Expériences : autres forces

Mécanique, cours 14.exp

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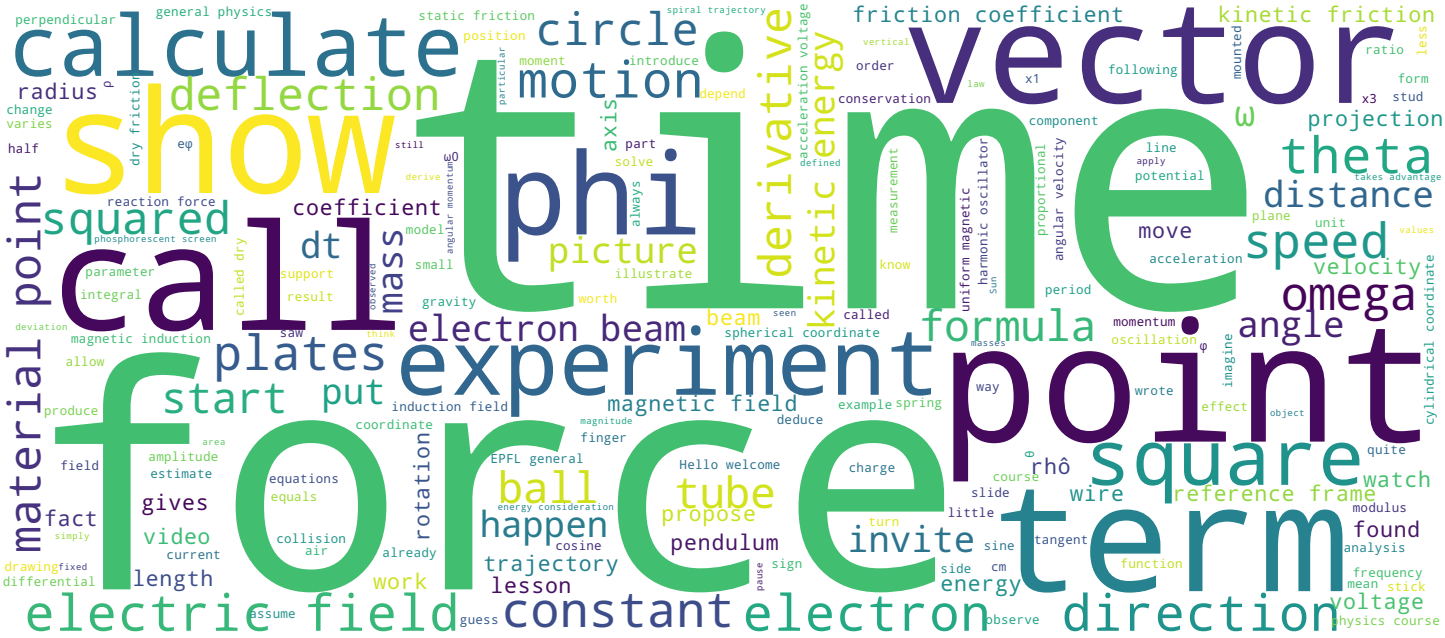


Video

Expériences : autres forces

- Déviation d'un faisceau d'électrons
  - dans un champ électrique
  - dans un champ magnétique
- Frottement sec
- Frottement visqueux

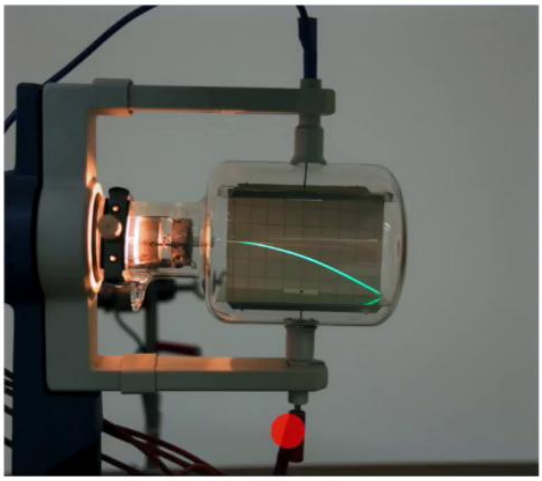
Hello. Welcome to the EPFL general physics course. In this lesson, I have introduced some forces associated with electromagnetic effects and also the friction force models. And now I'd like to illustrate the existence of these forces by some experiments. First we will see the deflection of an electron beam under the effect of an electric field or under the effect of a magnetic induction field. We will then look at the so-called dry friction, and then a small experiment on viscous friction which we have already met and modelled.

