

Kinetic and static friction: the formulas, the coefficient of friction table and the normal force

Kinetic (sliding) friction	$f = \mu_k N$	fixed once the object slides; opposes the sliding
Static friction	$f_s \leq \mu_s N$	adjusts to the push, up to the maximum $\mu_s N$; equals it only on the point of sliding
Normal force, flat ground	$N = mg$	add an extra downward push, subtract an upward pull
Normal force, slope of angle θ	$N = mg \cos \theta$	down-slope pull $mg \sin \theta$; sliding starts when $\tan \theta = \mu_s$

μ is a number with no units for a PAIR of surfaces, measured not calculated; μ_s is nearly always larger than μ_k (harder to start than to keep moving; a rolling tyre grips better than a skidding one). Friction does not depend on the contact area or (in the school model) on the speed.

Coefficient of friction table (typical textbook values)

Surfaces	μ_s static	μ_k kinetic
rubber on dry concrete	1.0	0.8
rubber on wet concrete	0.7	0.5
glass on glass	0.94	0.4
steel on steel, dry	0.74	0.57
aluminium on steel	0.61	0.47
copper on steel	0.53	0.36
wood on wood	0.25 to 0.5	0.2
wood on concrete	0.6	0.5
steel on steel, lubricated	0.15	0.06
waxed ski on wet snow	0.14	0.1
waxed ski on dry snow		0.04
ice on ice	0.1	0.03
Teflon on Teflon	0.04	0.04
human joint (synovial fluid)	0.01	0.003

Static against kinetic

	Static	Kinetic
when	not sliding	sliding
size	whatever prevents sliding, up to $\mu_s N$	$\mu_k N$, fixed
example	parked car on a hill; a box not yet moving	sledge on snow; skidding tyre; sliding box

Method for every problem: draw the forces (weight, normal, friction, pushes), find N from the forces perpendicular to the surface, friction = μN , net force along the surface, then $F = ma$.

From

sciencewithshobha.com/blog/kinetic-friction-formula-f-mu-n-static-against-kinetic-friction-the-coefficient-of-friction-table-for-common-surfaces-and-worked-examples-with-a-printable-sheet/ · 1-on-1 online physics and chemistry, free 30-minute first class.

Worked examples and practice

The question	The working	The answer
10 kg box slides, $\mu_k = 0.3$: friction?	$0.3 \times 10 \times 9.8$	29.4 N
push to keep it at constant speed	equals the friction	29.4 N
push to start it, $\mu_s = 0.4$	0.4×98	39.2 N
pushed with 60 N while sliding: acceleration	$(60 - 29.4) \div 10$	3.06 m/s ²
1,200 kg car skids, $\mu_k = 0.8$, from 20 m/s: stopping distance	$a = 0.8 \times 9.8 = 7.84$; $d = v^2/2a$	25.5 m
same car on a wet road, $\mu_k = 0.5$	$a = 4.9$; $d = 400/9.8$	40.8 m
5 kg block on a 30° slope, $\mu_k = 0.2$	$N = 42.4$ N; $f = 8.5$ N; pull = 24.5 N; net 16 N	$a = 3.2$ m/s ² down the slope
angle at which a book slides, $\mu_s = 0.35$	$\tan \theta = 0.35$	19.3°

Practice

- [] 1. A 15 kg box slides with $\mu_k = 0.25$: friction?
- [] 2. The push for constant speed?
- [] 3. If $\mu_s = 0.35$, the push to start it?
- [] 4. Pushed with 80 N while sliding: acceleration?
- [] 5. A 900 kg car skids with $\mu_k = 0.7$ from 25 m/s: stopping distance?
- [] 6. A 30 kg sledge on snow, $\mu_k = 0.05$: friction and the pull for constant speed?
- [] 7. A 4 kg block on a 20° slope, $\mu_s = 0.5$: does it slide? Show both forces.
- [] 8. The same block sliding on a 35° slope, $\mu_k = 0.3$: acceleration?
- [] 9. Someone leans 50 N on a sliding 10 kg box, $\mu_k = 0.3$: friction?
- [] 10. A book slides off a desk tilted to 25°: μ_s ?

Answers

- 1) 36.75 N 2) 36.75 N 3) 51.45 N 4) 2.88 m/s² 5) $a = 6.86$, $d = 45.6$ m 6) 14.7 N; 14.7 N 7) pull 13.4 N, max static friction 18.4 N: no 8) pull 22.5 N, friction 9.6 N, $a = 3.2$ m/s² 9) $N = 148$ N, $f = 44.4$ N 10) $\tan 25^\circ = 0.47$

Draw the force diagram for question 7