



# Expériences : le phénomène de résonance



- Mode propre
- Transitoire
- Réponse harmonique pour différents amortissements
- Excitation résonante de pendules
- Excitation résonante de diapasons

Mécanique | 2013 7

Hello, welcome to the EPFL general physics course. In this lesson and in this particular module, I will show the important aspects of the resonance phenomenon. First we will look at a harmonic oscillator free of any external force. We'll observe what we call the "proper" mode. Then we'll add an external solicitation, we'll see that there are transients that appear, and once these transients are damped, we have what we call the harmonic response. And we will see this harmonic response for a system practically free of damping or notoriously damped. Then we will look at resonances between pendulums. And finally, to illustrate the general character of the resonance phenomenon, we will look at acoustic resonances.

Notes

Summary



0m 03s



- On tire sur le plot et on le laisse osciller dans l'air
- On mesure la fréquence, approx. 1.4 Hz

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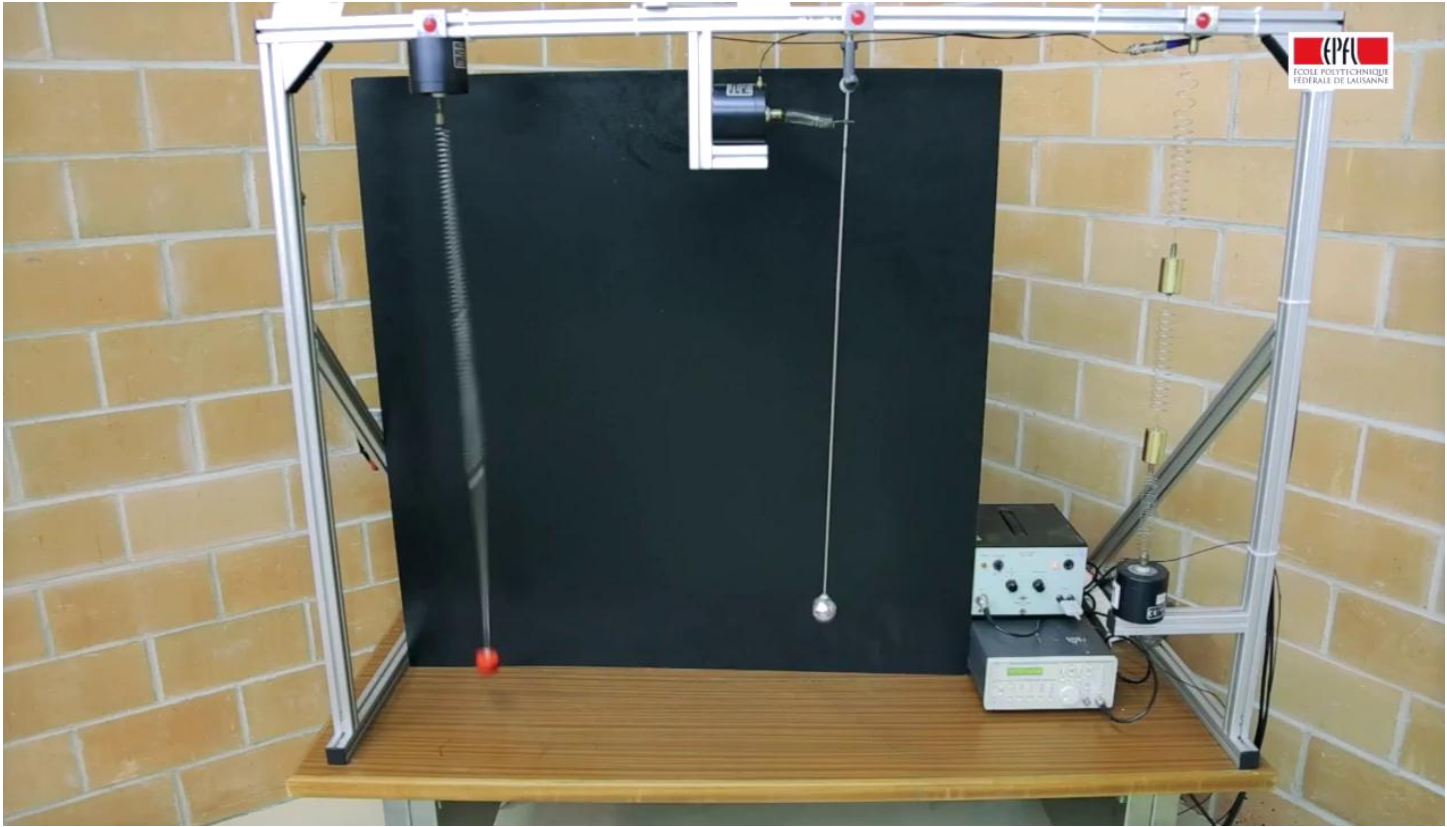
So, I start with a mass hanging from a spring, there is nothing else acting on this spring but gravity. And I'm going to switch the system on. We'll observe the oscillations and a detector will tell us what is the natural frequency of this system.