Notes

Summary

0m 04s

Faisceau d'électrons, champ électrique



- Un tube cathodique produit un faisceau d'électrons
- Le faisceau rase la surface d'un écran fluorescent
- Deux plaques en haut et en bas produisent un champ électrique

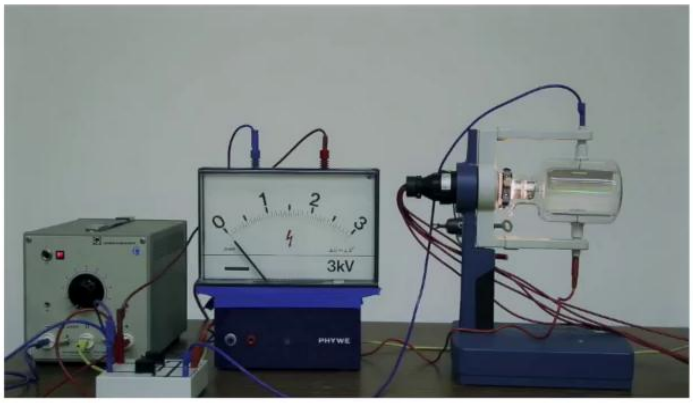
I start with the deflection in an electric field. Here you have a device that produces an electron beam. The electron beam is visualized by a phosphorescent screen and the electron beam shaves the phosphorescent screen, hence the green trace here. Here an electric field was produced by two plates, one here, one there. The whole thing is in a vacuum chamber. And here you see the high voltage power cables.

Notes

Summary

0m 43s

Faisceau d'électrons, champ électrique



- La déviation dépend de l'intensité du champ électrique produit par les plaques chargées à la tension indiquée.

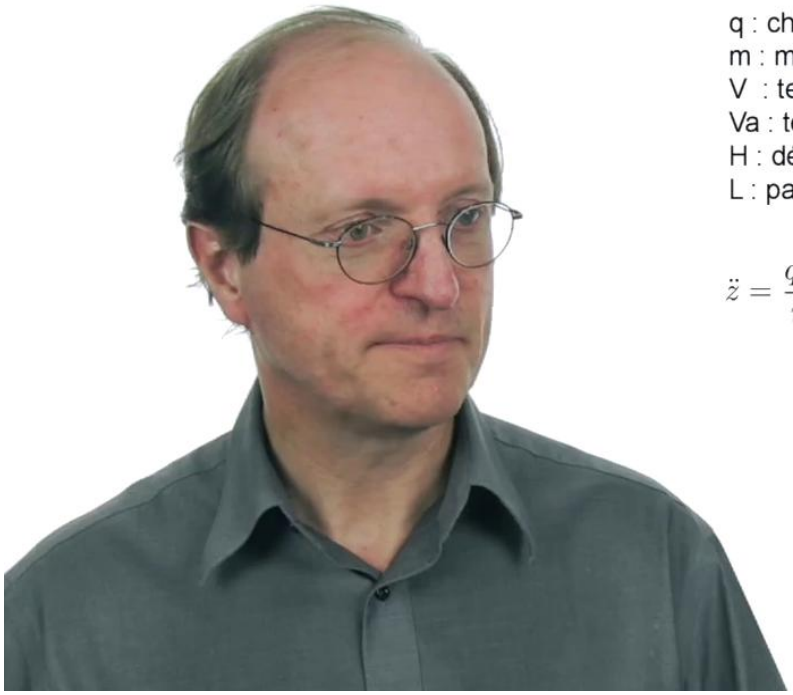
Now I invite you to watch the experiment.

Notes

Summary

1m 25s

Ordre de grandeur



q : charge de l'électron
m : masse de l'électron
V : tension entre les plaques
Va : tension d'accélération
H : déviation verticale
L : parcours horizontal dans E présumé uniforme

$$\ddot{z} = \frac{qE}{m} = \frac{q}{m}\frac{V}{D} \qquad H = \frac{1}{2}\frac{q}{m}\frac{V}{D}t^2$$

I propose to do an order of magnitude calculation, I would like to show you that you can guess some of the parameters, as long as you have some experience, like the speed of the electrons and deduce the curvature, or if you want the deflection of the beam, when the beam comes out of the plates that impose the electric field. I invite you to take a break and try to solve the problem by yourself. Here is how I propose to analyze quantitatively the beam deflection. I give myself some parameters. The charge of the electron, q, its mass, m, the voltage across the plates of the capacitor which define the electric field, this voltage I call V. I also have an acceleration voltage of the electrons in the tube, the part of the tube that forms the beam, this voltage I call Va for voltage, a, for acceleration. H I will call H, the vertical deflection and L, the horizontal path in the presumed horizontal electric field although this is certainly not quite the case. I write the equation of motion, I have a force qE. So I call z the vertical coordinate. I have mZ point which is qE. Now the electric field I write as V over D, where V is the electric voltage and D is the distance between the plates, a distance I don't know very well, but we'll guess it from the picture.

