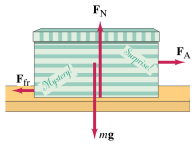
Static and kinetic friction between two flat surfaces

- **Opposes** the direction of motion or attempted motion
- Static if the object does not slide
- Static friction can increase to a maximum

$$0 \le f_s \le f_{s,\max} = \mu_s F_N$$

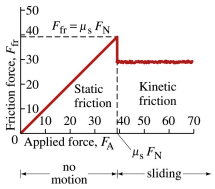


- Kinetic friction if it does slide

$$f_k = \mu_k F_N$$

- Generally speaking

$$f_k < f_{s,\max} \quad \therefore \ \mu_k < \mu_s$$



Coefficients of friction

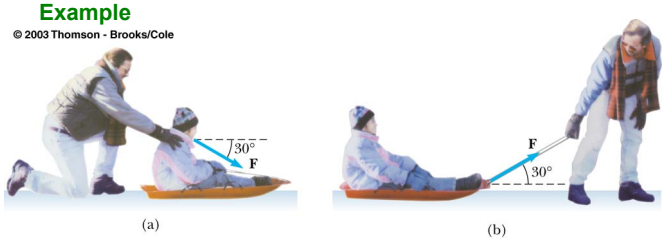
$$f \le \mu_s N$$
$$f = \mu_k N$$
$$\mu_s > \mu_k$$

TABLE 4.2 Coefficients of Friction[a]

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

[a] All values are approximate.

Example

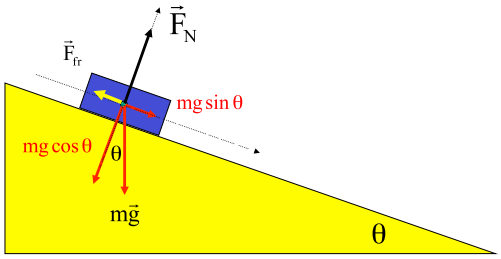


The man pushes/pulls with a force of 200 N. The child and sled combined have a mass of 30 kg, and the coefficient of kinetic friction between sled and ground is μ_k=0.15. For each case:

(a) What is the frictional force opposing his efforts?
(b) What is the acceleration of the child?

f_k=59 N, a=3.80 m/s^2 / f_k=29.1 N, a=4.8 m/s^2

Measuring coefficients of friction

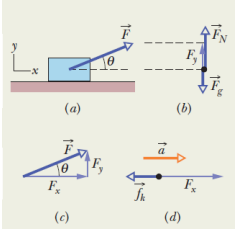


$\mu_s = \tan\theta$ This θ is when the block is on the verge of slipping

$\mu_k = \tan\theta$ This θ is when the block has constant velocity down the plane (acceleration is 0)

Example

What is the optimal angle to pull a block in order to maximize the acceleration if the coefficient of kinetic friction is μ_k=0.40?



Example

What is the acceleration of the system when friction present?