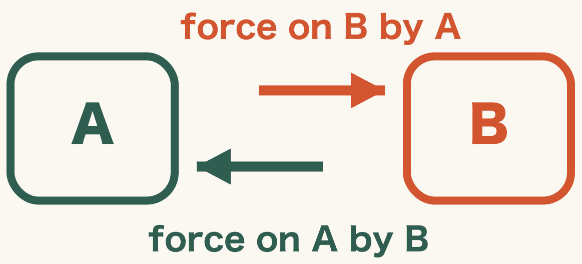
FORCES & MOTION

Newton's Third Law

Every force belongs to an interaction between two objects.



ESSENTIAL QUESTION

If interaction forces are equal and opposite, how can either object accelerate?

LESSON MAP

Build the idea in four moves.

01 — OBSERVE

A force never appears alone.

02 — PAIR

Name both objects and both forces.

03 — SEPARATE

Do not confuse pairs with balance.

04 — APPLY

Use one free-body diagram at a time.

THE HABIT

For every force, ask: “Which object exerts it, and which object receives it?”

OBSERVE

The rower moves because the water pushes back.

The oar pushes water backwards; the water pushes the oar and boat forwards.

1 **Boat acts on water**

The oars accelerate water backwards.

2 **Water acts on boat**

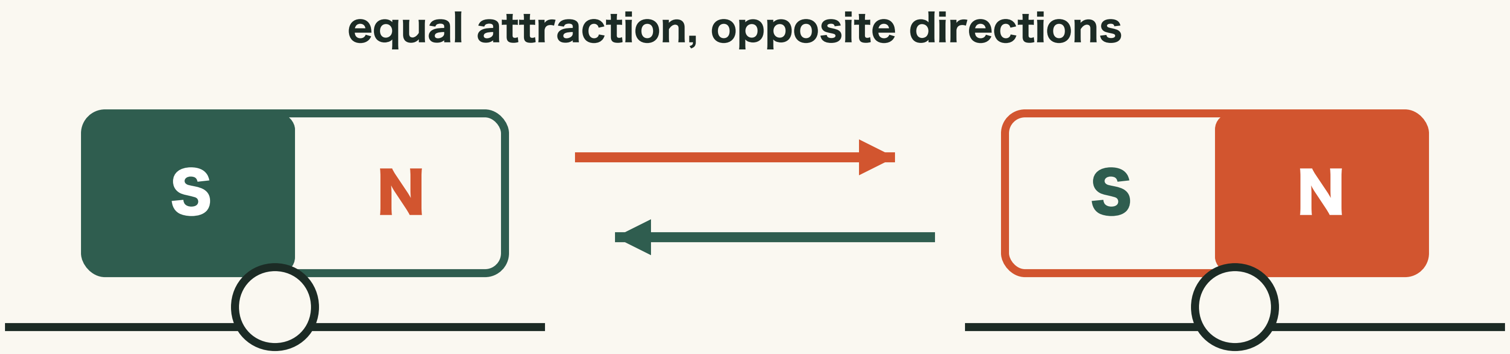
The water accelerates the boat forwards.

3 **One interaction**

The two forces exist together.

Contact is not required for an interaction.

Magnets, charged particles, and gravitating masses exert forces across space.



Forces reveal interactions, not necessarily touching.

MODEL

Every interaction produces a matched pair.

The force on A by B is equal in magnitude and opposite in direction to the force on B by A.

$$\vec{F}_{A\leftarrow B} = -\vec{F}_{B\leftarrow A}$$

SAME MAGNITUDE

$$|\vec{F}_{A\leftarrow B}| = |\vec{F}_{B\leftarrow A}|$$

OPPOSITE DIRECTION

The minus sign records opposite vectors.

DIFFERENT OBJECTS

One force acts on A; the other acts on B.

CHECK

A true third-law pair passes four tests.

Use these tests before calling two forces an action–reaction pair.

01

Same interaction

Both forces have the same physical type: contact, gravity, electric, and so on.

02

Different objects

The forces act on the two partners, never on one object.

03

Equal & opposite

The vectors have equal magnitude and opposite direction.

04

Simultaneous

They begin, change, and disappear together.

COMPARE

Third-law pairs are not balanced forces.

The difference is not size or direction. It is which object receives each force.

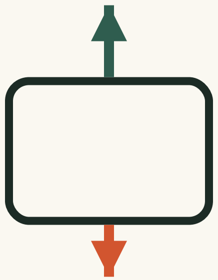
INTERACTION PAIR

Forces act on different objects

They cannot cancel on a single free-body diagram.