Notes

Summary

1m 42s

Ordre de grandeur

q : charge de l'électron
m : masse de l'électron
V : tension entre les plaques
Va : tension d'accélération
H : déviation verticale
L : parcours horizontal dans E présumé uniforme

$$\ddot{z} = \frac{qE}{m} = \frac{q}{m}\frac{V}{D} \qquad H = \frac{1}{2}\frac{q}{m}\frac{V}{D}t^2$$

$$t = \frac{L}{v} \qquad qV_a = \frac{1}{2}mv^2$$

$$H = \frac{1}{4}\frac{V}{V_a}\frac{L^2}{D} \qquad V_a \approx 2.5\,kV \qquad V \approx 1.4\,kV$$

$$L \approx 10\,cm \qquad D \approx 5\,cm$$

$$H \approx 3\,cm$$

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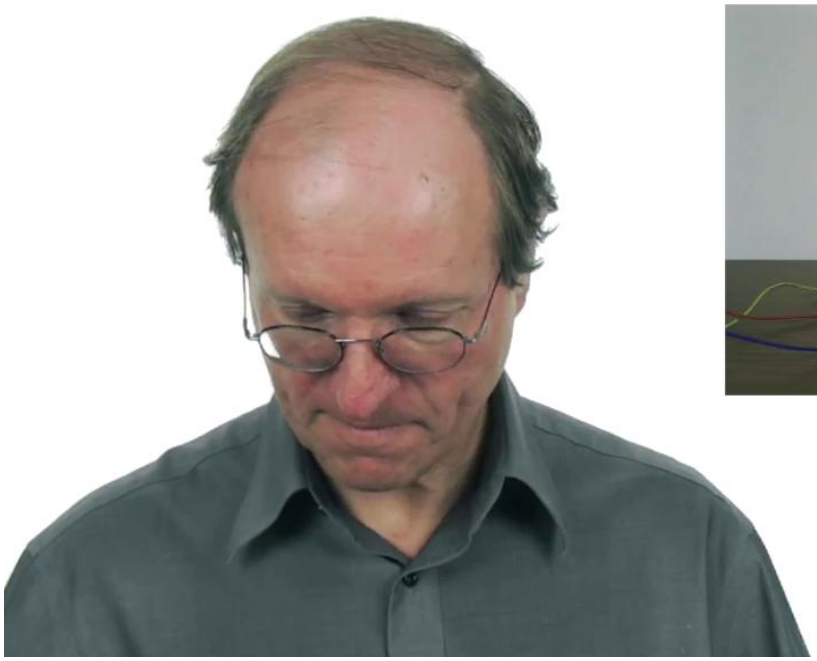
This differential equation is easy to solve, it's like the one for gravity, for ballistics. I'll call H the deflection of the beam so I have H equal to half of this constant times t squared, where t is the travel time through the part of the tube that has an electric field. Now this time t, I will call it as L, the length traveled in the electric field divided by the speed of the electrons. To calculate the speed of the electrons, I will use an energy consideration. I will say that the kinetic energy of the electrons, half of mv squared is equal to the electrostatic energy q times Va of the electrons coming out of the gun. With these formulas I obtain, for the deflection H, the formula you see with the ratio of the voltage between the plates and the acceleration voltage of the electrons and the ratio L square to D, L being the length of the plates, D, the distance between the plates. Now I give experimental values. For the length of the plates, I estimate it to be 10 cm, the gap I estimate it to be 5 cm, the acceleration voltage, I went to see, it was about 2.5 kV and we saw the measurement of the voltage V : 1.4kV. With these numerical data, I find a deviation of 3 cm, which is not far from what we observed.

