Static Friction

Physics | JEE Main & Advanced

Don't Memorize. Visualize.

> Static friction is as large as it needs to be to stop sliding, and no larger. It matches the push, up to its limit $\mu_s N$. It is not always $\mu_s N$.

STATIC FRICTION

The friction on a body that is not sliding. It takes whatever value keeps the body at rest.

Its largest value is $\mu_s N$.

NORMAL FORCE N

The push of the surface on the body, at right angles to the surface.

On a level floor with no other vertical force, $N = mg$.

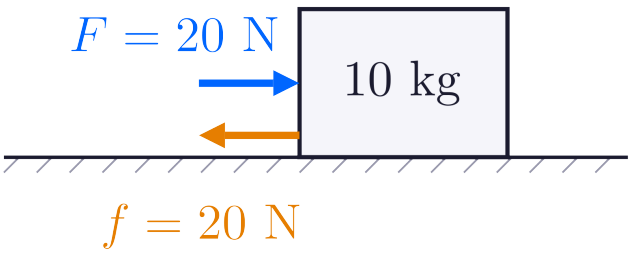
The block in the Short

A 10 kg block rests on a floor with $\mu_s = 0.5$; take $g = 10\ \mathrm{m\,s^{-2}}$.

The limit

$N = mg = 100$ N, so the most static friction can give is

$$\mu_s N = 0.5 \times 100 = 50\ \mathrm{N}.$$



Push with $F = 20$ N. The block does not move, so the forces on it balance:

$$f = F = 20\ \mathrm{N}.$$

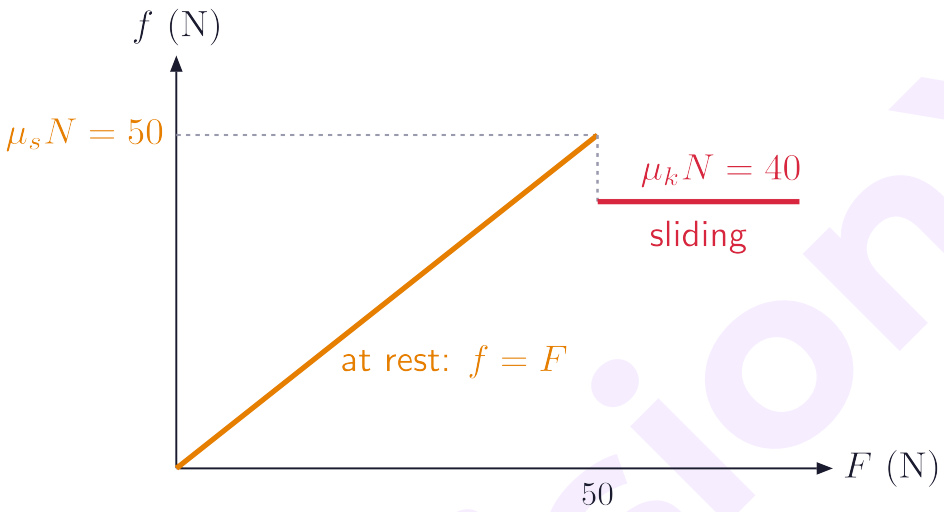
Not 50 N: friction only matches what is trying to move the block.

Why friction cannot be 50 N here

If friction were 50 N against a 20 N push, the net force would be 30 N backwards, and the block would start sliding towards the person pushing it. Static friction opposes sliding between the two surfaces; it can never start the block sliding the other way. So at rest it takes exactly the value that balances the push.

The whole story in one graph

As the push grows from zero, friction grows with it, equal to it, until it reaches $\mu_s N$. Push past that and the block slides; friction then becomes kinetic, $\mu_k N$, which is usually a little smaller (here $\mu_k = 0.4$, so 40 N).



