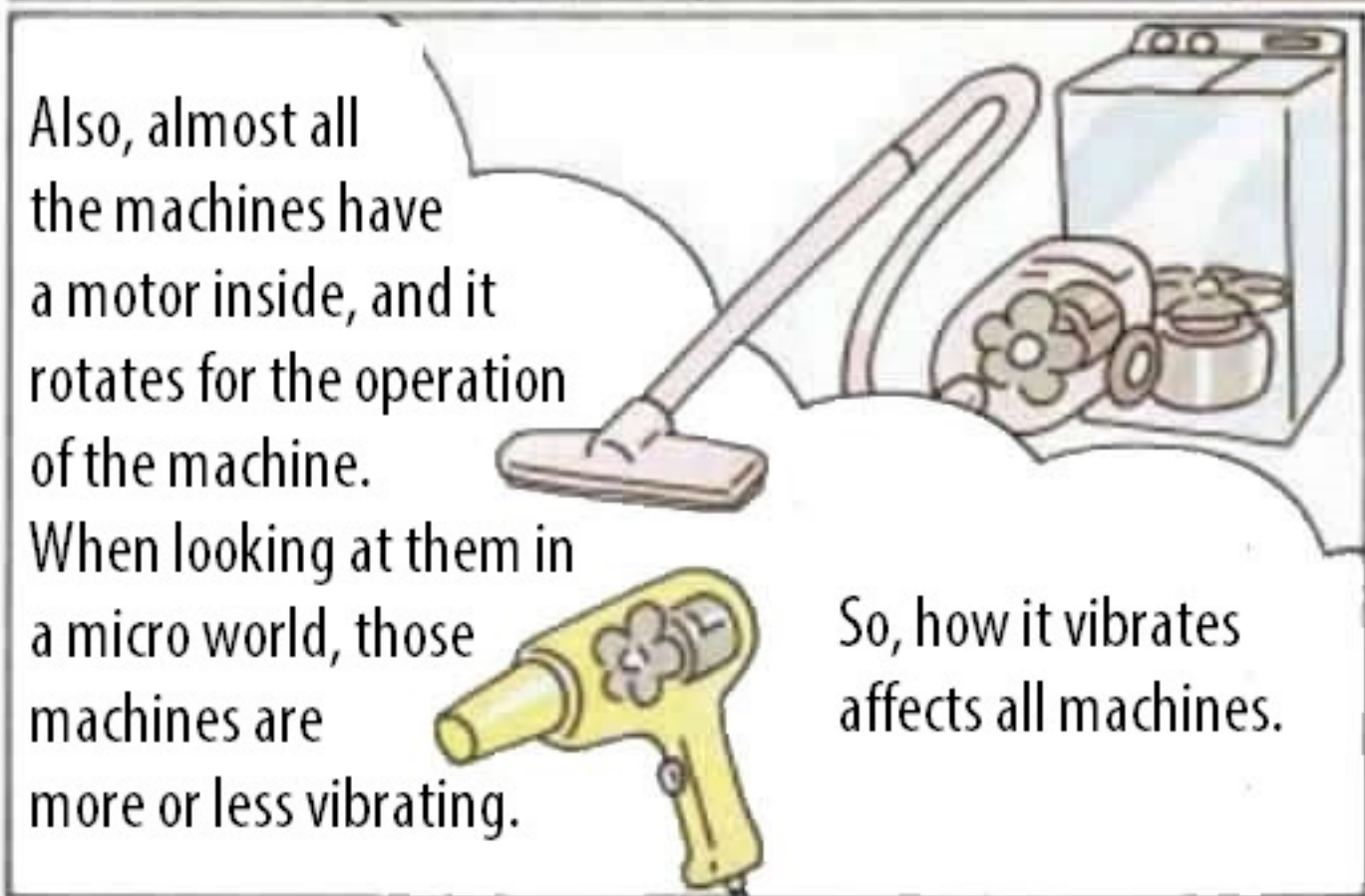






Yes.  
The completed product is manufactured in those factories through various tests.

I did not know that at all!  
I have only seen the completed product.

