Friction

Physics 1425 Lecture 8

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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…

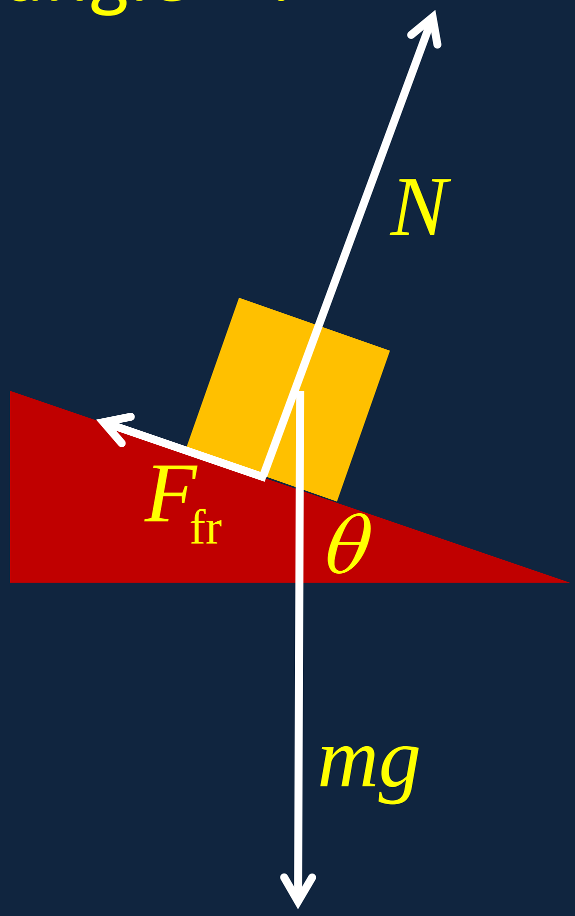
- Both will begin to slide at the same time!

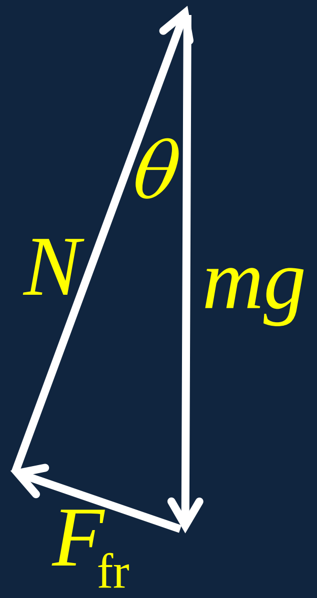
- The disk has far more surface on the board, but experimentally the maximum static frictional force, just before it begins to slide, depends only on the materials of the surfaces and the pressure between them, that is, the normal force.

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

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:

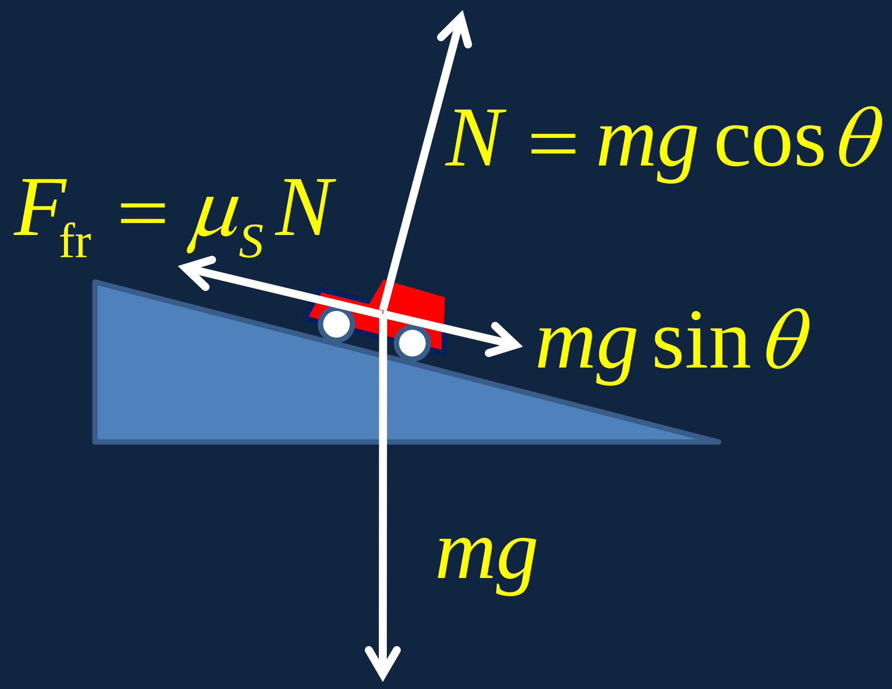
$$\left(F_{\text{fr}}\right)_{\max} = \mu_S N$$

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

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

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:



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

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!