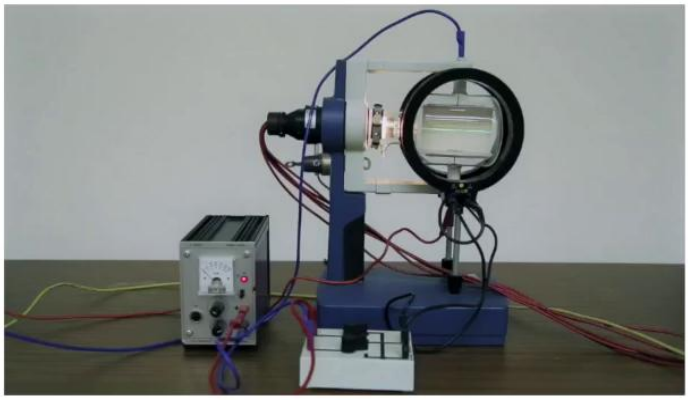
Notes

Summary

3m 41s

Faisceau d'électrons, champ magnétique





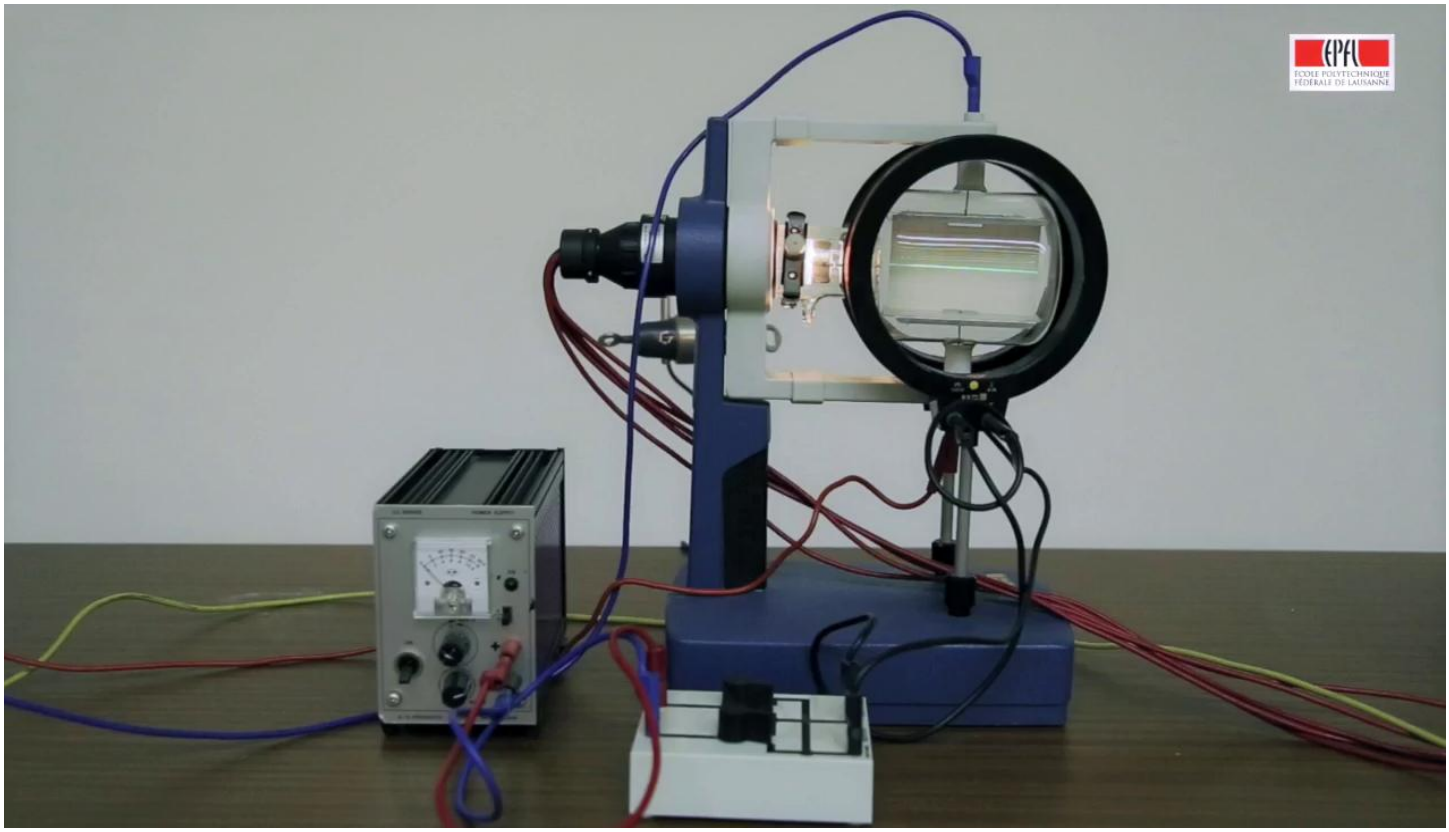
- Faisceau d'électrons visible par écran fluorescent
- Bobine (noire) produit un champ d'induction B

I now turn to the deflection of an electron beam by a magnetic field. We have more or less the same experiment but this time, we have mounted on this black frame, which appears on the picture. You have mounted a coil of wire and we are going to feed the wire with a current. This current will produce a magnetic field which is normal, roughly normal to the picture plane. Let's see what happens.

