Friction

Physics 1425 Lecture 8

Michael Fowler, UVa.

Warm Up Question

- A brass cube and a flat brass disk of the same weight are on a flat board. The board is gradually tilted until sliding begins. Which slides first?

A. The brass cube

B. The flat brass disk

C. Both at the same time

Frictional Force is Independent of Contact Area…

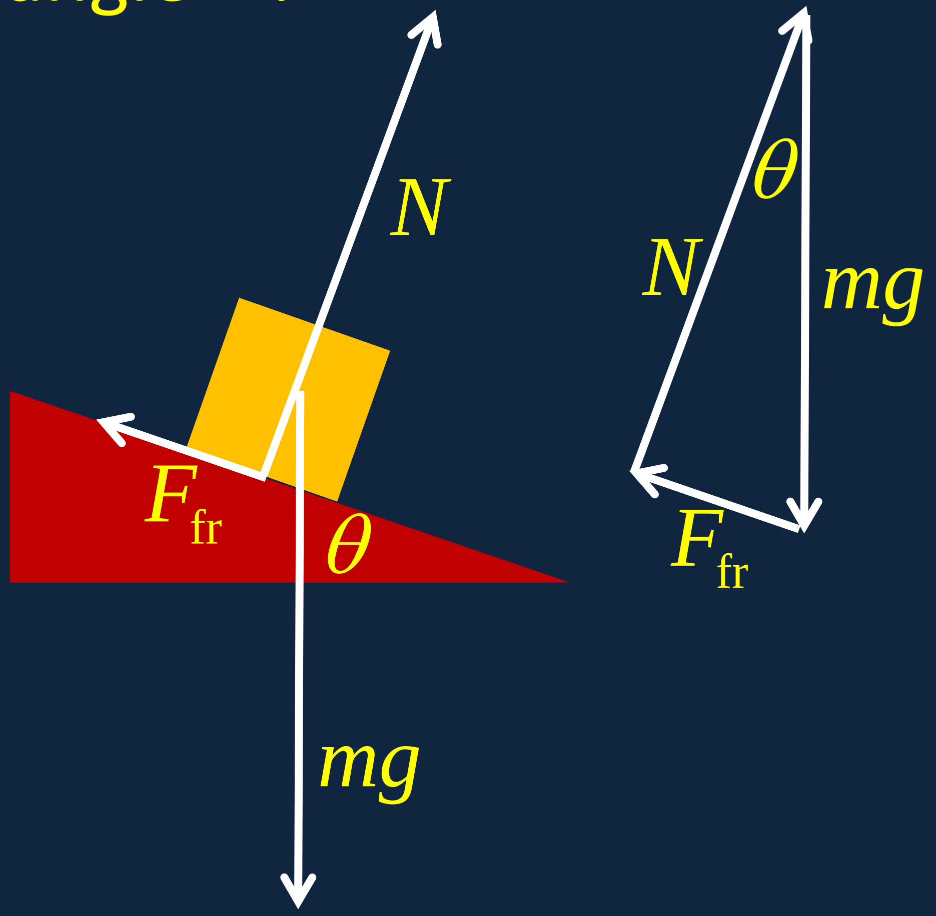
- Both will begin to slide at the same time!

- The disk has far more surface on the board, but experimentally the maximum static frictional force, just before it begins to slide, depends only on the materials of the surfaces and the pressure between them, that is, the normal force.

Free Body Diagram for Block on Slope

- At maximum pre-slide angle θ :

Note frictional force is parallel to surface. Forces on block must add to zero as vectors since it is at rest.