ConcepTest 5.2 Antilock Brakes

Antilock brakes keep the car wheels from locking and skidding during a sudden stop. Why does this help slow the car down?

1) $\mu_k > \mu_s$ so sliding friction is better
2) $\mu_k > \mu_s$ so static friction is better
3) $\mu_s > \mu_k$ so sliding friction is better
4) $\mu_s > \mu_k$ so static friction is better
5) none of the above

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Static friction is greater than sliding friction, so by keeping the wheels from skidding, the static friction force will help slow the car down more efficiently than the sliding friction that occurs during a skid.

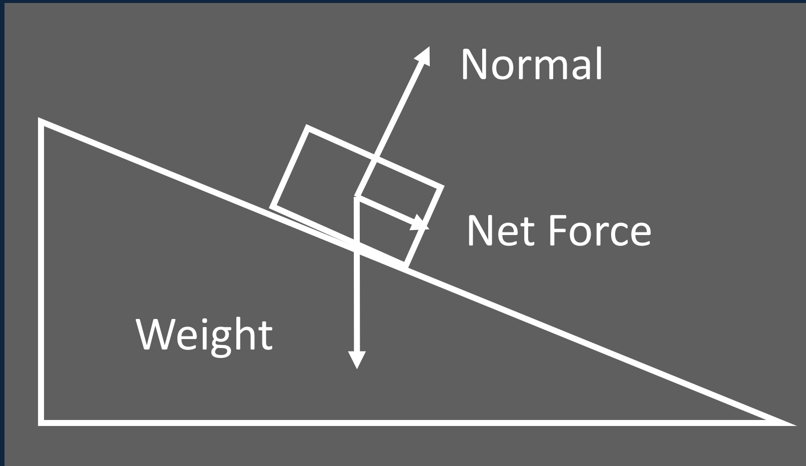
Friction Coefficients are Very Approximate…

- 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!

ConcepTest 5.5a Sliding Down I

A box sits on a flat board. You lift one end of the board, making an angle with the floor. As you increase the angle, the box will eventually begin to slide down. Why?

1) component of the gravity force parallel to the plane increased
2) coefficient of static friction decreased
3) normal force exerted by the board decreased
4) both #1 and #3
5) all of #1, #2, and #3



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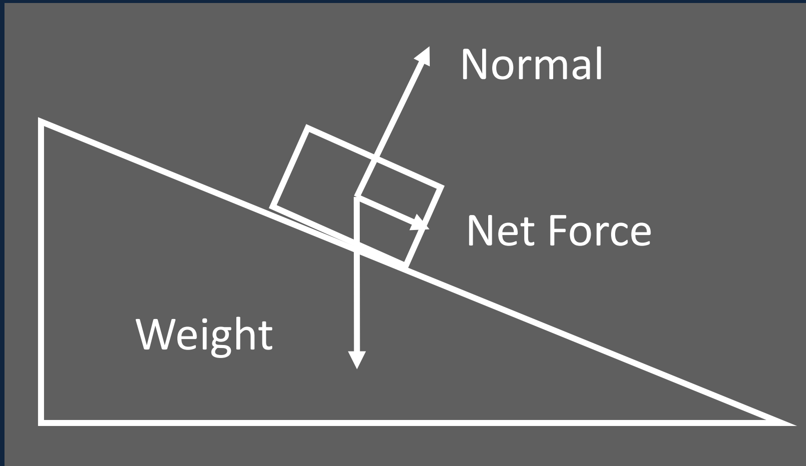
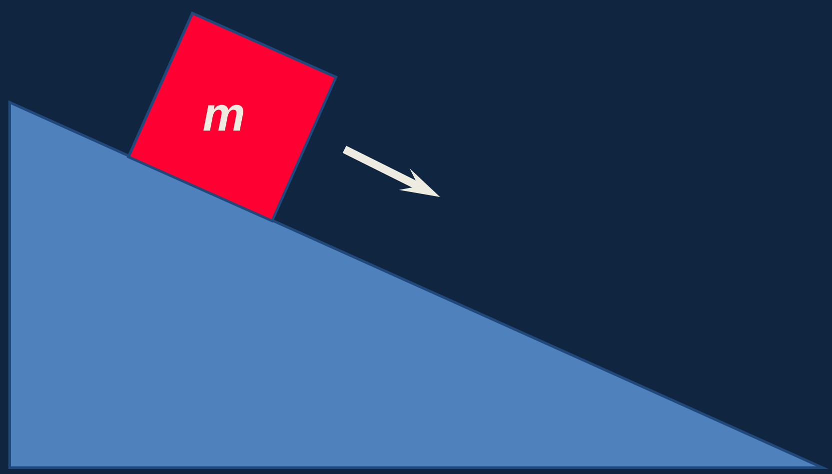
As the angle increases, the **component of weight parallel to the plane increases** and the **component perpendicular to the plane decreases** (and so does the normal force). Because friction depends on normal force, we see that the **friction force gets smaller** and the **force pulling the box down the plane gets bigger**.



