FORCES DAY 7: INCLINED PLANES

WARMUP **Day 5–6 Review**

A 10 kg crate is pushed horizontally with 50 N on a level floor with $\mu_k = 0.30$. Find the acceleration — FBD, friction, then $\Sigma F = ma$.

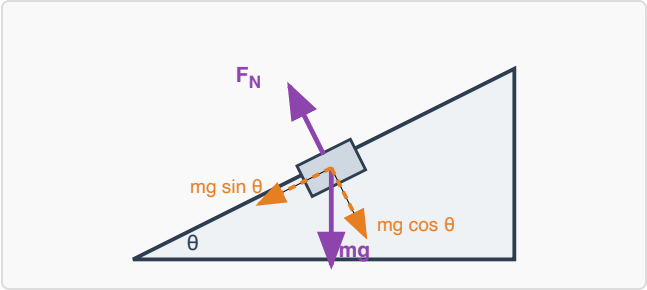
Physics in the Wild — The Runaway Truck Ramp: On steep mountain highways you'll see gravel ramps angling up off the shoulder. A truck with failed brakes steers in, and the ramp does the stopping with today's two tools: an uphill component of gravity (mg sin θ working against the motion) and deep gravel (enormous friction). Engineers size the angle and length with exactly the equations on this page.

GRAVITY, SPLIT ALONG THE RAMP

Tilt the axes to match the incline. Gravity splits into:

- **mg sin θ** — along the ramp, pulling downhill
- **mg cos θ** — into the ramp, balanced by $F_N = mg \cos \theta$

Frictionless: **$a = g \sin \theta$** — the mass cancels.
With friction: **$a = g(\sin \theta - \mu_k \cos \theta)$**



FRICTIONLESS FIRST

WE DO Exercise 1: The Mass That Cancels (Again)

A block slides down a frictionless 30° incline. **(a)** Find its acceleration. **(b)** A 5.0 kg block and a 50 kg block are released together — which reaches the bottom first? Justify with the equation, not a guess.

YOU DO Exercise 2: Normal Force on a Slope

A 4.0 kg block rests on a 37° incline. Find the normal force. Compare your answer to mg = 39.2 N: why is F_N smaller on a slope than on level ground?

sin or cos? Test the extremes. At θ = 0° the ramp is flat: nothing pulls along it (sin 0 = 0 ✓) and F_N = mg (cos 0 = 1 ✓). At θ = 90° it's a wall: full g along (sin 90 = 1 ✓), zero normal force (cos 90 = 0 ✓). If your formula fails the extremes, the sin and cos are swapped.

NOW ADD FRICTION

WE DO **Exercise 3: Sliding Down with Friction**

A crate slides down a 30° ramp with $\mu_k = 0.20$. Find the acceleration using $a = g(\sin\theta - \mu_k \cos\theta)$, keeping units visible. *Friction uses $F_N = mg\cos\theta$ — the slope version, not mg.*

YOU DO **Exercise 4: The Constant-Velocity Confession**

A block slides down a 37° ramp at *constant velocity*. **(a)** What does constant velocity tell you about $mg\sin\theta$ versus the friction force? **(b)** Show that $\mu_k = \tan\theta$ and compute it.

PAPER PRACTICE

PRACTICE PROBLEMS

P1 Steep and Frictionless

Find the acceleration of a block sliding down a frictionless 53° incline.

P2 Normal Force

A 10 kg crate rests on a 30° ramp. Find the normal force.

P3 Coasting Uphill

A skateboarder rolls up a frictionless 30° ramp at 12 m/s. **(a)** Find the deceleration. **(b)** How far up the ramp does she travel before stopping?

P4 The Critical Angle

A box sits on a board with $\mu_s = 0.40$. The board is slowly tilted. At what angle does the box begin to slide?

Hint: at the critical angle, $mg \sin\theta$ exactly equals the maximum static friction $\mu_s mg \cos\theta$.