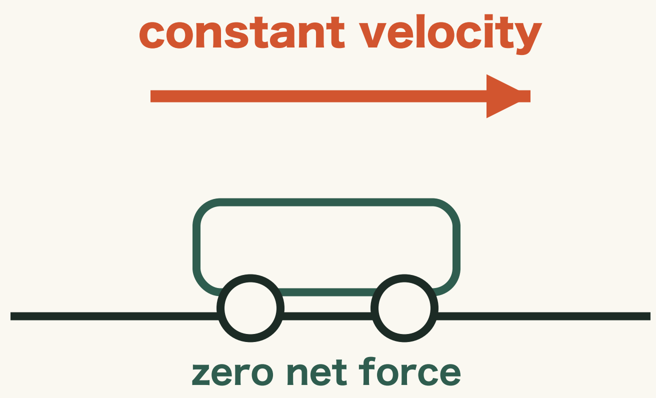
FORCES & MOTION

Newton's First Law

Motion does not need a force to continue. A change in motion does.

ESSENTIAL QUESTION

If a moving object naturally keeps moving, why do everyday objects slow down and stop?



LESSON MAP

Replace an everyday illusion with a precise rule.

01

QUESTION

Does force sustain motion, or does friction hide the truth?

02

IDEALISE

Reduce resistance and extend Galileo's pattern.

03

STATE

Connect zero net force to constant velocity.

04

APPLY

Use inertia to predict what happens next.

A SCIENTIFIC HABIT

When observation and explanation disagree, identify the hidden influence before changing the rule.

OBSERVE

A coasting scooter slows down - but why?

The same observation supports two explanations. Only one survives a better test.

FIRST GUESS

“Motion runs out without a push.”

This treats force as something that must continually maintain velocity.

BETTER EXPLANATION

Resistance changes the motion.

Rolling resistance and air drag produce a backward net force, so the scooter slows.

QUESTION

Friction can disguise an object's natural motion.

Galileo challenged the old conclusion by changing the conditions of the test.

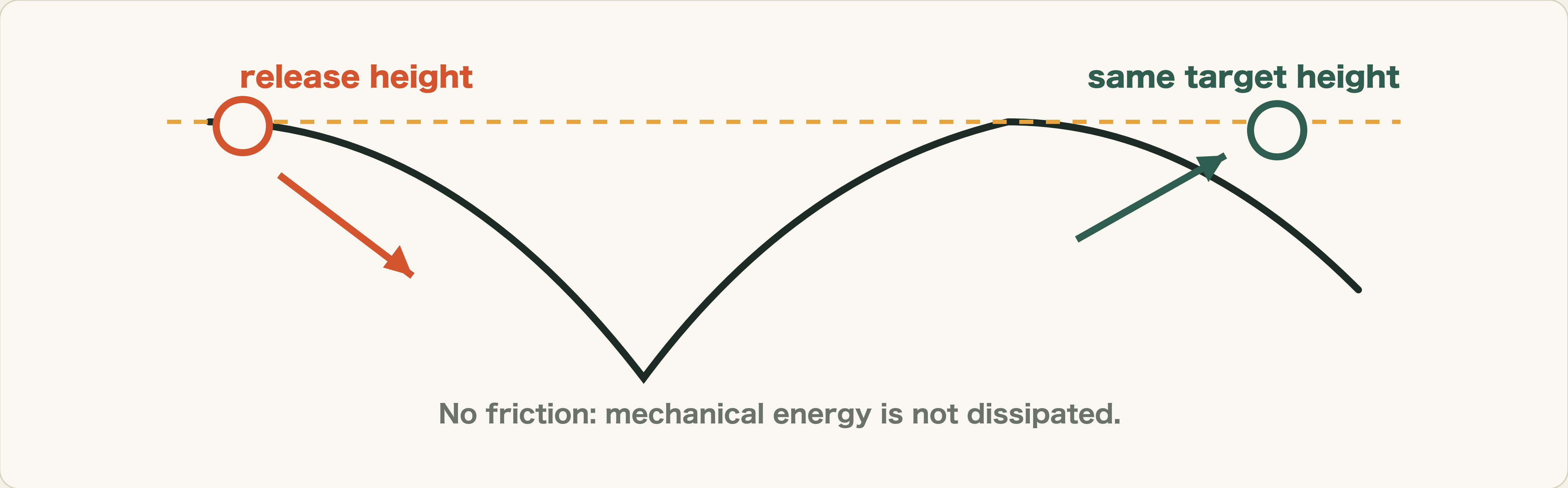
1. **Everyday observation**
   Objects on rough surfaces slow down quickly.
2. **Change one influence**
   Make the surface smoother, so friction becomes smaller.
3. **Follow the pattern**
   With less friction, the object travels farther before stopping.
4. **Idealise**
   Ask what would happen in the limit of zero resistance.