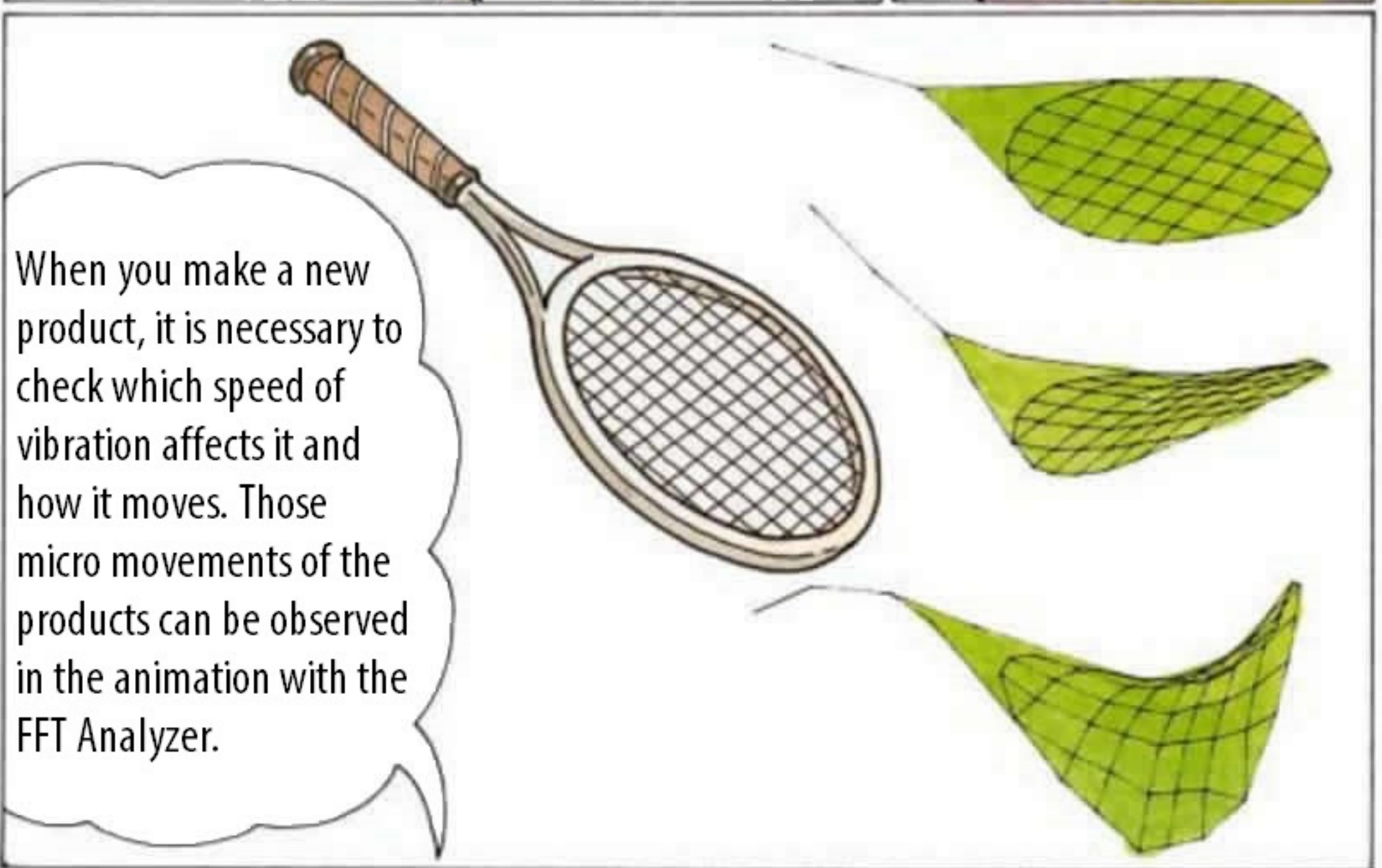


Also, almost all the machines have a motor inside, and it rotates for the operation of the machine.  
When looking at them in a micro world, those machines are more or less vibrating.

So, how it vibrates affects all machines.



Well, that is true.