Notes

Summary

5m 19s



We can reverse the polarity. Obviously the deflection goes the other way. Here we go. Once again, I suggest we pause and estimate the order of magnitude of the magnetic field, the magnetic induction field B in this experiment.

Notes

Summary

6m 06s

Ordre de grandeur

On avait trouvé la relation : $r = \frac{v_1}{\omega} = \frac{mv_1}{qB}$

$$qV_a = \frac{1}{2}mv^2 \qquad v_1 \approx 7\,10^7 ms^{-1}$$

$$B \approx 8mT$$

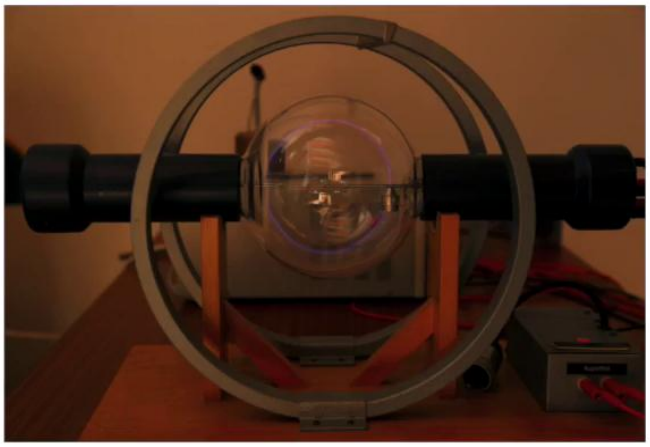
So here is how I proceed. We had found the relation between, for an electron in a uniform magnetic induction field, we had found the radius of the circle of the projection of the trajectory, the trajectory is a spiral projected in the normal plane, to the field B we have a circle of radius r which is given by the formula indicated here. Now we have this energy consideration which allows us to calculate the speed of the electrons. I'll take again for Va, 15kV. This gives me a speed of 7 times 10 power 7 meters per second minus 1. And from this, I deduce with the above formula, I deduce a field of 8mT, and I can tell you that this is a pretty reasonable value.

Notes

Summary

6m 30s

Faisceau d'électrons, champ magnétique



- Faisceau d'électron dans un gaz raréfié
- Champ B symétrique : cercle,
- Champ B hors axe de symétrie : spirale

I would like to show you the spiral trajectory. To do this, I can't just use a flat phosphor screen. Now I would like to show you the experiment with a tube. Here you have a spherical tube. Partially evacuated, there is a gas which is ionized by the electron beam. You should be able to see a bluish circle on the picture. At this moment there is already in the big rings that you see on the side, there is a field, a current going through, which produces the magnetic field, which causes a deflection of the beam. The trajectory is circular. We will now show an inhomogeneous field, at least off axis, which will allow us to see the spiral.

Notes

Summary

7m 28s

Faisceau d'électrons, champ magnétique

- Faisceau d'électron dans un gaz raréfié
- Champ B symétrique : cercle,
- Champ B hors axe de symétrie : spirale

Then we have to make it totally dark. It's a measurement, it's a photo that is difficult to take. We had to wait 20 seconds for the exposure time. I hope you see a blue line on your picture. This is the spiral trajectory. The field here is not homogeneous but allows to see the general character of an electron in a more or less uniform magnetic field.

Notes

Summary

8m 22s

Frottement sec

- La force au décrochage est proportionnelle à la force de réaction
- La force en glissement est inférieure à la force au décrochage.

We change completely the subject. I'm moving on to friction. I would like to show you now what is called dry friction, it is the friction that we can have for example when we have a wooden block which slides on a dry table. I invite you to start watching the video and you will see what happens.