A force is needed to overcome resistance - not to sustain velocity itself.

IDEALISE

On a frictionless track, the ball regains its original height.

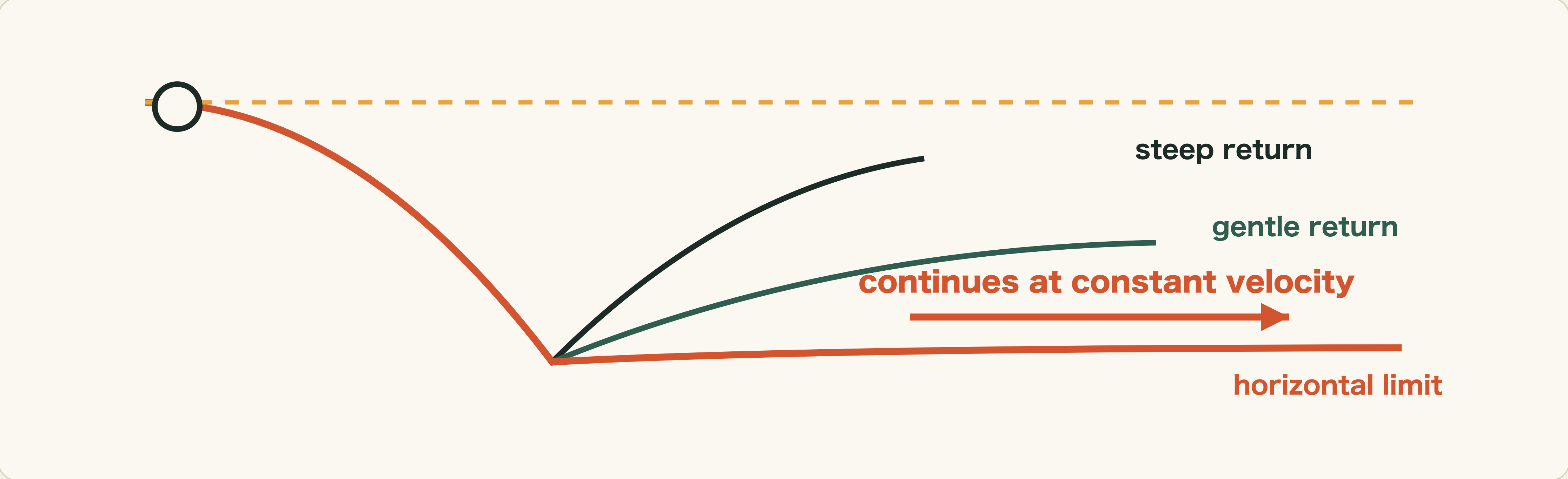
The upward slope changes the direction of motion, but the target height stays the same.



EXTRAPOLATE

Flatten the second slope, and the ball travels farther.

In the horizontal limit, it can never regain the height - so it never stops.



The ideal experiment combines real evidence with logical extrapolation.

STATE

Zero net external force means constant velocity.

In an inertial reference frame, rest is simply constant velocity equal to zero.

$$\sum \vec{F}_{\mathrm{ext}} = 0 \quad \Longrightarrow \quad \frac{\mathrm{d}\vec{v}}{\mathrm{d}t} = 0$$

AT REST

$$\vec{v} = 0$$

Position stays unchanged.

MOVING

$$\vec{v} = \text{constant}$$

Speed and direction stay unchanged.

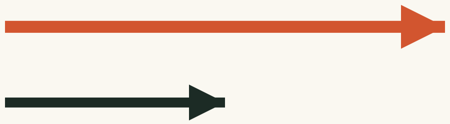
INTERPRET

Force changes velocity - not merely position.

A net force is required for speeding up, slowing down, or turning.