When you make a new product, it is necessary to check which speed of vibration affects it and how it moves. Those micro movements of the products can be observed in the animation with the FFT Analyzer.





Amplitude ↑

Frequency →

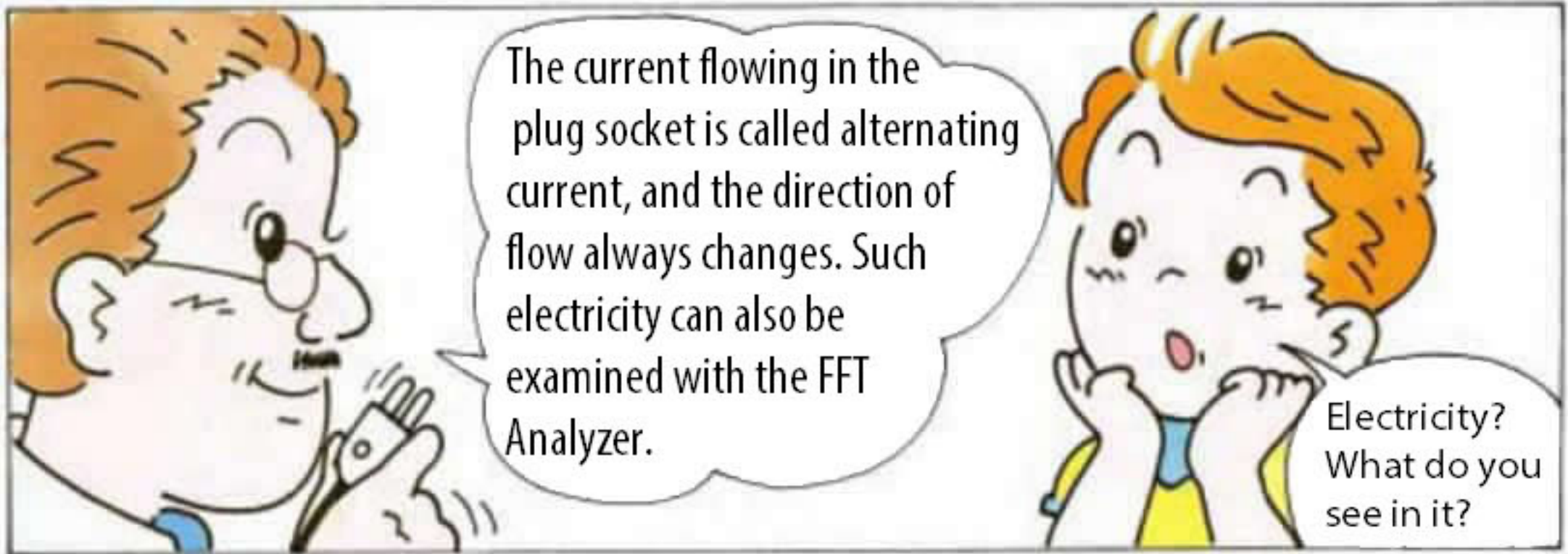
Whirrr.....

Rat-tat-tat...