Notes

Summary



1m 02s



We will read, we will remember this value which we will use later: 1,40 Hz Now, we will have fun to switch on the vibrating pot which is electromagnetically controlled at the top of the spring and we will make this vibrating pot oscillate at a frequency which differs from the natural frequency by 0,1 Hz. What will happen is that the system will oscillate with two modes of oscillation, the one imposed with the frequency of the vibrating pot and the natural mode. The two differ by 0,1 Hz. This will give us a beat every ten seconds. I invite you to watch. Here we go, we're engaging the system. You can watch the time passing. You see, there's a beat. The pad stops. And there's a new one. And every ten seconds or so, there's a beat. Now we show what happens when we put ourselves exactly at the resonance frequency, we have a huge oscillation that develops quite rapidly. So much so that, by the way, we don't really have a harmonic oscillator anymore. So you see, we're not even in the linear regime.

Notes

Summary

1m 35s





- On enclanche le pot vibrant à une fréquence décalée de 0.20Hz de la fréquence propre.
- On constate un battement
- Le battement dure aussi longtemps que l'oscillation libre.

Mécanique | 2013 10

Now we'll put the oscillator in water. I would also like to show this phenomenon of beating between the proper mode and the mode that we impose with the vibrating pot. As the damping takes place very quickly, I have to put a bigger frequency difference. I will put 0,20 Hz of difference between the natural mode and the frequency of the excitation. So there will be a beat every five seconds. And you'll see that the beat disappears, fades quickly.