01

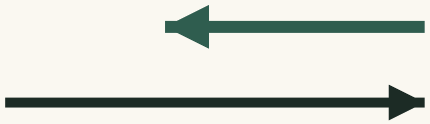
Speed up



Net force points with velocity; the speed increases.

02

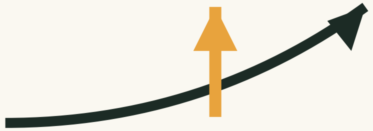
Slow down



Net force opposes velocity; the speed decreases.

03

Turn

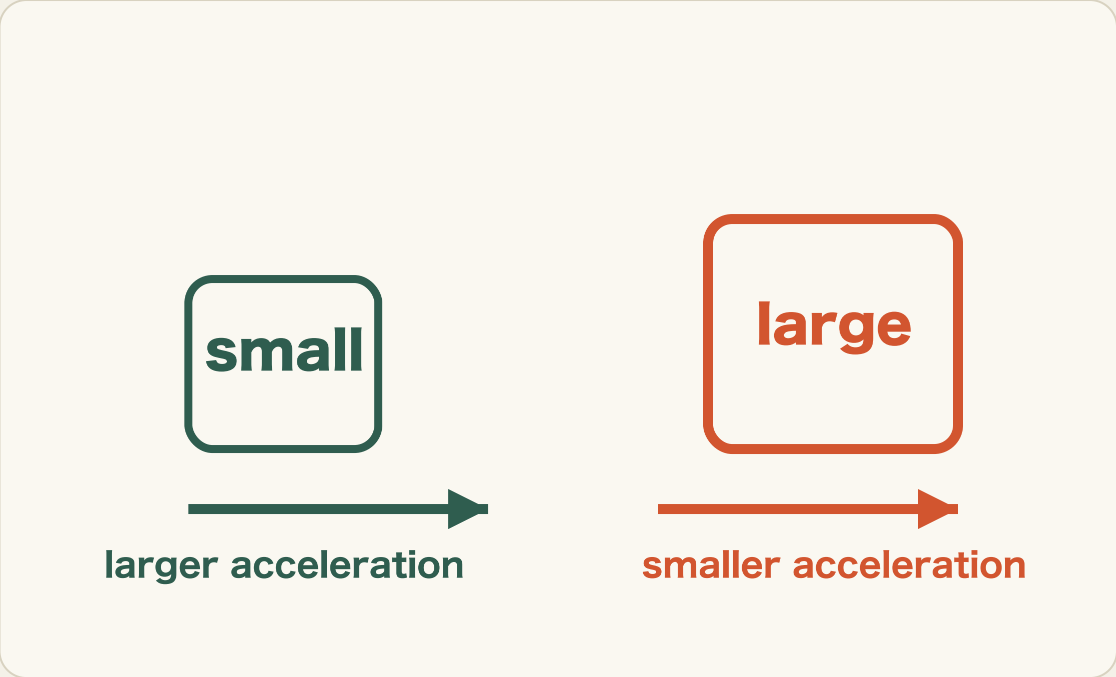


A sideways net force changes direction, even at constant speed.

DEFINE

Inertia is resistance to a change in velocity.

Every object has inertia. Mass measures how strongly an object resists acceleration.



1. **Inertia is a property**
   It is not a force and does not need to be "activated".

2. **More mass, more inertia**
   The same net force produces less acceleration.

3. **Motion does not add inertia**
   At a given mass, an object has the same inertia whether moving or at rest.

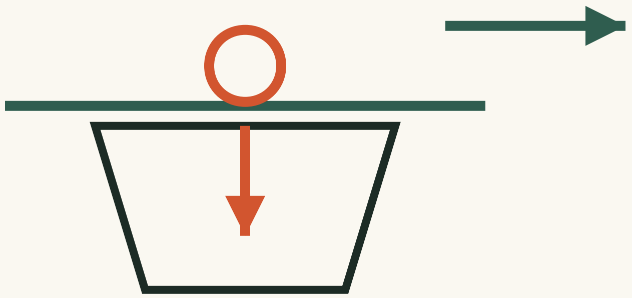
OBSERVE

Quickly remove the support; the object barely moves.

A short interaction gives little time for friction to change the object's horizontal velocity.

CARD AND COIN

The coin falls into the glass



The card moves sideways; gravity then pulls the nearly stationary coin down.