Number of rotation

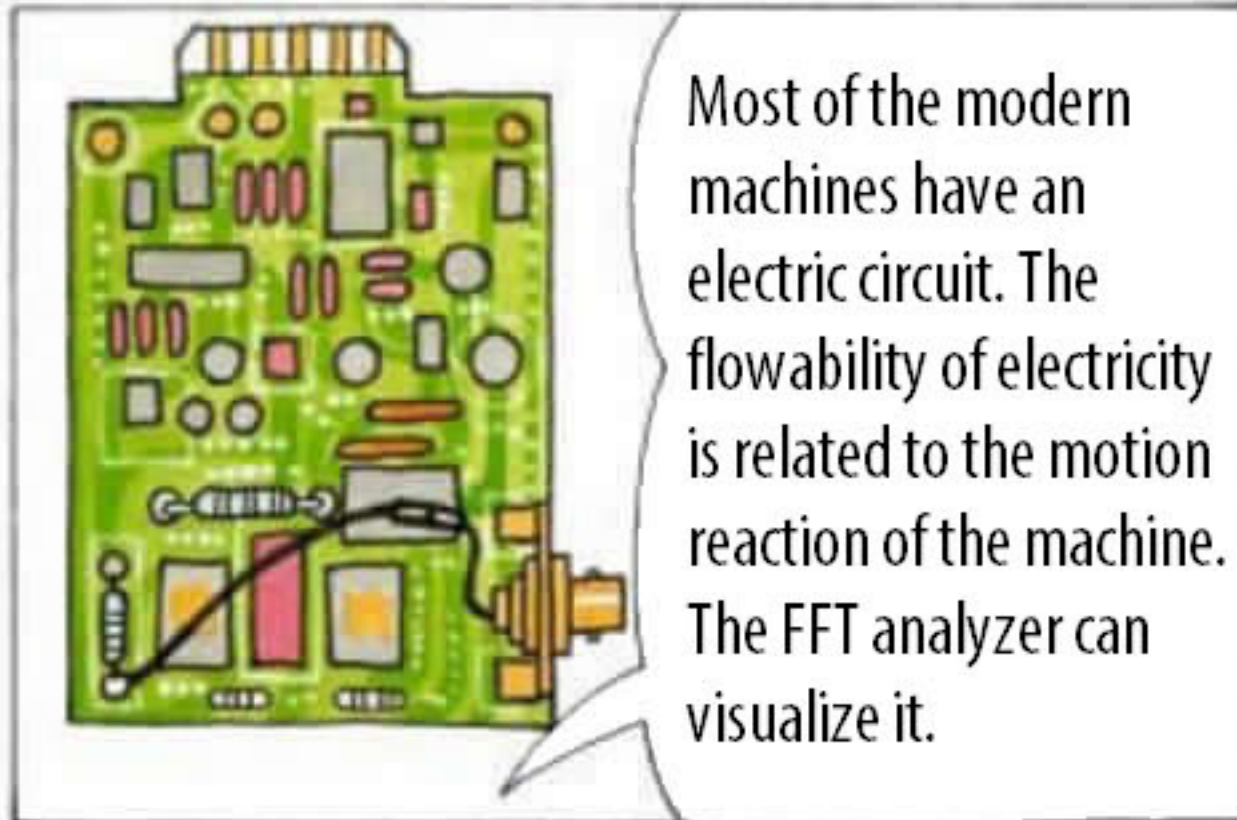
Look at this Wavy.  
When turning on the fan,  
the rotation speed increases.  
As the speed increases, the  
ridge of the waveform on the  
screen shifts to the right. The  
ridge gradually increased,  
and then decreased after  
a huge sound.

The machines such as a car  
or a motorcycle are used  
changing the rotating  
speed of a motor. It is  
necessary to check how the  
sound and fluctuation  
change beforehand.

