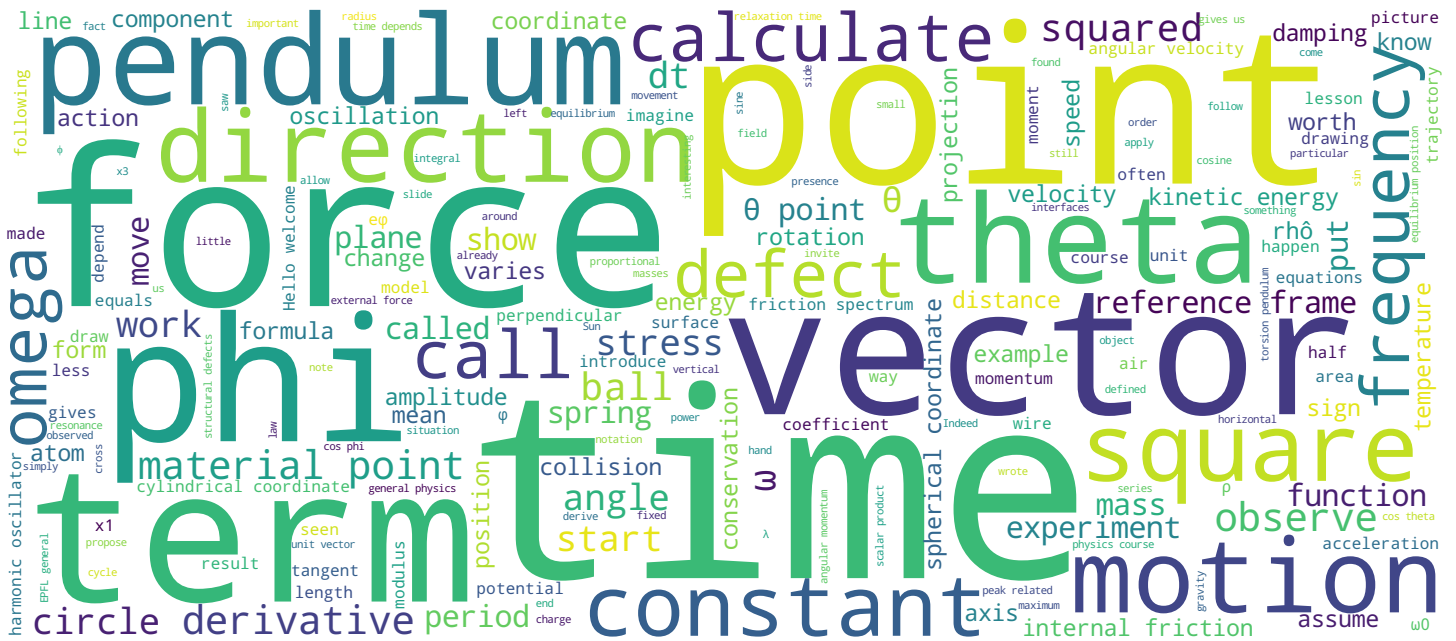


Pendule de torsion et frottement interne

Mécanique, cours 7

Daniele Mari



Video



Pendule de torsion et frottement interne



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Hello, my name is Daniele Mari, I am doing research in the field of material physics, and I use for my experiments inverse torsion pendulums, like the one you saw in mechanics class.

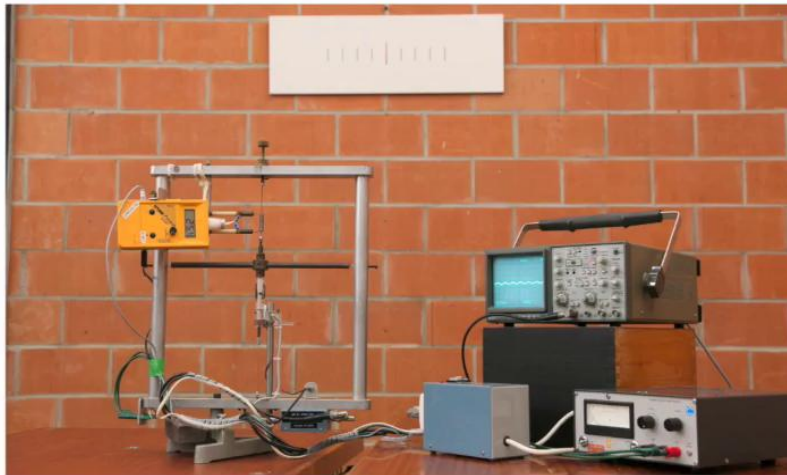
Notes

Summary



0m 04s

Pendule de torsion inversé



$$I\ddot{\theta} + b\dot{\theta} + k\theta = 0$$

$$\ddot{\theta} + 2\lambda\dot{\theta} + \omega_0^2\theta = 0$$

$$\lambda = \frac{b}{2I} \quad \omega_0^2 = \frac{k}{I}$$

Indeed, you know that the equation of motion of a case system is given by $I \ddot{\theta} + b \dot{\theta} + k \theta = 0$. k is the constant of the sample restoring torque, which is proportional to the shear modulus, and I is the moment of inertia of the pendulum. We can also write $\ddot{\theta} + 2\lambda \dot{\theta} + \omega_0^2 \theta = 0$ with λ the damping factor, and ω_0 the angular natural frequency of the pendulum.