ConcepTest 5.5b Sliding Down II

A mass *m* is placed on an inclined plane ($\mu > 0$) and slides down the plane with constant speed. If a similar block (same μ) of mass 2*m* were placed on the same incline, it would:

1) not move at all
2) slide a bit, slow down, then stop
3) accelerate down the incline
4) slide down at constant speed
5) slide up at constant speed



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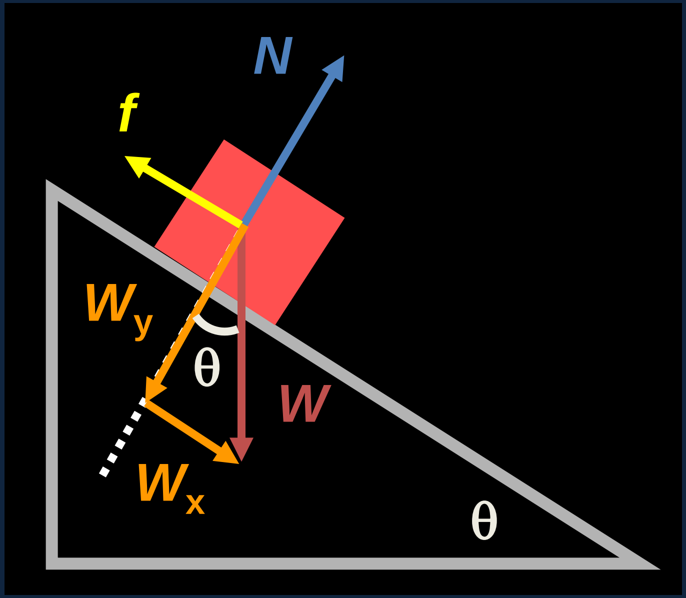
The component of gravity acting down the plane is **double** for 2*m*. However, the normal force (and hence the friction force) is also **double** (the same factor!). This means the two forces still cancel to give a net force of zero.



Problem from Book

- (*a*) Show that the minimum stopping distance for an automobile traveling at speed v is equal to $v^2/2\mu_S g$ where μ_S is the coefficient of static friction between the tires and the road, and g is the acceleration of gravity.

- (*b*) What is this distance for a 1200-kg car traveling 95 km/h if $\mu_S = 0.65$?

- (*c*) What would it be if the car were on the Moon (the acceleration of gravity on the Moon is about $g/6$) but all else stayed the same?

Problem from Book

- A small box is held in place against a rough vertical wall by someone pushing on it with a force directed upward at 28° above the horizontal. The coefficients of static and kinetic friction between the box and wall are 0.40 and 0.30, respectively. The box slides down unless the applied force has magnitude 23 N. What is the mass of the box?

Problem from Book

- A child slides down a slide with a 34° incline, and at the bottom her speed is precisely half what it would have been if the slide had been frictionless. Calculate the coefficient of kinetic friction between the slide and the child.