Notice: $F_{fr} = N \tan\theta$

Coefficient of Static Friction

The magnitude of the maximum static frictional force (just before sliding) is found to be directly proportional to the normal force:

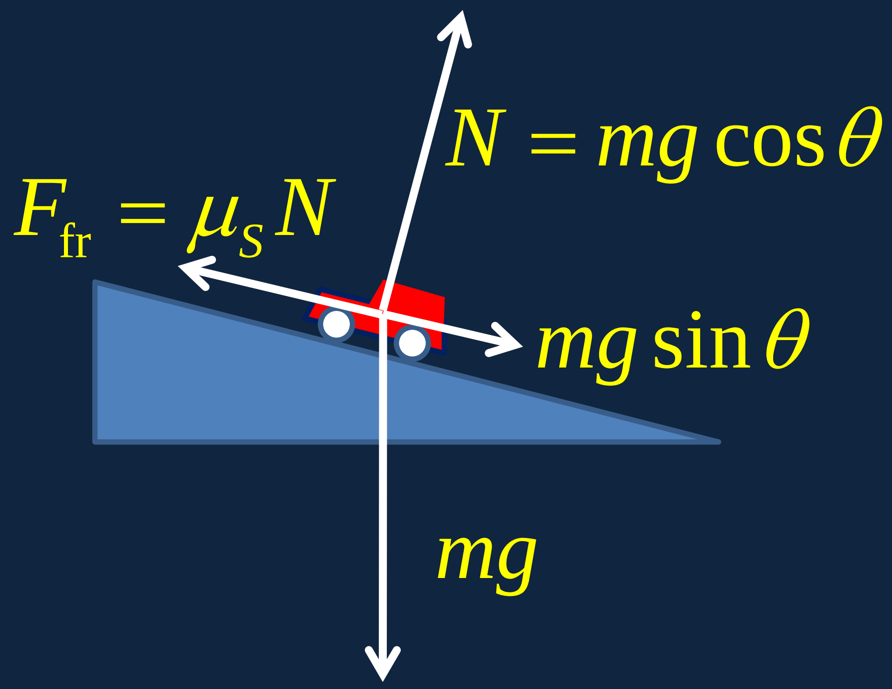
$$\left(F_{\mathrm{fr}}\right)_{\mathrm{max}} = \mu_S N$$

- μ_S is called the coefficient of static friction.
- If θ_{fr} is the tilt angle where sliding begins,

$$\mu_S = \tan\theta_{\mathrm{fr}}$$

How Steep a Hill Can a Car Climb?

- Assuming a powerful engine, the incline is limited by the coefficient of static friction. The friction force from the road will push the car up the hill, provided:



$$F_{\mathrm{fr}} = \mu_S N = \mu_S mg\cos\theta > mg\sin\theta$$

Bottom line: if the car can be parked on the hill, $\tan\theta < \mu_S$, and the engine is strong enough, it can climb the hill!

Looking more closely…

- It seems odd that the frictional force doesn't depend on the size of the area of contact.

- But in fact, the observed "area of contact" is an *illusion*!
- Microscopically, the surfaces are rough, the area of true contact is much smaller, and that area increases linearly with the normal force. These tiny areas weld or bond, holding the surfaces together until sideways force breaks these bonds.

- If atomically smooth surfaces are put together, they *will* bond all over: an almost infinite friction coefficient!

Sliding: Kinetic Friction

- The frictional drag force when one surface slides over another is determined by the coefficient of kinetic friction:

$$F_{\mathrm{fr}} = \mu_K N$$

- Just as in the static case, there is no dependence on the *observed* area of contact, the force is independent of sliding speed, and proportional to the normal force.

- It must be that $\mu_K < \mu_N$, or the cube on the tilted board would stop as soon as it started to slide!

Friction Coefficients are Very Approximate…

- There's a reason tables of friction coefficients often give only one significant figure.
- Surfaces vary greatly on a microscopic scale: they oxidize, have thin films of water, other surface impurities, all of which can affect the bonding strength at true contact, and therefore the friction.
- Claimed friction coefficients for lubricated or greasy surfaces are *to be trusted even less*: an actual layer of oil between surfaces gives a viscous drag almost independent of normal force, and dependent on speed!