Notes

Summary

8m 56s

Frottement sec

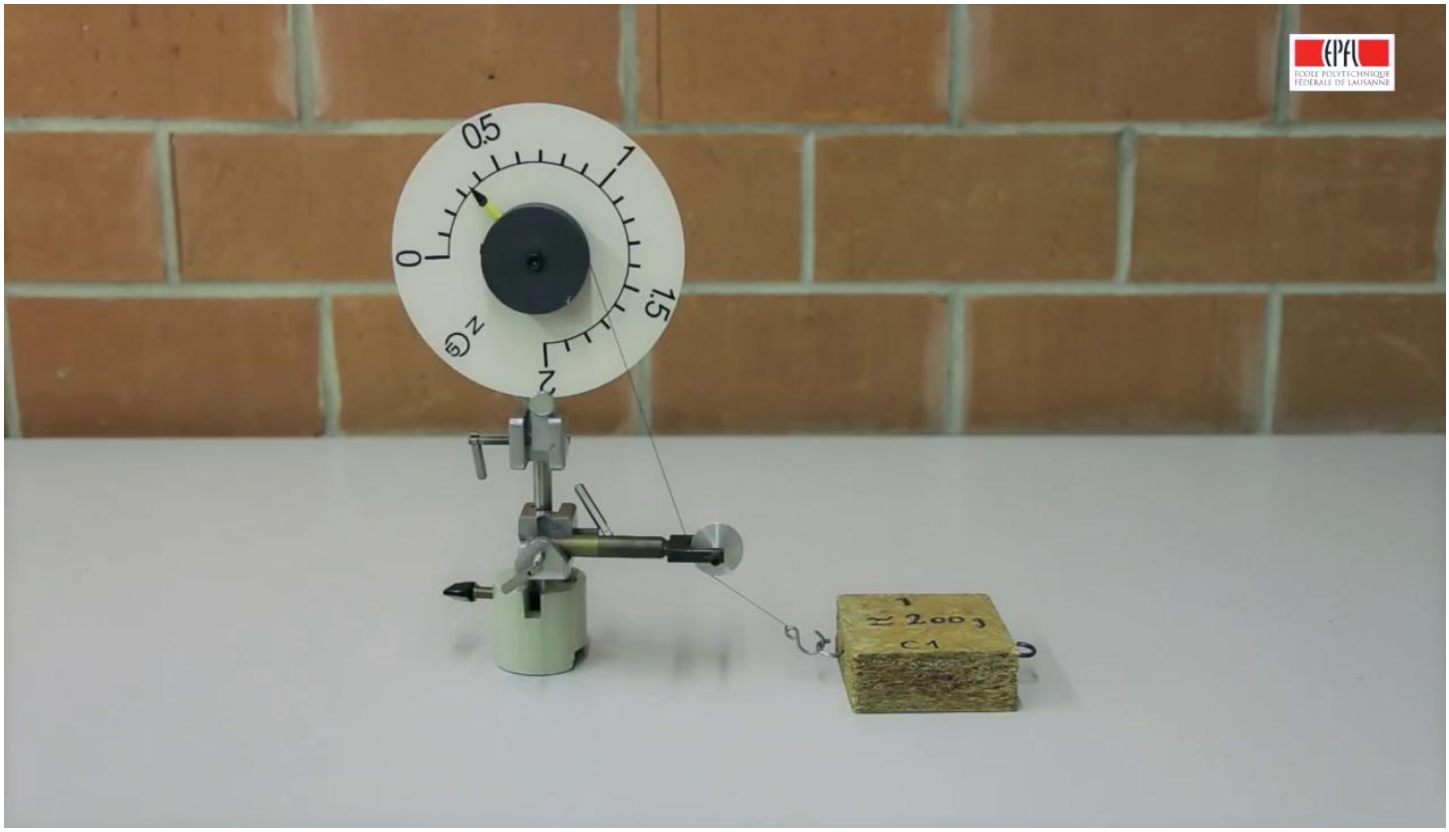
- La force au décrochage est proportionnelle à la force de réaction
- La force en glissement est inférieure à la force au décrochage.

There, something interesting has already happened. If I take the video from the beginning, you will see that our dynamometer indicates a maximum force, and then when the block slides, another value of the force. These two values of the force correspond to the coefficient of static friction and the coefficient of kinetic friction.

Notes

Summary

9m 21s



Let's watch this video again. Here it is.

Notes

Summary

9m 47s

Frottement sec

- La force au décrochage est proportionnelle à la force de réaction
- La force en glissement est inférieure à la force au décrochage.

You can see that the kinetic friction is smaller than the stall value that we have to reach before the pad moves. We also said that this force was proportional to the reaction force, so if we add a block on top of the first one, we have to reach twice the force. So we were at about 0,7 on this measuring device, with two studs we should arrive at 1,4. Let's see what happens.

Notes

Summary

9m 55s

Frottement sec

- La force au décrochage est proportionnelle à la force de réaction
- La force en glissement est inférieure à la force au décrochage.

