ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

http://go.epfl.ch/traite-meca-1-14

Autres forces

Mécanique, cours 14.1

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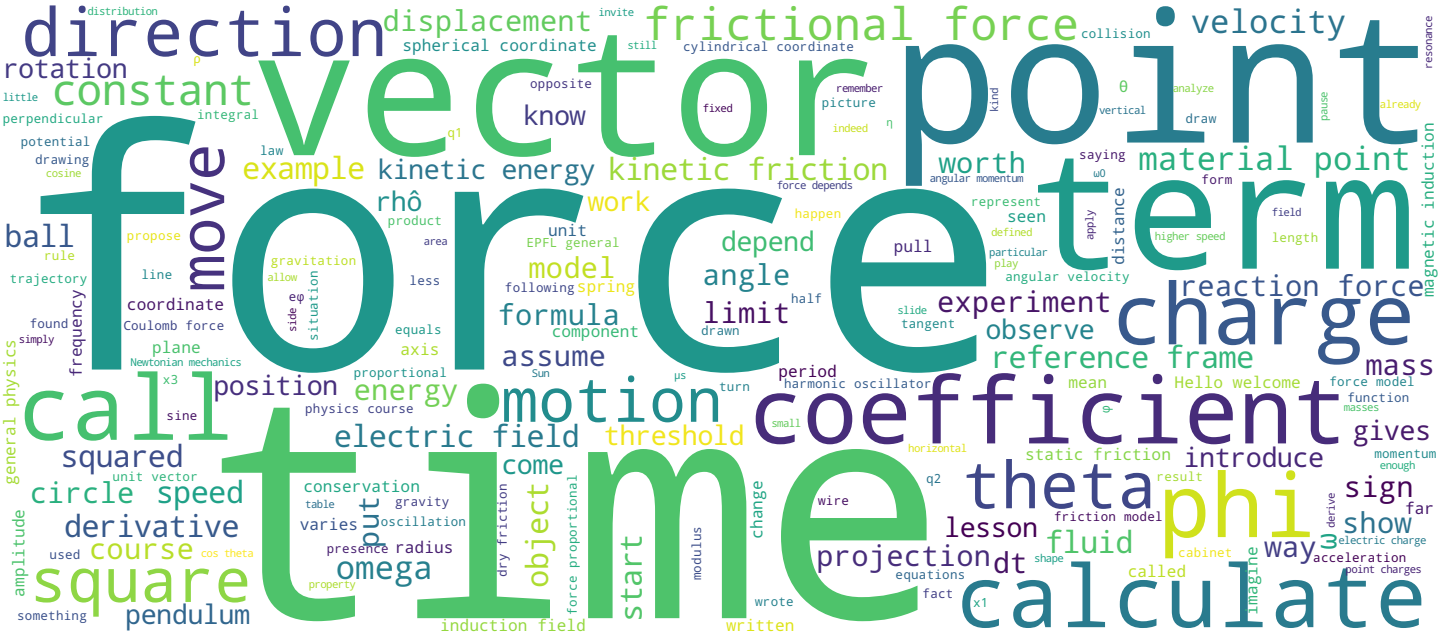

Video

Autres forces

- Force de Coulomb
- Champ électrique
- Force de Lorentz
- Modèles de forces de frottement

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Hello, welcome to the EPFL general physics course. So far, we have learned to do Newtonian mechanics with the force of gravity, or the force of gravitation, the restoring force of a spring, the friction force proportional to the speed, and the forces associated with geometric constraints. In this lesson, I would like to introduce some additional force models I would like to first introduce the Coulomb force, between point charges, point electric charges, the force associated with an electric field, the force of a charged particle in a magnetic induction field, and finally, I would like to review some frictional force models.

Notes

Summary

0m 04s

Définition : force de Coulomb

Deux charges ponctuelles : q_1 q_2

$$\boldsymbol{F} = \frac{q_1 q_2}{4\pi\varepsilon_0 r^2}\,\frac{\boldsymbol{r}}{r}$$

