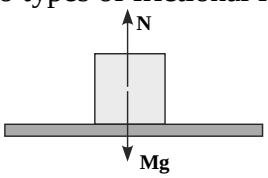
FRICTION

One type of force that we have not yet considered is that due to friction. The following situations demonstrate the two types of frictional forces we will be considering – static and kinetic frictional forces.

no applied force;
object remains at rest

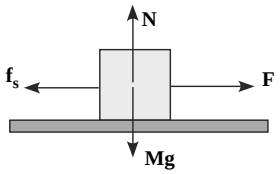
friction force = 0



no tendency of motion;
no relative motion

weak applied force;
object remains at rest

friction force = f_s

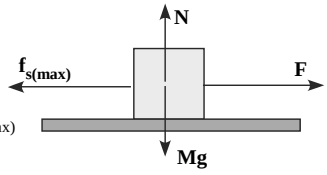


tendency of motion to the right

$f_s = F$

stronger applied force;
object on the verge of moving

force of friction = $f_{s(max)}$

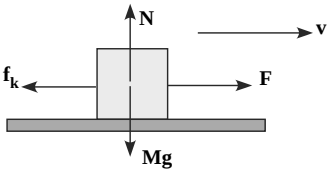


tendency of motion to the right

$f_{s(max)} = F$

force of friction = f_k

object sliding to the right at constant velocity;



relative motion to the right

$f_k = F$

The previous examples demonstrated the two types of frictional forces:

1. Kinetic frictional force (f_k) - Relative motion between objects
2. Static frictional force (f_s) - **NO** relative motion between objects

Experimentally it is found that f_k and f_s are both proportional to the normal force acting on an object:

$\boxed{f_k = \mu_k N}$ Kinetic Frictional Force

$\boxed{f_s \leq \mu_s N}$ Static Frictional Force

μ_k = coefficient of kinetic friction
μ_s = coefficient of static friction

The equality in $f_s \leq \mu_s N$ holds **only** when the object is on the verge of moving. This corresponds to the maximum static frictional force:

$\boxed{f_s(\max) = \mu_s N}$ When object is on verge of moving

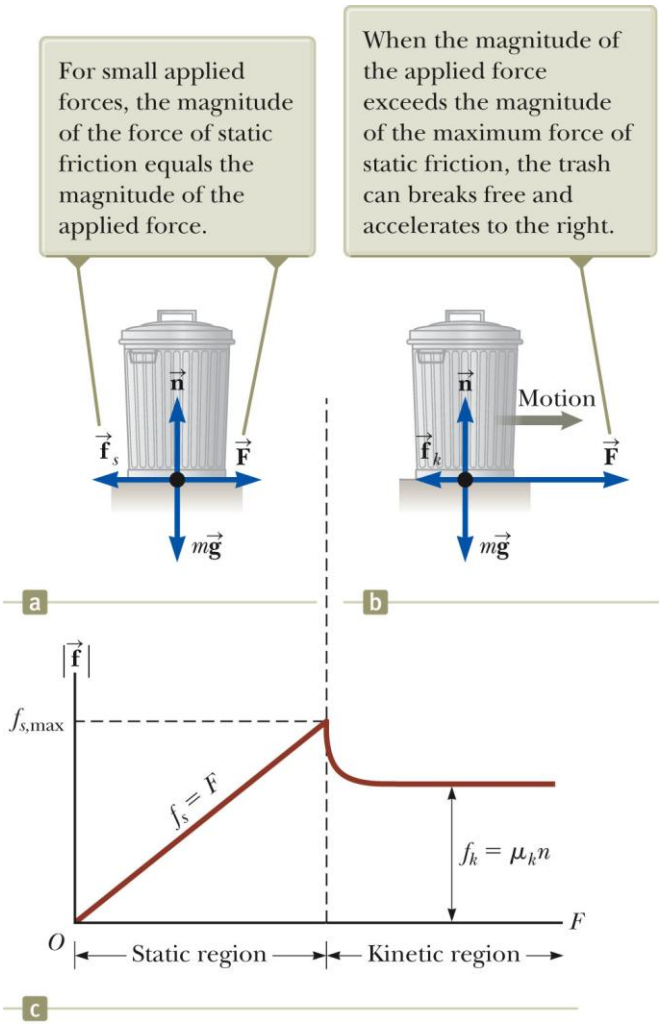
The inequality in $f_s \leq \mu_s N$ holds when the applied force on object is less than $f_s(\max) = \mu_s N$.

1. μ_s is generally greater than μ_k
2. f_k is in the opposite direction of the relative motion of an object.
3. f_s is in the opposite direction of the tendency of motion of an object.

TABLE 5.1 *Coefficients of Friction*

	μ_s	μ_k
Rubber on concrete	1.0	0.8
Steel on steel	0.74	0.57
Aluminum on steel	0.61	0.47
Glass on glass	0.94	0.4
Copper on steel	0.53	0.36
Wood on wood	0.25–0.5	0.2
Waxed wood on wet snow	0.14	0.1
Waxed wood on dry snow	—	0.04
Metal on metal (lubricated)	0.15	0.06
Teflon on Teflon	0.04	0.04
Ice on ice	0.1	0.03
Synovial joints in humans	0.01	0.003

Note: All values are approximate. In some cases, the coefficient of friction can exceed 1.0.


For small applied forces, the magnitude of the force of static friction equals the magnitude of the applied force.
When the magnitude of the applied force exceeds the magnitude of the maximum force of static friction, the trash can breaks free and accelerates to the right.
$\vec{\mathbf{n}}$
$\vec{\mathbf{f}}_s$
$\vec{\mathbf{F}}$
$m\vec{\mathbf{g}}$
Motion
$\vec{\mathbf{f}}_k$
a
b
$|\vec{\mathbf{f}}|$
$f_{s,\max}$
$f_s = F$
$f_k = \mu_k n$
F
O
Static region
Kinetic region
c