Not bad. We are at about a 1.4. And now, I propose to put three studs.

Notes

Summary

10m 38s

Frottement sec : glissade-arrêt

- Traction continue : le ressort s'allonge.
- Quand la force de frottement statique atteint le maximum, le plot avance et le ressort se contracte.

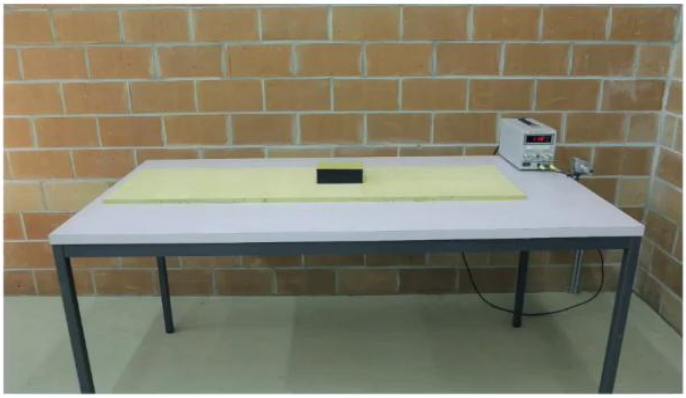
And indeed around 2.1, it's stalling as expected. So, now I'm going to show you an amusing experiment which illustrates or takes advantage of the fact that the static friction coefficient is greater than the kinetic friction coefficient. I invite you to watch this experiment.

Notes

Summary

10m 55s

Frottement sec : glissade-arrêt



- Traction continue : le ressort s'allonge.
- Quand la force de frottement statique atteint le maximum, le plot avance et le ressort se contracte.

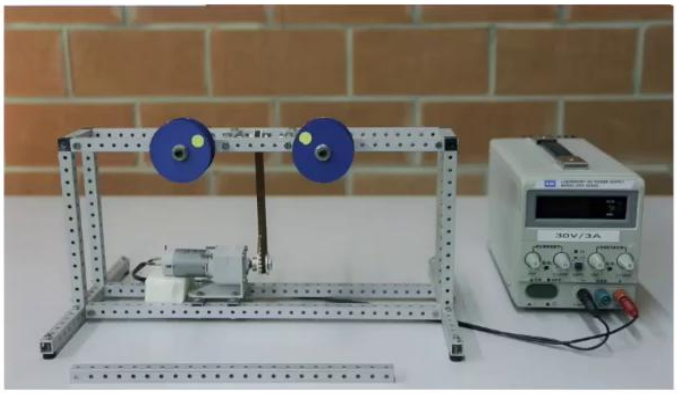
This jerky movement comes precisely from the fact that we have a big difference between the static friction coefficient and the kinetic friction coefficient.