$$\frac{1}{4\pi\varepsilon_0} = 8.988\,10^9\,\frac{Nm^2}{C^2}$$

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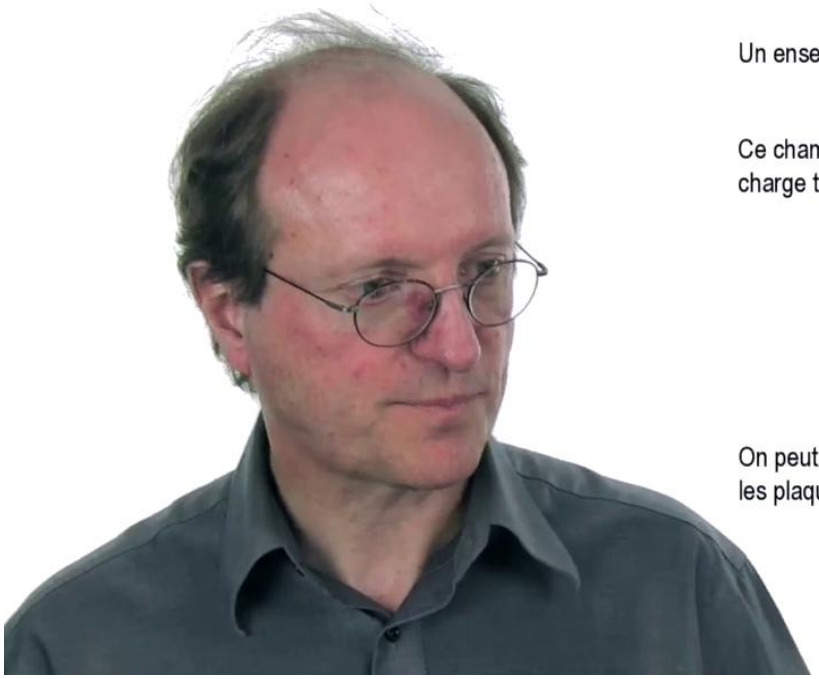
I'll start with the Coulomb force. I imagine that I have two point charges, of value *q1* and *q2*. There is a force, that has the same structure as the force of gravitation, so it is a *1/r²* law, there is the product of the charges involved, and the coefficient that gives the intensity of the force is *1 / (4 Π ε 0)* whose value is given here in SI units If the vector *r*,which I have drawn here, is the vector that binds the charge *q1* to the charge *q2*, that is *r* and so if *q1* and *q2* have the same sign, this coefficient is positive, and so the force is directed in that direction, and that's what we know, when you have equal charges, they repel each other so the force is repulsive, the force comes like this.

Notes

Summary

0m 59s

Définition : champ électrique



Un ensemble de charges produit un champ électrique $\boldsymbol{E}$

Ce champ caractérise la force que ces charges exercent sur une charge test q :

$$\boldsymbol{F} = q\boldsymbol{E}$$

On peut produire un champ électrique uniforme en chargeant les plaques d'un condensateur plan.

I move on to the force described by an electric field. If we have a given distribution of electric charge, we can calculate what we call the electric field produced by these charges. It belongs to a course in electromagnetism, to show how one can calculate such an electric field. The electric field, in fact, characterizes the force that a test charge *q* feels in the presence of this given distribution of charges. So we have a force *F* which is written *q* times the electric field. Here, in the context of this course, it is enough to remember that, when we have a plane capacitor, so two parallel charged metal plates we have between the plates, a field that is approximately uniform.

Notes

Summary

2m 18s

Définition : force de Lorentz

En présence d'un champ d'induction magnétique $\boldsymbol{B}$

une charge q de vitesse $\boldsymbol{v}$

subit une force : $\boldsymbol{F} = q\boldsymbol{v} \wedge \boldsymbol{B}$

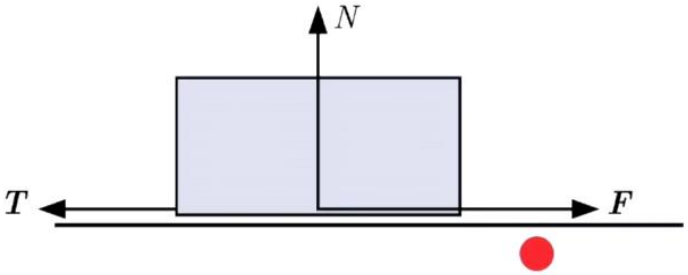
I now turn to the Lorentz force. We assume that we have a magnetic induction field *B*, that a charge is moving at speed *v* in the reference frame in which we produced the magnetic induction field *B*, we then have a force acting on the charge, which is written $qv \wedge B$. We're going to analyze the motion of a charge in the presence of a constant and uniform magnetic field in the other module later.