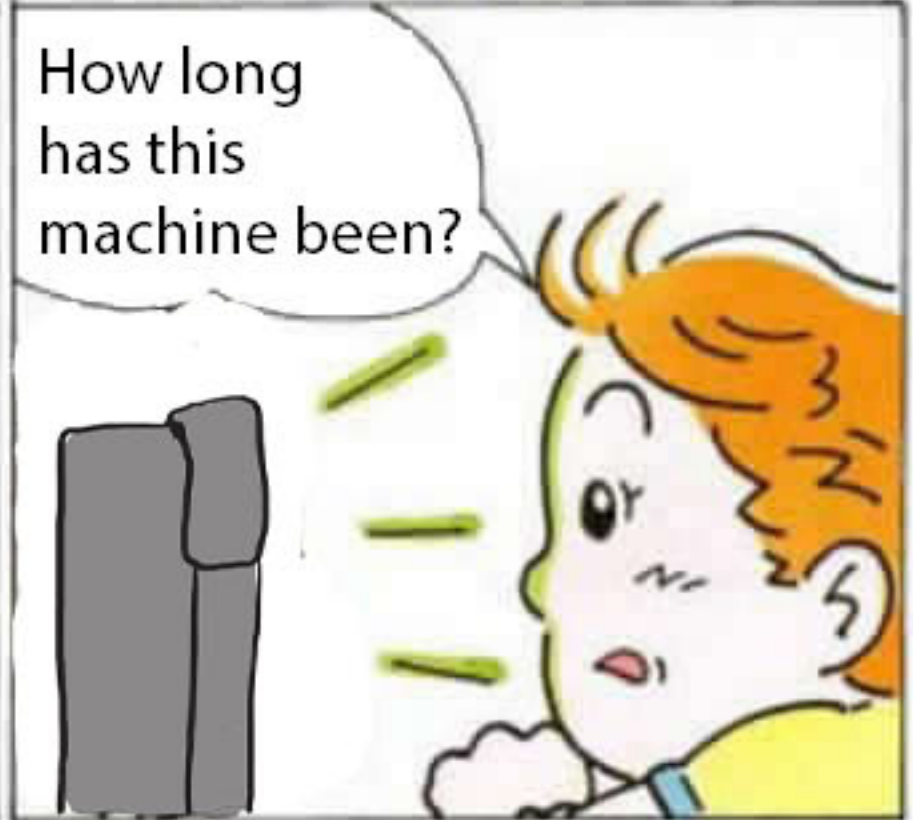


The current flowing in the plug socket is called alternating current, and the direction of flow always changes. Such electricity can also be examined with the FFT Analyzer.

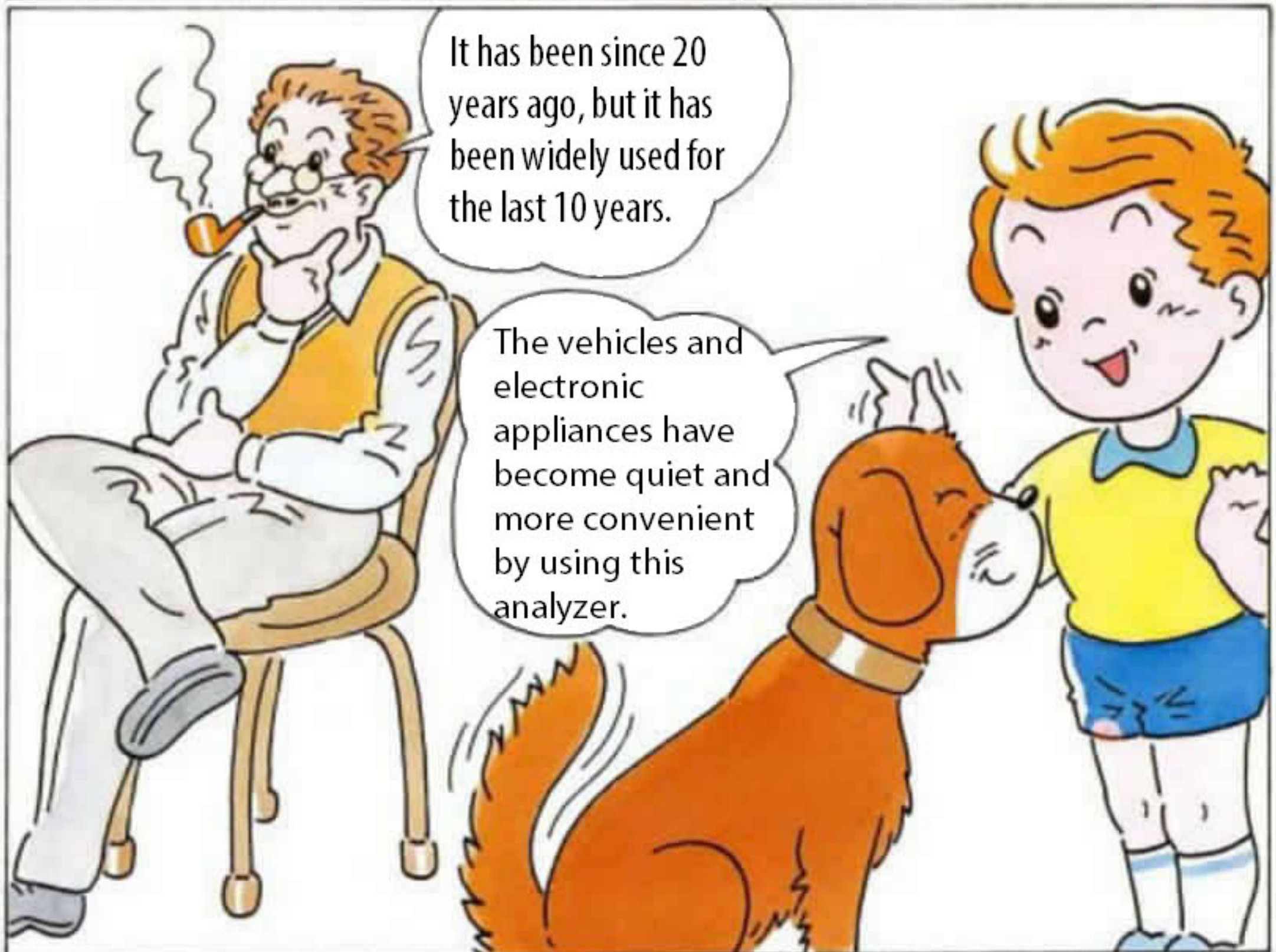
Electricity? What do you see in it?



