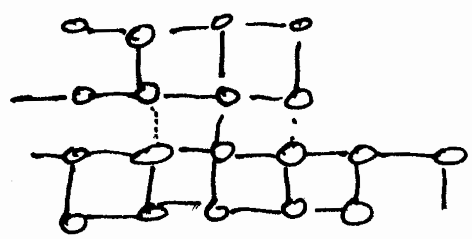
FRICTION

We all have a feeling for friction — its difficult to push a body with a rough surface across another rough surface (e.g. wooden crate across concrete), much easier to push a smooth body across a smooth surface (say a hockey puck across ice). Also its much more difficult to push a heavy body than a light one. Newton's 1st Law tells us that we should not have to apply a force to keep a body in uniform motion, but we all know that a considerable force is necessary to keep a 100 lb crate moving along a concrete sidewalk. There must be some other force acting to slow the body down which we must counteract by pushing (or pulling) on the crate — that force is friction. We understand frictional forces very poorly and considerable research is currently underway to understand it better. There are several kinds of friction which behave differently: wind resistance is different from the rolling friction of a wheel rolling along a surface, and that in turn behaves differently from the frictional forces from sliding one surface upon another. We will restrict ourselves to the case of <u>sliding friction</u>.

Even in this restricted case the frictional forces between surfaces of different kinds are different

TWO ROUGH SURFACES



Here microscopic edges "catch one another

Some surfaces form tiny bonds

We can describe frictional forces only approximately. There are experimentally determined rules which allow us to calculate the behavior of systems with friction. These rules describe the observed behavior of frictional forces, but they are not deep physical principles like Newton's laws.

Let's examine our own experiences of the way friction behaves. Suppose you are attempting to push a very heavy crate along the floor.

You push — nothing happens

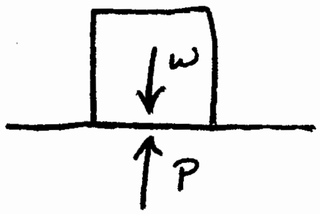
You double your efforts — still nothing pushing as hard as you can happens

A friend comes along and pushes with you — finally the crate begins to move

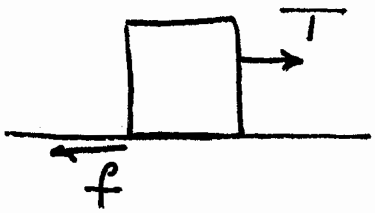
Once the crate is moving you find that less effort is required to keep it moving. With same effort you can keep it moving yourself

Your friend jumps on the crate for a ride and you find you can no

Consider a body resting on a surface with weight w; by Newton's 3rd law there is

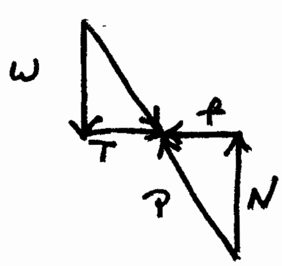


an equal and opposite force P pushes upward



We begin to pull on the body with a force T — the body does not move

There must be a force $f = -T$, which prevents the block from moving (equilibrium). We increase T and still the body doesn't move, thus f must have increased as well. f is the frictional force between the surfaces. If we consider the net forces



In the case in which the block remains static we have

$$\vec{f}_s = -\vec{T}$$

where we use s to denote static friction

As we increase T, f_s continues to increase until it reaches a maximum and the body will start sliding.

This maximum value is given by

$$f_s^{max} = \mu_s N$$

(NB - this is not a vector equality)

Increase T until $T > f_s^{max}$ crate begins moving

where: μ_s is the "coefficient of static friction"

and N is the component of the force $\perp$ to the surface - the "normal" force. This force is equal to the force pushing down on the surface

In general

$$\boxed{f_s \le \mu_s N}$$

Once T exceeds $f_s^{max} = \mu_s N$ the body will move – the frictional bonds cannot hold as strongly

$$\boxed{f_s = \mu_k N}$$

where μ_k = "coefficient of kinetic or sliding friction"

generally $\mu_k < \mu_s$

(That's why crate slides easier once you've got it going – also why you accelerate more rapidly if you don't "peel out" from a stop sign)

mind jumping on increases N

To a good approximation μ_k is independent of velocity surface area etc.

		μ_s	μ_k
Examples:	Steel-Steel	0.74	0.57
	Copper on Cast iron	1.05	0.29
	Ice-Ice	0.10	0.05
	Teflon-Teflon	0.04	0.04

SOME COEFFICIENTS OF FRICTION

ERIALS	μ_s	μ_k
STEEL - STEEL	0.74	0.57
COPPER - CAST IRON	1.05	0.29
GLASS - GLASS	0.94	0.40
ICE - ICE	0.10	0.02
ALUM - ICE	0.04	
SKI WAX - ICE	0.02	
LEATHER - PAVEMENT	0.5	~0.03
WOOD - WOOD	0.3-0.5	
TEFLON - ANYTHING	0.04	0.04
RUBBER - SOLIDS	1.0-4.0	
RUBBER - CONCRETE (DRY)	1.0	0.8
RUBBER - CONCRETE (WET)	0.30	0.25