Notes

Summary



Pendule de torsion inversé



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$$\ddot{\theta} + 2\lambda\dot{\theta} + \omega_0^2\theta = 0$$

$$\lambda = \frac{b}{2I} \quad \omega_0^2 = \frac{k}{I}$$

Now, it is interesting to note that the damping which can be observed here on the oscilloscope is caused by the presence in the spring of the pendulum of defects of crystalline structure whose motion, under the action of stress can be described by an equation very similar to that of the pendulum itself. The damping of the air, contrary to what one might think, is very low for oscillation frequencies of the order of a few Hertz.

Notes

Summary



Pendule de torsion inversé



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$$\lambda = \frac{b}{2I} \quad \omega_0^2 = \frac{k}{I}$$

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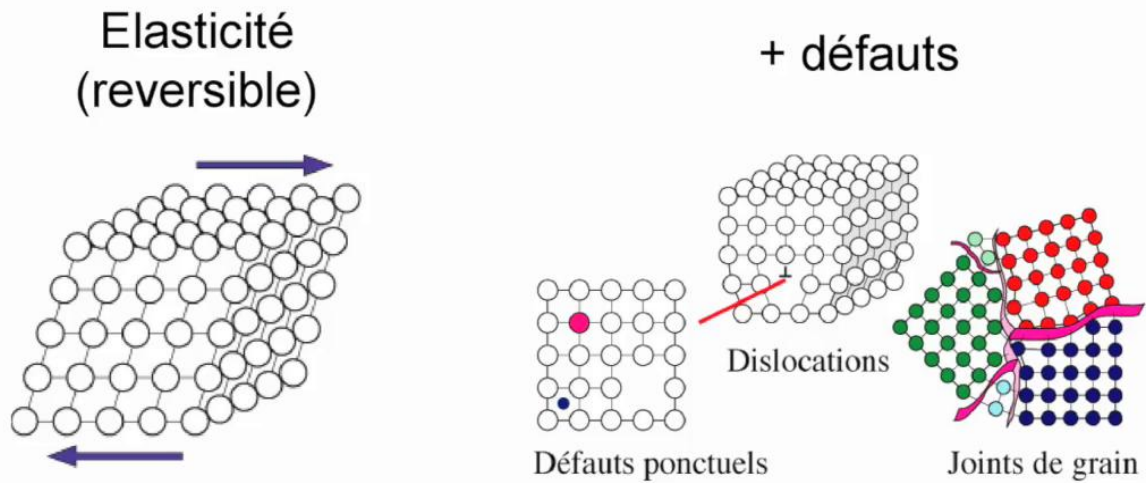
Indeed, the wire representing the spring of our pendulum is constituted by a crystal, or more often by a poly-crystal, as we can see in this picture, in which the atoms are periodically arranged. But this arrangement is never perfect.

Notes

Summary



1m 45s



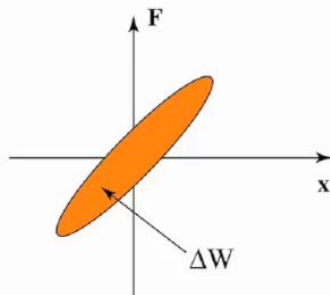
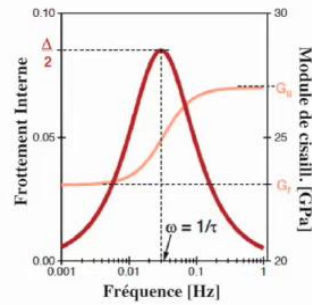
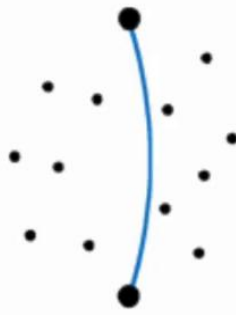
There are defects such as gaps, which can be seen here: an atom is missing, dislocations: here, this plane is displaced from its equilibrium position, or interfaces which are called grain boundaries. All mechanical properties of crystals depend on the elasticity, i.e. the reversible motion with respect to its equilibrium position of the atoms, and the reversible or irreversible motion of the structural defects.