Most of the modern machines have an electric circuit. The flowability of electricity is related to the motion reaction of the machine. The FFT analyzer can visualize it.

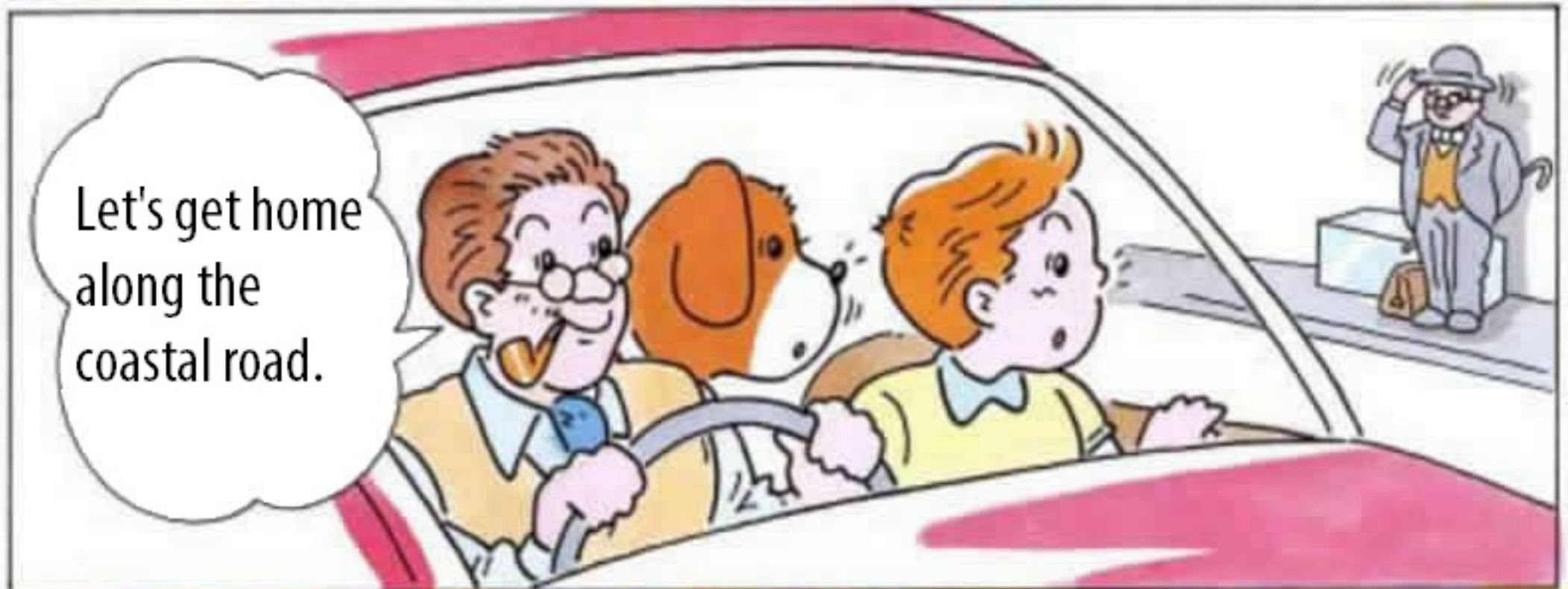
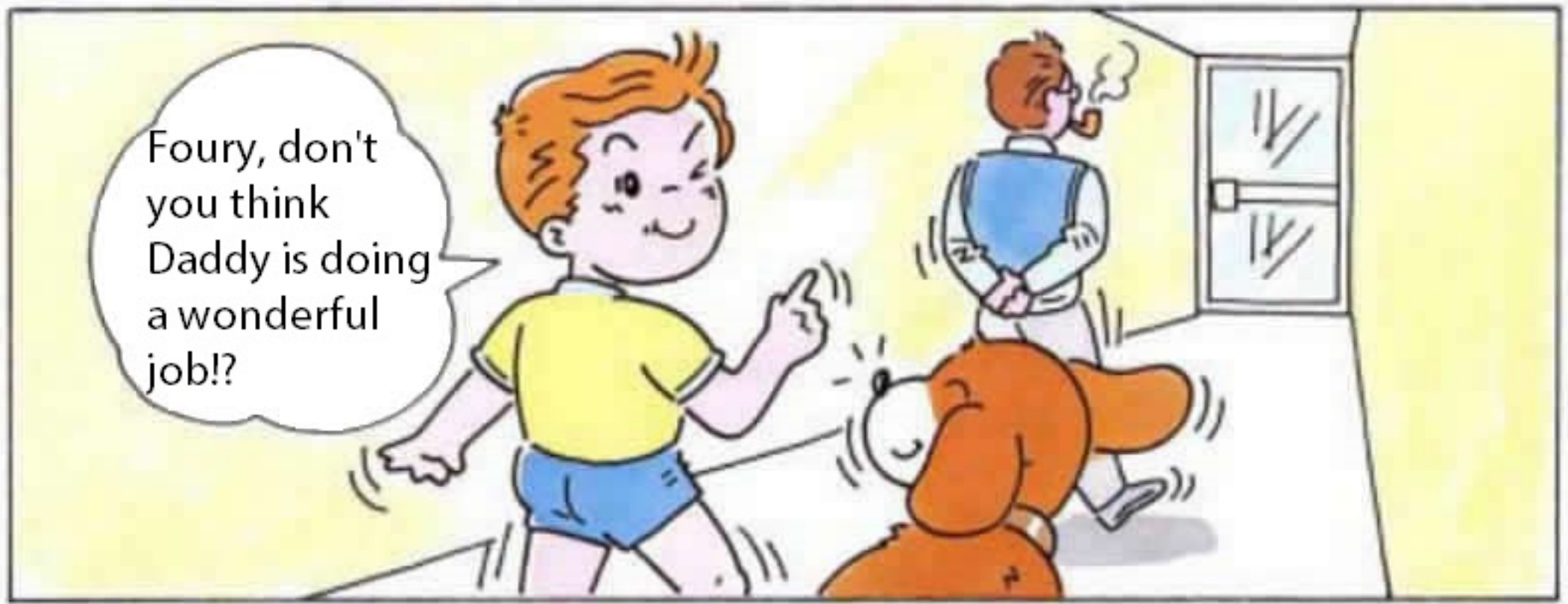


How long has this machine been?



It has been since 20 years ago, but it has been widely used for the last 10 years.

The vehicles and electronic appliances have become quiet and more convenient by using this analyzer.






## Conclusion

This book was made for the general people to know about the FFT Analyzer. However, the FFT Analyzer is used in a very specific field, so it seems very difficult to understand smoothly. That is why this book starts with the physical explanation of the natural phenomena.

The concept of the FFT does not exist in our general idea, so we cudgel our brains to explain it simply. We found some books which this field was written in an easy way. By reading those books, we were surprised to learn that wave fluctuations are not only caused by sounds or vibrations but also by the various natural phenomena in our surroundings. We hope this book will help you feel familiar with the wave motion. Also, we would be happy if you could leave in the corner of your head that a tool called FFT Analyzer is helping us to make our lives convenient.





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