Notes

Summary

11m 54s

Frottement sec



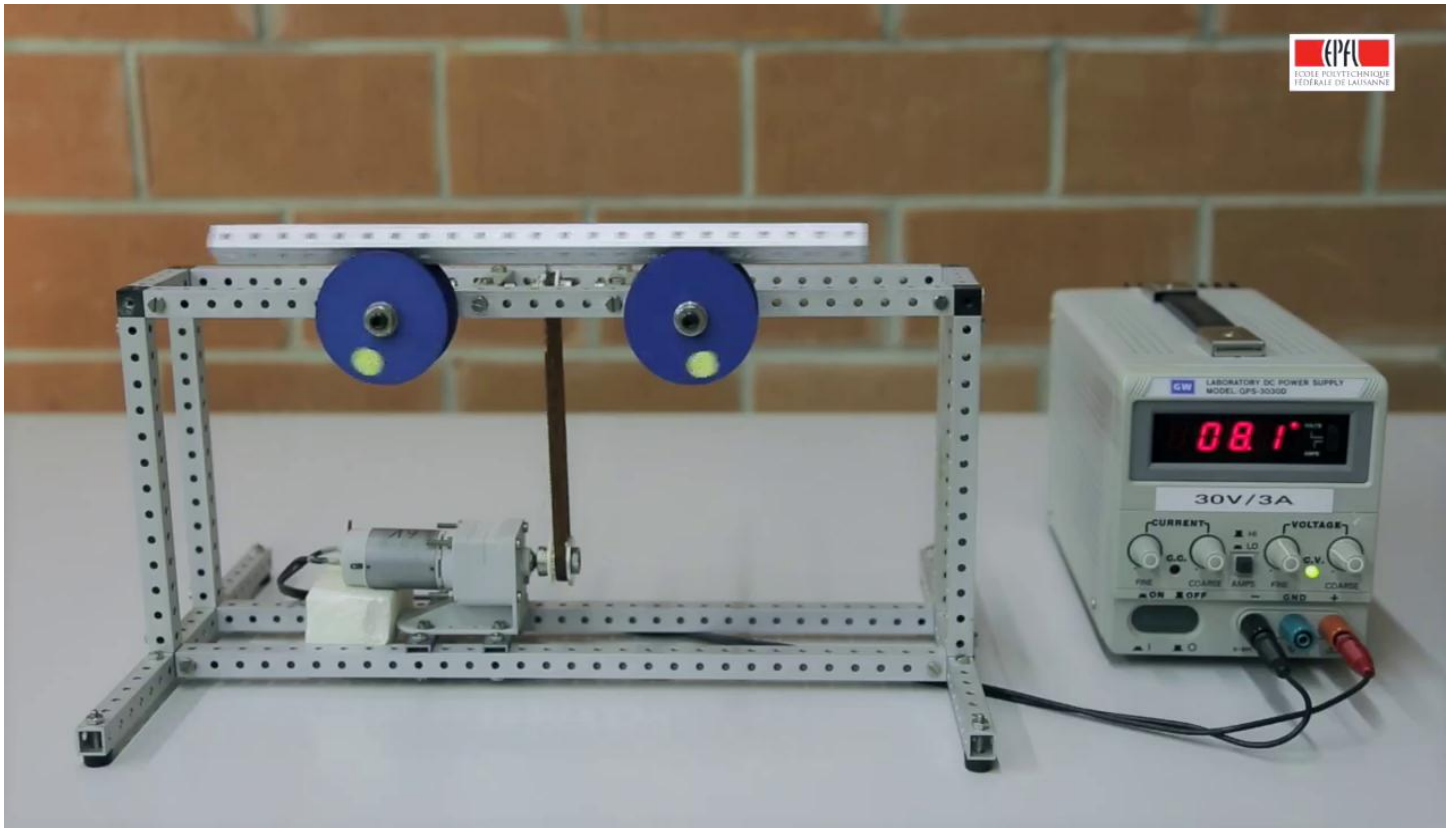
- Expérience similaire : bâton horizontal soutenu par deux doigts horizontaux. On rapproche les doigts.

I'll show you another experiment that takes advantage of this phenomenon.

Notes

Summary

12m 06s



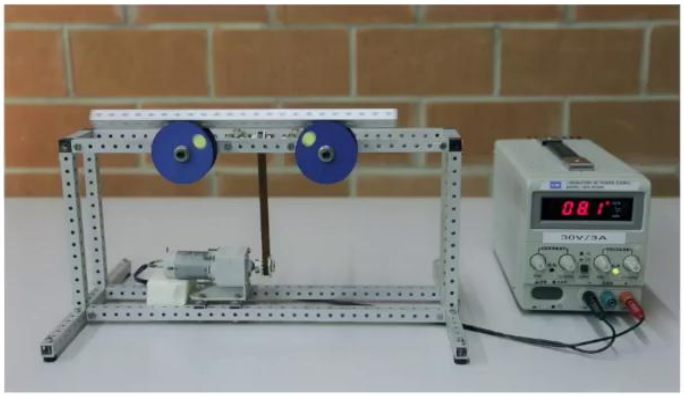
I think the best thing to do is to watch.

Notes

Summary

12m 11s

Frottement sec



- Expérience similaire : bâton horizontal soutenu par deux doigts horizontaux. On rapproche les doigts.

You can try to analyze this motion by taking a stick, a broomstick, something like that, that you hold between two fingers and you bring the fingers together, you'll see that there's always a finger that slides and a finger that's stationary, relative to your stick or your broomstick. In the quiz, there is a place where you calculate the reaction force of a support, of two supports when you have a beam that is placed on both supports. This is the kind of analysis you have to do to understand what is going on here.

Notes

Summary

12m 33s

Frottement visqueux

- Un cylindre tombe dans un tube ouvert à l'air.
- La chute change si l'air doit s'écouler autour du cylindre.

To finish, I'd like to show an experiment that highlights the viscous character of the air. We are going to make a cylinder fall into a tube. The first time with the mouth of the tube free, and the second time the tube will be blocked, and it is therefore necessary at this moment, that the air circulates along the cylinder which is falling in the tube and the viscosity makes that the fall is very clearly slowed down.

Notes

Summary

13m 11s

We plug it. And that's it.

Notes

Summary

13m 49s