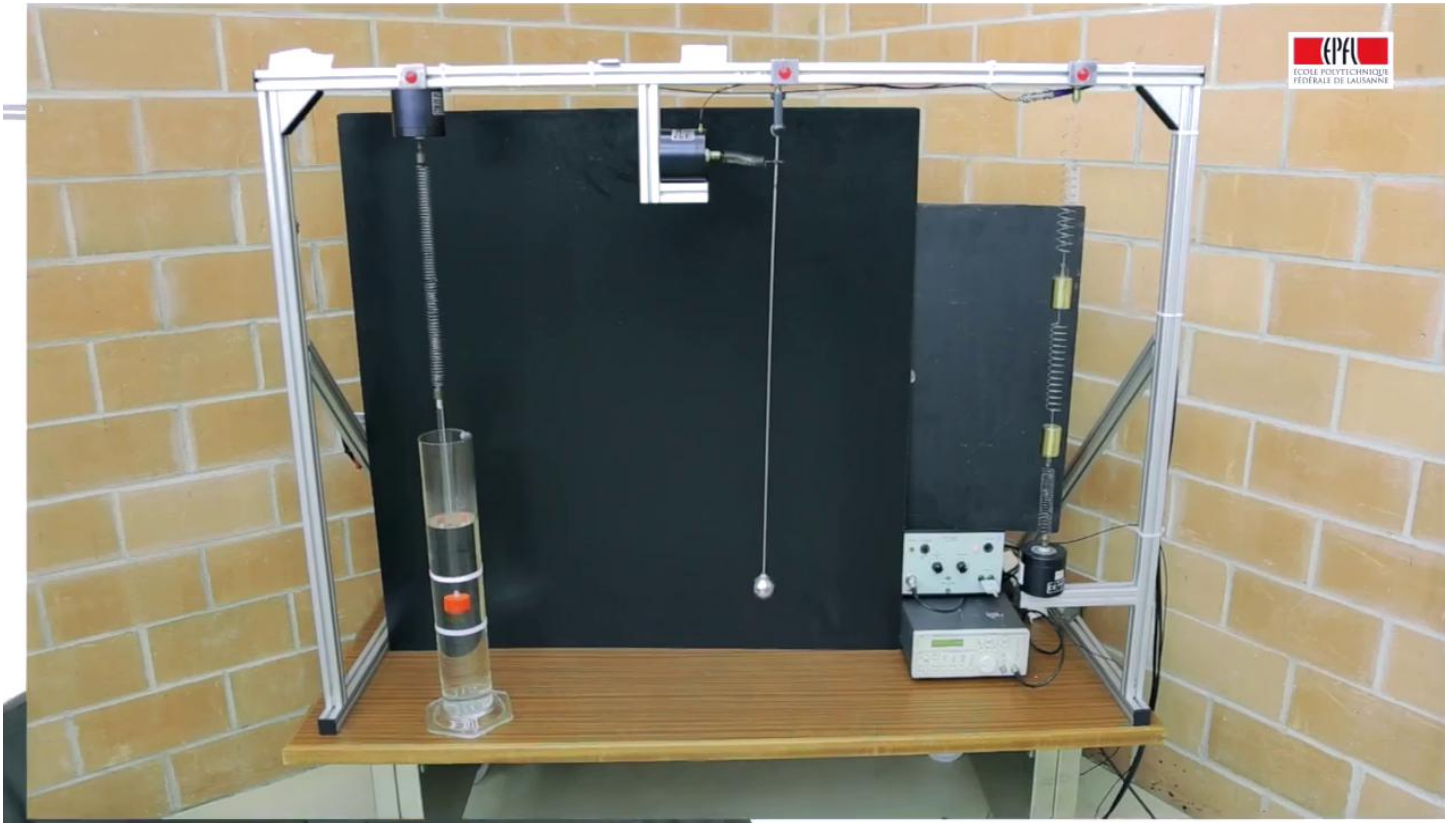
Notes

Summary



3m 09s





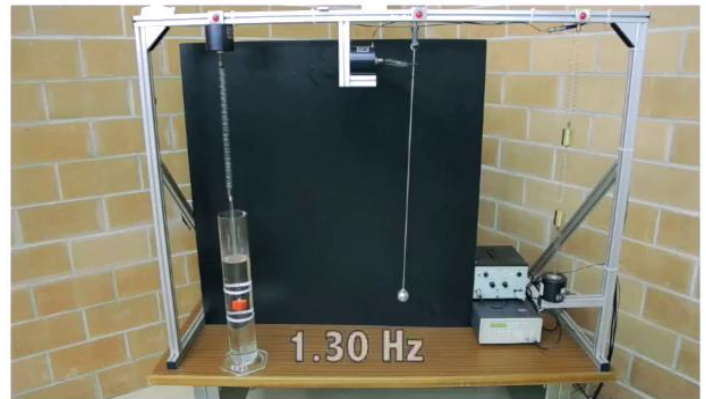
Let us observe. There is a beat. There you can still see it a little. The third time it will be more difficult to tell if the pot stops.

Notes

Summary

3m 43s





- On enclanche le pot vibrant légèrement hors résonance
- On note l'amplitude à la résonance.
- Même amplitude à une fréquence voisine