Notes

Summary



Frottement Interne



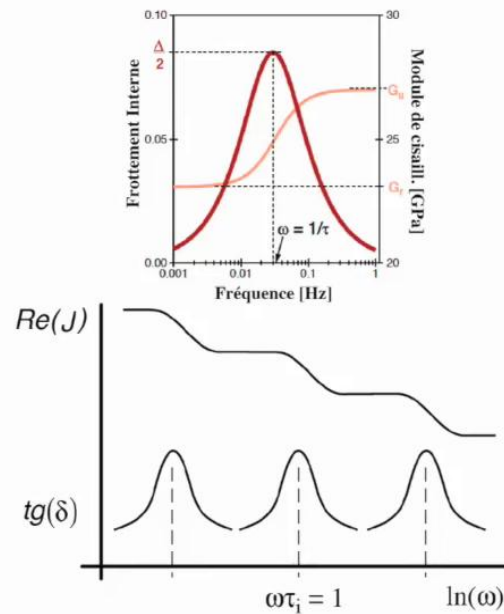
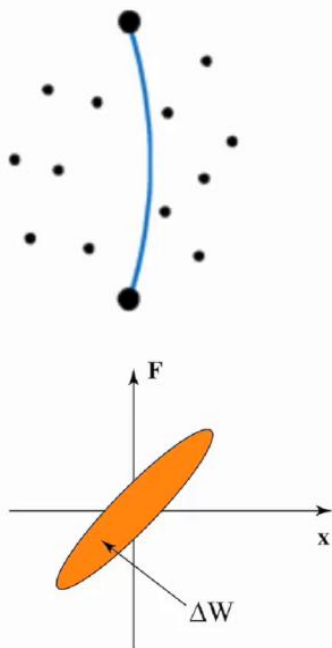
When the defects of crystal structure move under the action of a constraint, like this dislocation represented by an elastic string, they dissipate energy because the external force applied to the defects times its displacement constitutes a work. We could draw a force times displacement diagram over a cycle or period of oscillation, and the area of the cycle gives us the energy dissipated, usually in the form of heat. We call this dissipated energy *internal friction*. Now the motion of a defect under the action of stress is not instantaneous, but time dependent. In other words, for the system to reach an equilibrium, it takes a certain time, called *relaxation time*. Since this time depends on the frequency, we will have a maximum energy dissipation when the frequency of excitation of the pendulum is such that $\omega = 1/\text{time}$. At this frequency, the air of this surface is also maximum. If we plot the damping as a function of frequency, we observe a peak, pointed here. At a very high frequency, the defects cannot follow the stress, and become immobile. At a very low frequency, on the other hand, the defects follow the stress very easily, there is no shift between stress and deformation, and this area becomes minimal.

Notes

Summary



Frottement Interne



spectre de frottement interne

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In a material, we can have a series of phenomena which give rise to relaxations. This is called an internal friction spectrum. Just like the lines of the light spectrum seen through a prism, an internal friction spectrum is made of a series of peaks corresponding to the movement of structural defects.

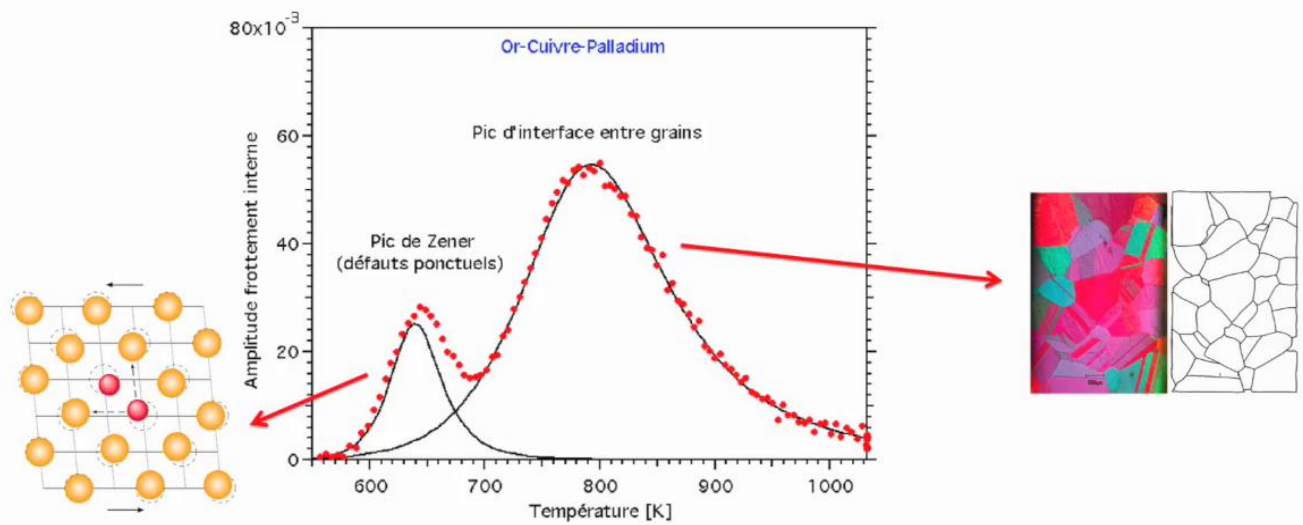
Notes

Summary



4m 43s

Spectre de frottement interne Au-Cu-Pd



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In this example, one can observe the internal friction spectrum as a function of temperature, in a gold, copper, palladium alloy. One can scan in temperature, because the relaxation time depends also on the temperature. At low temperature, we observe a peak related to point defects, in fact, copper beads in the gold matrix. And at higher temperature, we observe a peak related to the sliding of the interfaces between the grains, which you see here. I thank you for your attention.

Notes

Summary



5m 07s