TABLECLOTH AND DISHES

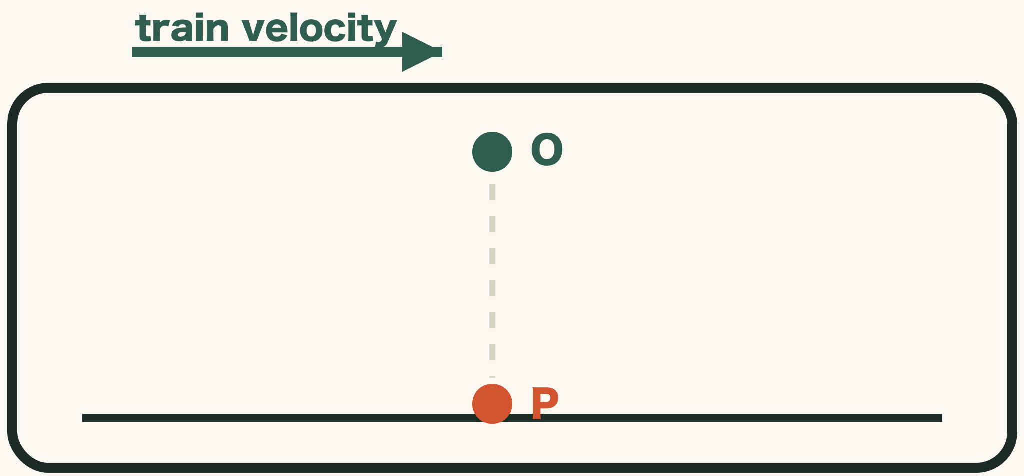
The dishes remain nearly in place

A fast pull limits the friction impulse transferred to the dishes.

APPLY

A falling drop keeps the train's forward velocity.

Inside a constant-velocity train, the drop lands directly below its release point.



Same horizontal velocity as the train throughout the fall

1. **Before release**
   Drop and train share the same forward velocity.
2. **During the fall**
   Gravity changes the vertical velocity, not the horizontal velocity.
3. **Result**
   Relative to the train, the drop falls straight down from O to P.

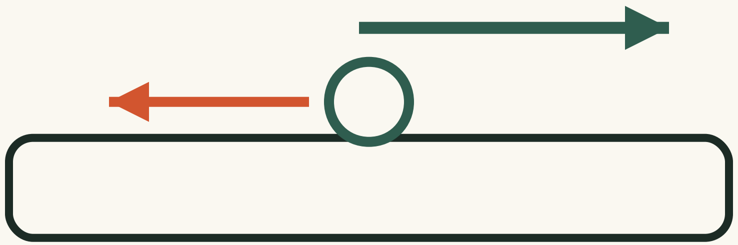
DIAGNOSE

Loose objects reveal a vehicle's acceleration.

They tend to preserve their previous velocity while the vehicle changes velocity beneath them.

VEHICLE ACCELERATES FORWARDS

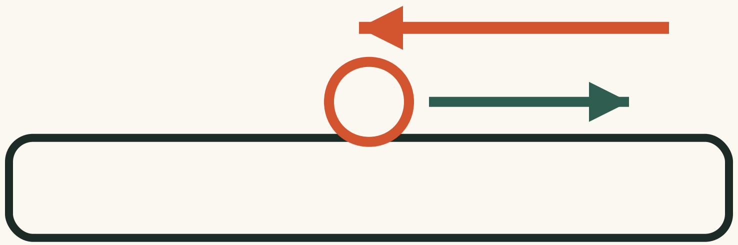
Loose objects lag backwards



Passengers lean back; liquid rises towards the rear.

VEHICLE BRAKES

Loose objects continue forwards



Passengers pitch forwards; liquid rises towards the front.

Describe acceleration, not just the vehicle's direction of travel.

COMMON TRAPS

Repair three misleading statements.

Precise language prevents incorrect force diagrams and predictions.

01

“Force keeps an object moving.”

Net force changes velocity. Zero net force preserves velocity.

02

“An object moves because of inertia.”

Inertia is a property, not a force. It describes resistance to velocity change.

03

“No net force means no forces.”

Several forces may act and balance so their vector sum is zero.

SUMMARY

An object does not need a net force to keep moving. It needs a net force only to change its velocity. Everyday objects stop because resistance supplies that force.

PROBLEM ROUTE

Choose the object → identify external forces → find the net force → decide whether velocity must stay constant or change.