Notes

Summary

3m 16s

Propriété : limite de la friction statique



$$F_{\max} = \mu_s N$$

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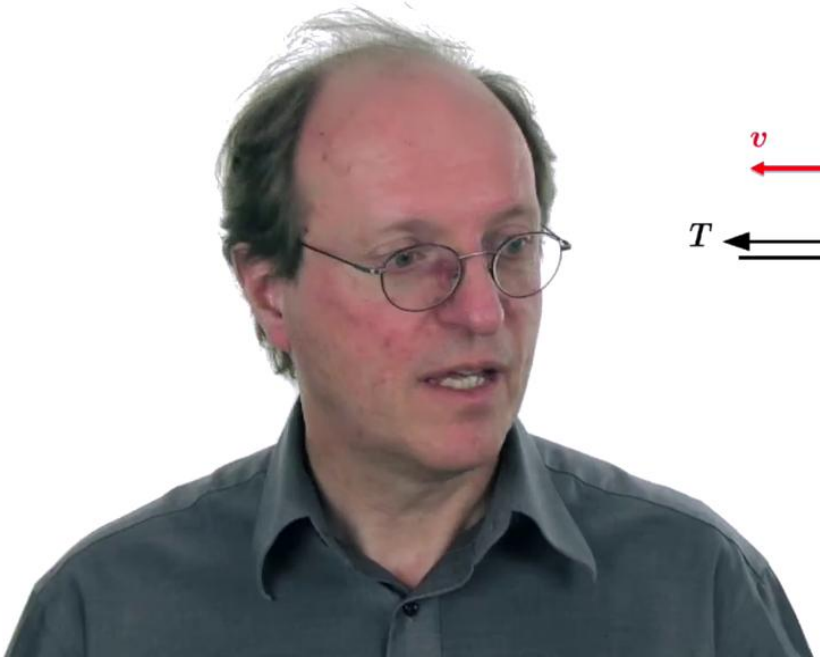
Now I'll move on to the friction model. In everyday life, we are used to having frictional forces, and here, I would like to consider the case of a block placed on a table, or a cabinet placed on the floor. You know that, if you pull on this cabinet, but not hard enough, the cabinet does not move. Why doesn't it move? Because there is a frictional force. What is this frictional force worth? Well, it adjusts in such a way that the cabinet doesn't move. So, so far we've seen forces, we've just seen for example the Coulomb force. You give two charges, the positions of the two charges, and you can calculate the force. Here, the force depends, this-force, which is the friction force, depends on the traction that we want to exert on our object. Now, there are some rules we can get. By the way, when we have such a situation, we say that we have a dry friction. So, there's a rule for dry friction, it's that you can pull with the force *T*, up to a certain limit. The force *F* will prevent movement until a threshold is reached. This threshold value, which I call *Fmax*, is proportional to the reaction force of the support on the object.

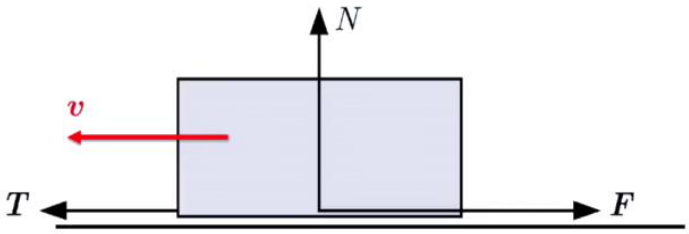
Notes

Summary

3m 51s

Propriété : friction cinétique





$$\boldsymbol{F} = -\mu_c |N| \frac{\boldsymbol{v}}{|\boldsymbol{v}|}$$

icient de frottement cinétique

$$\mu_c < \mu_s$$

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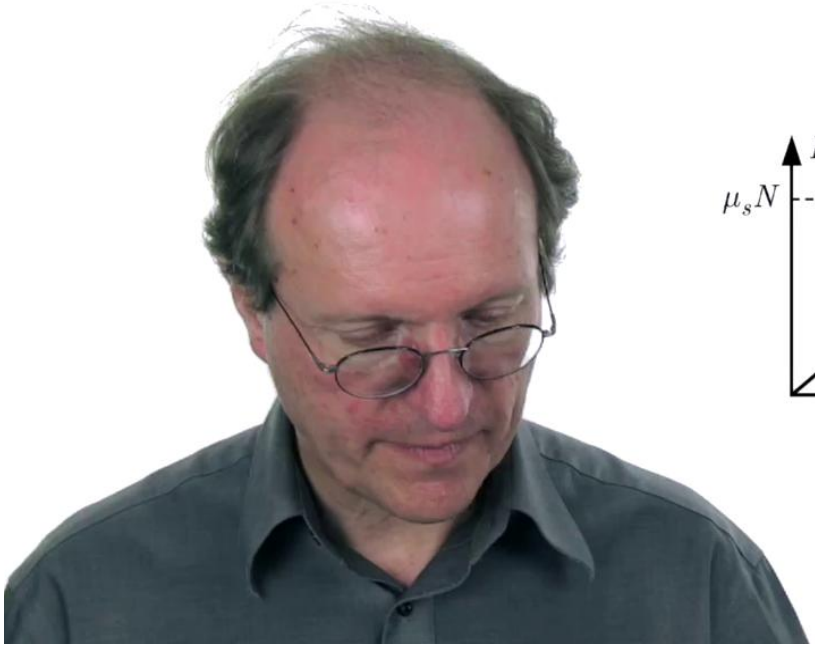
And the coefficient, I call it μs, and we call it the coefficient of static friction. Now, if we go beyond that threshold, the object moves, so I guess now I have a slip at a speed v, and so I call it kinetic friction to say that there is a displacement. This frictional force, now, experimentally, we can model it, by saying that it is opposite to the velocity, and it is proportional to the reaction force of the object support. And the coefficient μc is called the coefficient of kinetic friction. Experimentally, we observe that the coefficient of kinetic friction is smaller than the coefficient of static friction. Now I suggest you pause and try for yourselves to draw a picture of the frictional force, which represents the two models I just mentioned, the static friction model and the kinetic friction.