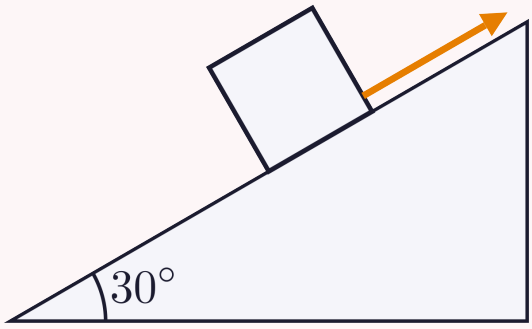
CAREFUL

On an incline the same trap appears. A 2 kg block rests on a $30°$ slope with $\mu_s = 0.7$. Friction is **not** $\mu_s mg\cos 30° \approx 12.12$ N. It only has to hold the block against the pull down the slope:

$$f = mg\sin 30° = 2 \times 10 \times \tfrac{1}{2} = 10 \text{ N}.$$

12.12 N is only the limit; the block stays because $10 < 12.12$.

$$f = mg\sin 30° = 10 \text{ N}$$



Solved example

The same 10 kg block ($\mu_s = 0.5$, $\mu_k = 0.4$) is pushed with 35 N, then with 60 N. Find the friction each time.

35 N. The limit is 50 N and $35 < 50$, so the block stays at rest: $f = 35$ N.

60 N. $60 > 50$, so the block slides: $f = \mu_k N = 0.4 \times 100 = 40$ N.

35 N, then 40 N

Key formulas

at rest: $f =$ the force trying to slide the body, $f \le \mu_s N$

sliding: $f = \mu_k N$ level floor: $N = mg$

Practice set

Easy to hard. Take $g = 10\ \mathrm{m\,s^{-2}}$. The answers start on the next page.

Q1. Quiz from the Short. A box on a level floor starts sliding when it is pushed horizontally with 50 N. It is pushed with 20 N. The friction on it is: (A) 20 N (B) 50 N (C) 0 N.

Q2. A 5 kg block rests on a level floor with $\mu_s = 0.4$ and $\mu_k = 0.3$. It is pushed horizontally with 25 N. Find the friction.

Q3. Find the least horizontal force that starts a 20 kg box moving if $\mu_s = 0.25$.

Q4. A 2 kg block rests on a 30° incline with $\mu_s = 0.7$. Find the friction on it.

Q5. A 1 kg book is pressed against a wall by a horizontal force of 50 N, and $\mu_s = 0.5$. Find the friction on the book.

Q6. A 4 kg block on a floor ($\mu_s = 0.5$, $\mu_k = 0.4$) is pulled horizontally with a force that rises slowly from zero. Find the friction when the pull is 10 N, 20 N and 30 N.

Watch the animated lesson on YouTube

Static Friction (Short)

Scan the code to open the JEEVisionX channel on YouTube. This lesson is in the JEE Concepts Visualization Shorts playlist.

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Answers

Q1

(A) 20 N

The largest static friction is 50 N, and 20 N is less, so the box stays at rest. At rest the forces balance: friction matches the push, 20 N. 50 N is only the limit.

Q2

15 N (kinetic)

$N = 50$ N, so the limit is $\mu_s N = 0.4 \times 50 = 20$ N. $25 > 20$, so the block slides: $f = \mu_k N = 0.3 \times 50 = 15$ N.

Q3

50 N

It starts when the push just exceeds $\mu_s N = 0.25 \times 200 = 50$ N.

Q4

10 N, up the slope

$f = mg \sin 30^\circ = 10$ N. The limit $\mu_s mg \cos 30^\circ = 7\sqrt{3} \approx 12.12$ N is larger, so the block stays at rest.

Q5

10 N, upwards

$N = 50$ N, so the limit is 25 N. Friction only holds the weight: $f = mg = 10$ N.

Q6

10 N, 20 N, 16 N

Limit $0.5 \times 40 = 20$ N. At 10 N and 20 N the block is at rest, so f equals the pull. Past 20 N it slides: $f = 0.4 \times 40 = 16$ N.

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