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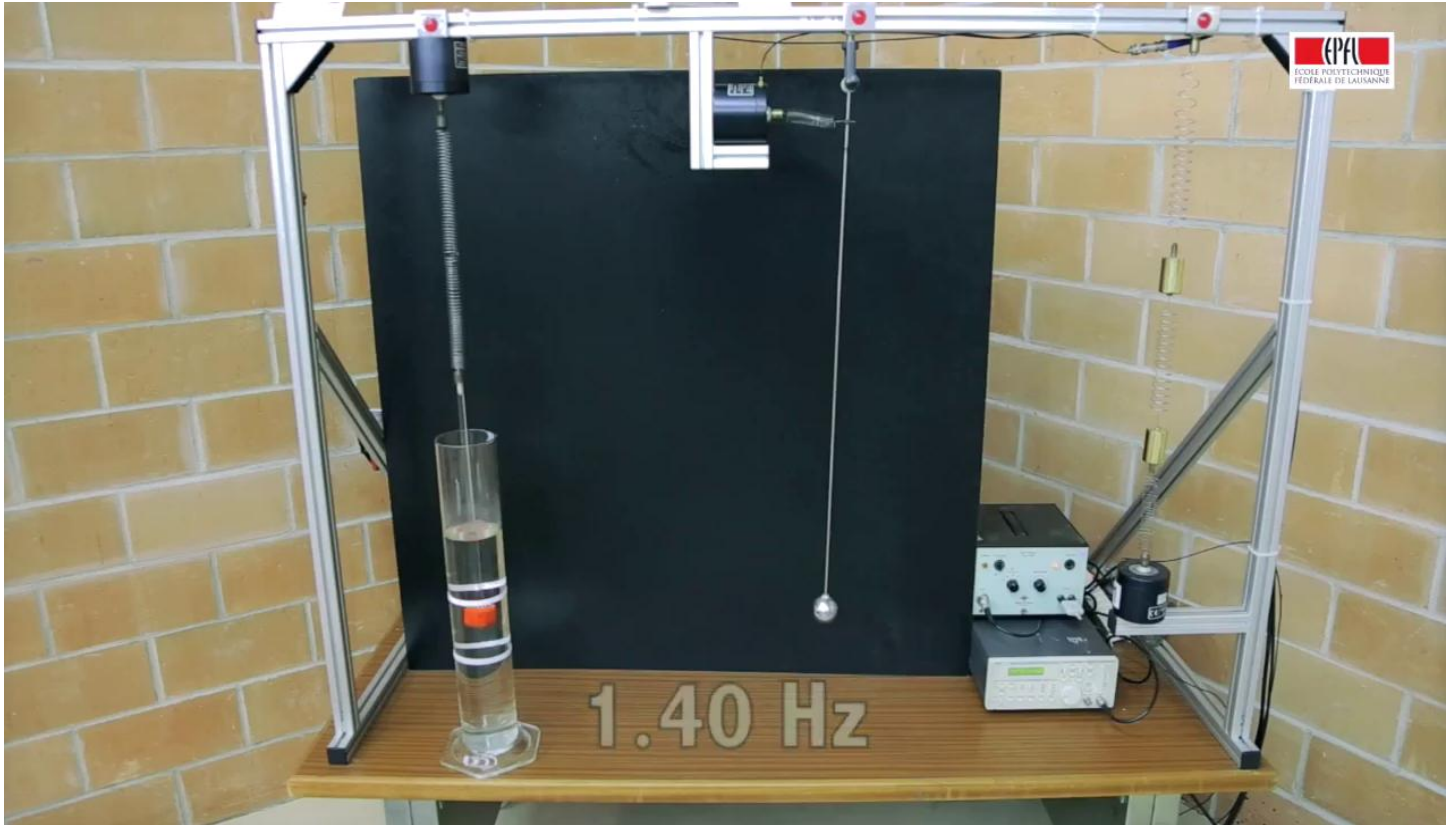
And if we wait, we can see that we are in a stationary regime which we will call the harmonic response. You will have noticed that the frequency was 1,15 Hz. It turns out that when we make precise measurements, we find that the natural mode, the frequency when there is no external force, the frequency is 1.35 Hz, is no longer 1.40 Hz as in the air. And this corresponds to what we saw when there is friction, the natural frequency  $\omega_1$ , well, the natural pulsation  $\omega_1$ , is the square root of  $\omega_0^2 - \gamma^2$  where  $\gamma$  qualifies the friction or the damping. Now we're going to look at this harmonic response, I'm starting in the water and we're going to observe that we can put ourselves about at the resonance frequency, that means the frequency of the eigenmode or we can put ourselves next to it and we'll have more or less the same amplitude.

Notes

Summary



4m 10s



Let's observe See the two white bands that allow you to locate the oscillation amplitude. If we now change to 1.40 Hz, you can wait, you will have the same amplitude.

Notes

Summary



5m 12s



# Spectre de la réponse harmonique



- On enclanche le pot vibrant :
- Amplitude modérée à 1.30 Hz (réponse harmonique)
- Amplitude énorme à 1.40 Hz