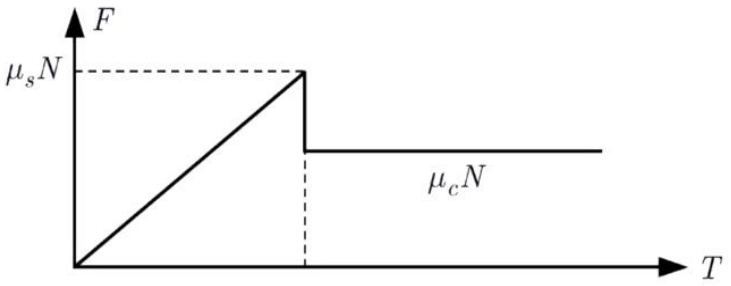
Notes

Summary

5m 25s

Modèle de frottement sec





So this is my way of representing what I've said so far, when you pull with a force below a threshold, the frictional force adjusts exactly, so here we have a slope of 1, the frictional force is equal and opposite to the pulling force, up to a limit, which is given by μs times the ground reaction force, beyond this limit, we have the kinetic friction model where the force is, to a first approximation independent of the velocity, and is worth the coefficient of kinetic friction times the reaction force.

Notes

Summary

6m 46s

Modèle de frottement visqueux

Faible vitesse :

η : viscosité

$$\boldsymbol{F} = -k\eta\boldsymbol{v}$$

k : coefficient géométrique

$k = 6\pi R$ (sphère de rayon R)

Vitesse plus grande:

$$\boldsymbol{F} = -C_x \frac{1}{2} \rho_{\text{fl}} v^2 S \left(\frac{\boldsymbol{v}}{v}\right)$$

ρ_{fl} densité du fluide

C_x coefficient de traînée

S aire projetée

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Now in the viscous case, whatever the traction force, on a horizontal surface, for example, we immediately have a displacement, and in the limit of low friction, we have something like this, here I give you the force for the displacement in a fluid, a fluid that would have a viscosity noted η and there is a geometric coefficient here, η is a property of the fluid, k depends on the shape of the object we want to displace in the fluid, and we have for example, to fix the ideas, k is $6\,\Pi\,r$ for a sphere of radius r. That's in the limit of very small displacements. Now that's a force proportional to the velocity. That's the kind of model we've used up to now when we wanted to introduce friction. Now if we have an object moving in a fluid, we have so-called "hydrodynamic" effects that come into play, at higher speed, a little bit higher. We have a formula like this, here we have a unit vector, to say that the force is opposed to the displacement, and the quantities which intervene here are the density of the fluid, a dimensionless coefficient which characterizes the fineness of the object, for example for an airplane wing, we define a coefficient of drag, and then, the force also depends on the projected surface, it is the projection, of the object on the plane perpendicular to the speed.

Notes

Summary

7m 32s

Modèle de frottement visqueux

Faible vitesse :

η : viscosité

$$\boldsymbol{F} = -k\eta\boldsymbol{v}$$

k : coefficient géométrique

$k = 6\pi R$ (sphère de rayon R)

Vitesse plus grande:

$$\boldsymbol{F} = -C_x \frac{1}{2} \rho_{\text{fl}} v^2 S \left(\frac{\boldsymbol{v}}{v}\right)$$

ρ_{fl} densité du fluide

C_x coefficient de traînée

S aire projetée

So, we can't go much further, if we go to higher speeds, we have turbulences, things become extremely complicated, and anyway here we enter the field of hydrodynamics, we leave the simple Newtonian mechanics of the material point.

Notes

Summary

9m 24s