BALANCED FORCES

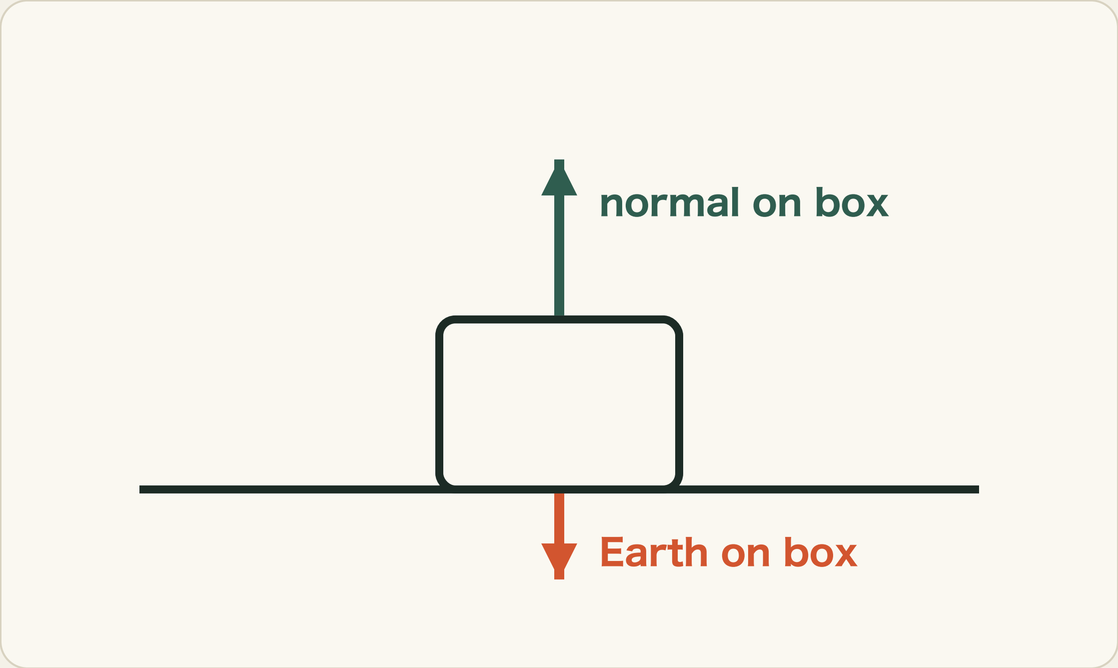
Forces act on the same object



They may add to zero, giving zero acceleration.

Draw one object at a time.

Only forces acting on the chosen object belong on its diagram.



1. **Choose the object**
   Here, the box is the system.

2. **List forces on it**
   The table's normal force and Earth's gravitational force act on the box.

3. **Keep partners elsewhere**
   The box-on-table and box-on-Earth forces belong to other diagrams.

DERIVE

Equal forces can produce unequal accelerations.

The third law fixes the force pair; the second law connects each force to its object's mass.

OBJECT A

$$a_A = \frac{F}{m_A}$$

OBJECT B

$$a_B = \frac{F}{m_B}$$

$$\frac{a_A}{a_B} = \frac{m_B}{m_A}$$

The lighter object accelerates more, even though both experience the same force magnitude.

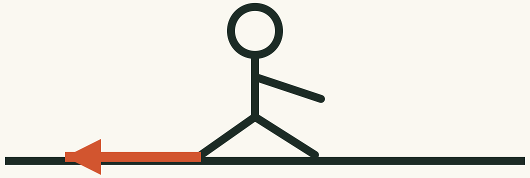
APPLY

Motion follows from pushing on something else.

Walking, rowing, and rockets use the same interaction logic.

01

Walking



You push the ground backwards; static friction pushes you forwards.

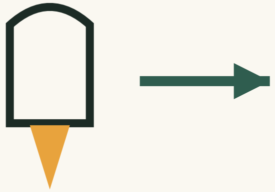
02

Rowing

The oars push water backwards; water pushes the boat forwards.

03

Rocket

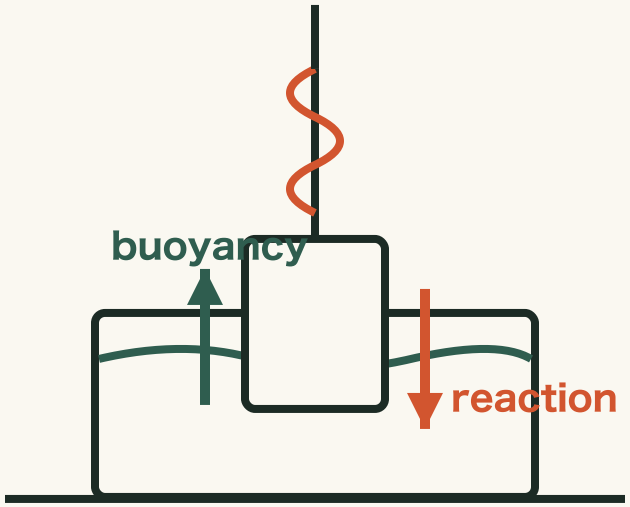


The engine pushes exhaust backwards; exhaust pushes the rocket forwards.

WORKED EXAMPLE

Buoyancy transfers a force to the scale.

A suspended 10 N block is partly immersed. The spring scale now reads 6 N.



1. FIND THE BUOYANT FORCE

$$F_B = 10\,\mathrm{N} - 6\,\mathrm{N} = 4\,\mathrm{N}$$

2. USE THE THIRD LAW

$$F_{\text{block on water}} = F_B = 4\,\mathrm{N}$$

The scale reading increases by $4\,\mathrm{N}$.

COMMON TRAPS

Three tempting statements are wrong.

Repair each statement by naming the objects carefully.

01

“The bigger object exerts more force.”

Wrong. Interaction forces are equal. The smaller mass usually accelerates more.

02

“The reaction happens afterwards.”

Wrong. Both forces exist and change at the same time.

03

“The pair cancels.”

Wrong for one object. The two forces act on different objects.

PROBLEM ROUTE

Use a reliable four-step method.

This route prevents nearly every action–reaction mistake.

01

Name the interaction.
Contact? Gravity? Electric? Magnetic?

02

Name both forces.
“Force on A by B” and “force on B by A”.

03

Choose one object.
Draw only the forces acting on that object.

04

Apply the second law.
Use the net force on the chosen object.

Third law identifies the pair. Second law predicts each object's motion.

SUMMARY

A force is one half of an interaction. Its partner is equal and opposite, acts on the other object, and appears at the same time. Separate the objects before analysing motion.

ANSWER TO THE ESSENTIAL QUESTION

Equal and opposite forces do not cancel on either object because they act on different objects.