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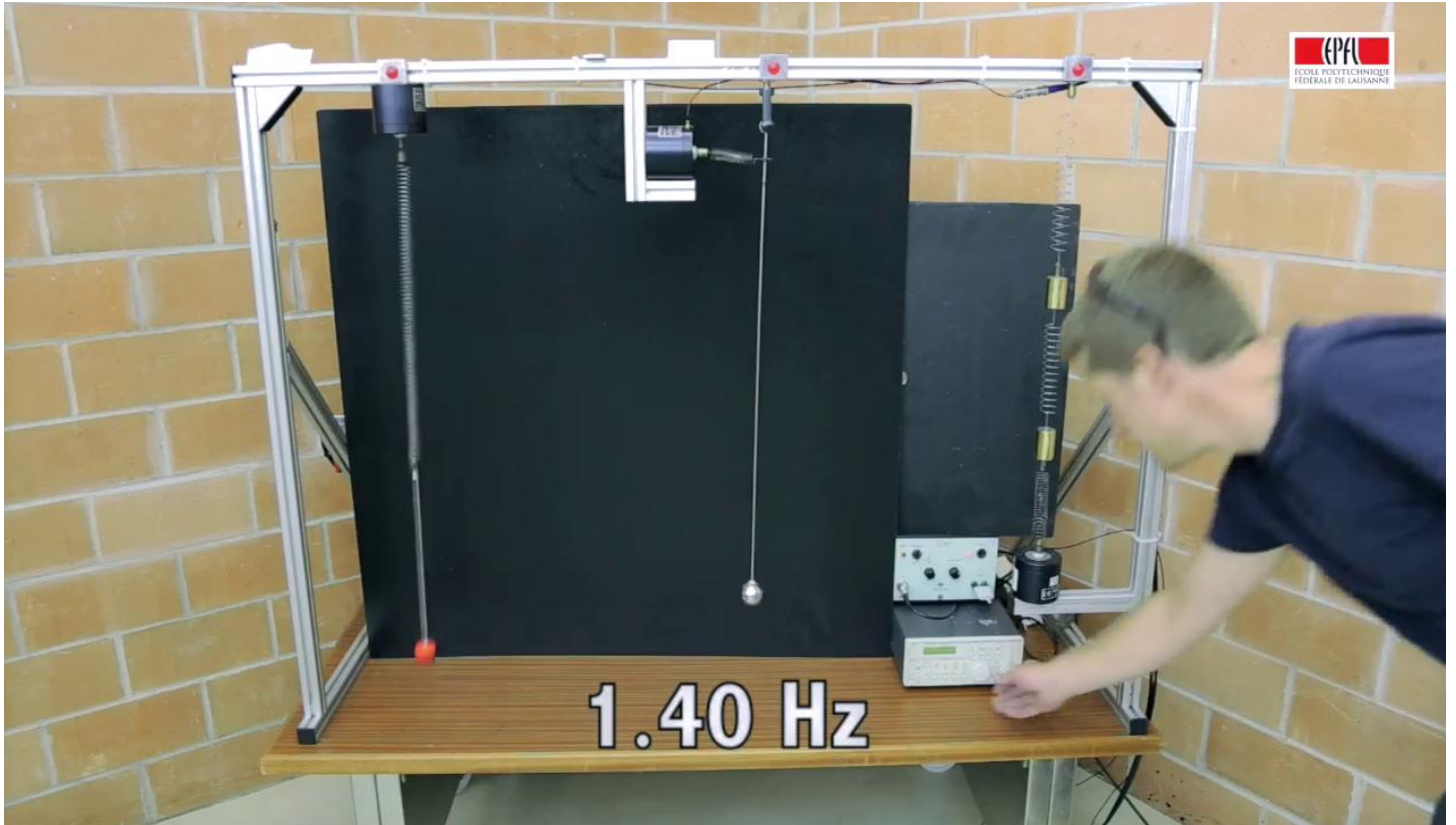
That's it Now we'll do the same experiment in the air. So in the air, there are beats that last a very long time. Because in the air, the clean mode is damped but very slowly. It takes several minutes for it to stop. So the film starts long after you switch on the system at 1.30 Hz. Then, and you will see that the amplitude is notorious, it is not by far as big as when we are at resonance at 1.40 Hz.

Notes

Summary



5m 44s



You can see this is not the beginning of the oscillation, it's after we switched on the system about three minutes ago. Now we go to 1.40 and, immediately, a much greater amplitude develops. So you can see that, in the air, the damping is very small. You just have to change the frequency a little bit and you change the amplitude completely. That's what we predicted. And there we leave completely the harmonic oscillator regime.

Notes

Summary



6m 17s



- On lance un pendule ...
- Après un moment, seul celui qui a la même longueur (donc la même fréquence) oscille grandement
- Les autres sont amortis

Mécanique | 2013 13

Now here is a dynamic system where you have several pendulums which are coupled because they are mounted on a soft plastic tube and we're going to throw the red ball and you're going to see that of all these oscillators, there is one that will respond to the solicitation. It's the one with the same length.

Notes

Summary



6m 53s





- On frappe un diapason, puis on le stoppe
- le deuxième génère un son, si les deux ont la même note.

Mécanique | 2013 14

To illustrate the fact that these resonance phenomena are very general, I propose you now to look at an experiment with tuning forks. You have two tuning forks here, mounted on a resonance box. Each one resonates at 440 Hz. We're going to hit one of them. And we'll observe that the other one starts to resonate, It will start to oscillate too.

Notes

Summary



7m 46s





You have a microphone, an oscilloscope.

Notes

Summary





- On frappe un diapason, puis on le stoppe
- le deuxième ne vibre pas, s'ils sont différents.

Mécanique | 2013 15

So, once again, we have shown that the right tuning fork was excited by the left tuning fork. And to show once again the sensitivity to frequency when we have a system with little damping. Let's take two tuning forks of different frequencies, these two tuning forks only differ by 5 Hz.

Notes

Summary



8m 25s



Let's do the same experiment.

Notes

Summary



8m 55s



- On frappe un diapason, puis on le stoppe
- le deuxième ne vibre pas, s'ils sont différents.

Mécanique | 2013 15

And there it is, the other tuning fork had not been excited.

Notes

Summary



9m 05s