AM-02.04 · SPACE ACADEMY

AM-02.04 — Force and Newton’s laws: why a rocket changes motion

How does force produce acceleration, and why does a rocket not need air to “push against”?

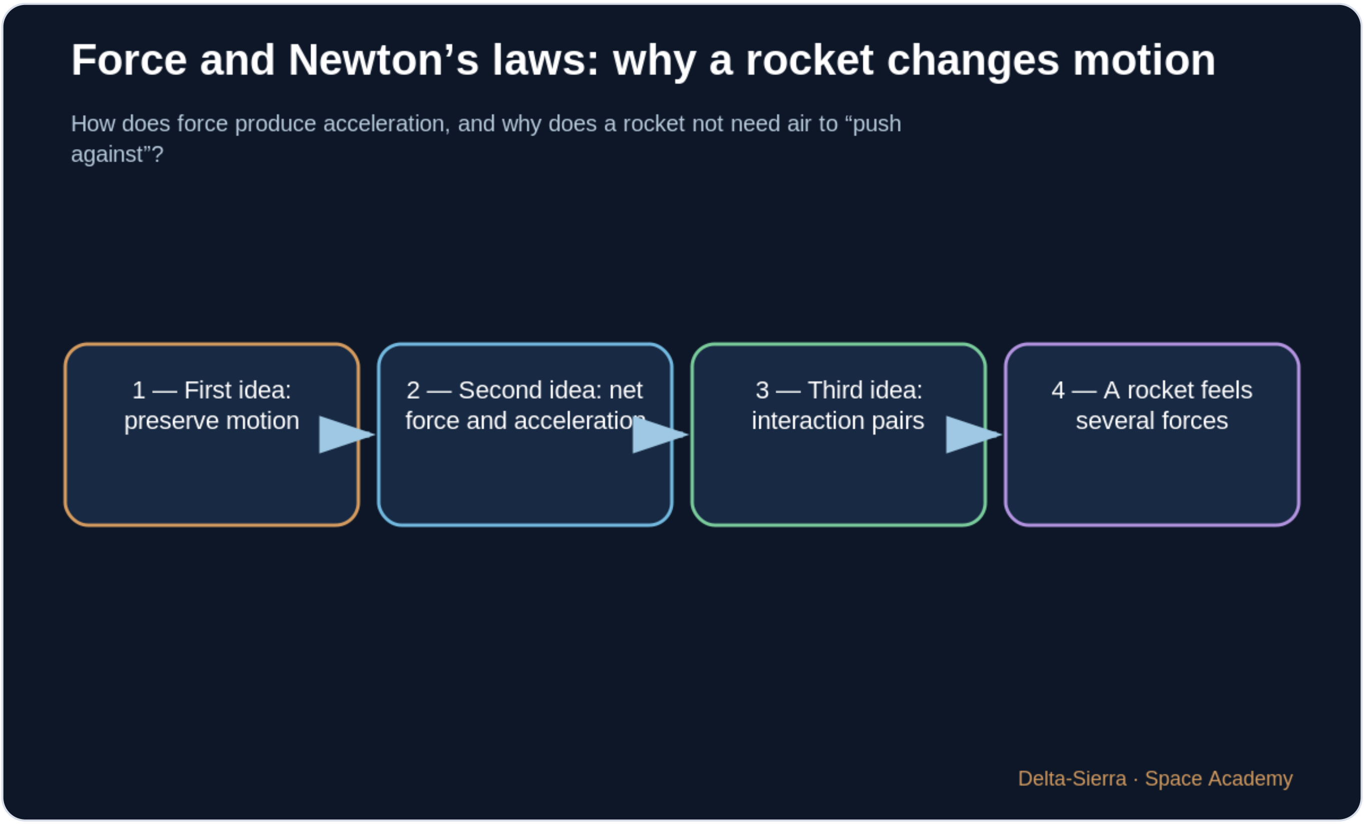
Course compass

Goal: understand every word, symbol, unit and operation before using the formula.

Method: concrete situation → vocabulary → step-by-step calculation → three examples → check.

1 — A force is a push or a pull

Rover wheels push, a cable pulls, the ground resists and gravity pulls downward. Each interaction can be represented by a force arrow with magnitude and direction.



Forces on a rover: drive, resistance, weight and ground reaction.

---

2 — Newton: the unit of force

$$1\ \mathrm{N} = 1\ \mathrm{kg} \cdot \mathrm{m/s^2}$$

N is read “newton”. One newton is the net force that gives 1 kg an acceleration of 1 m/s^2.

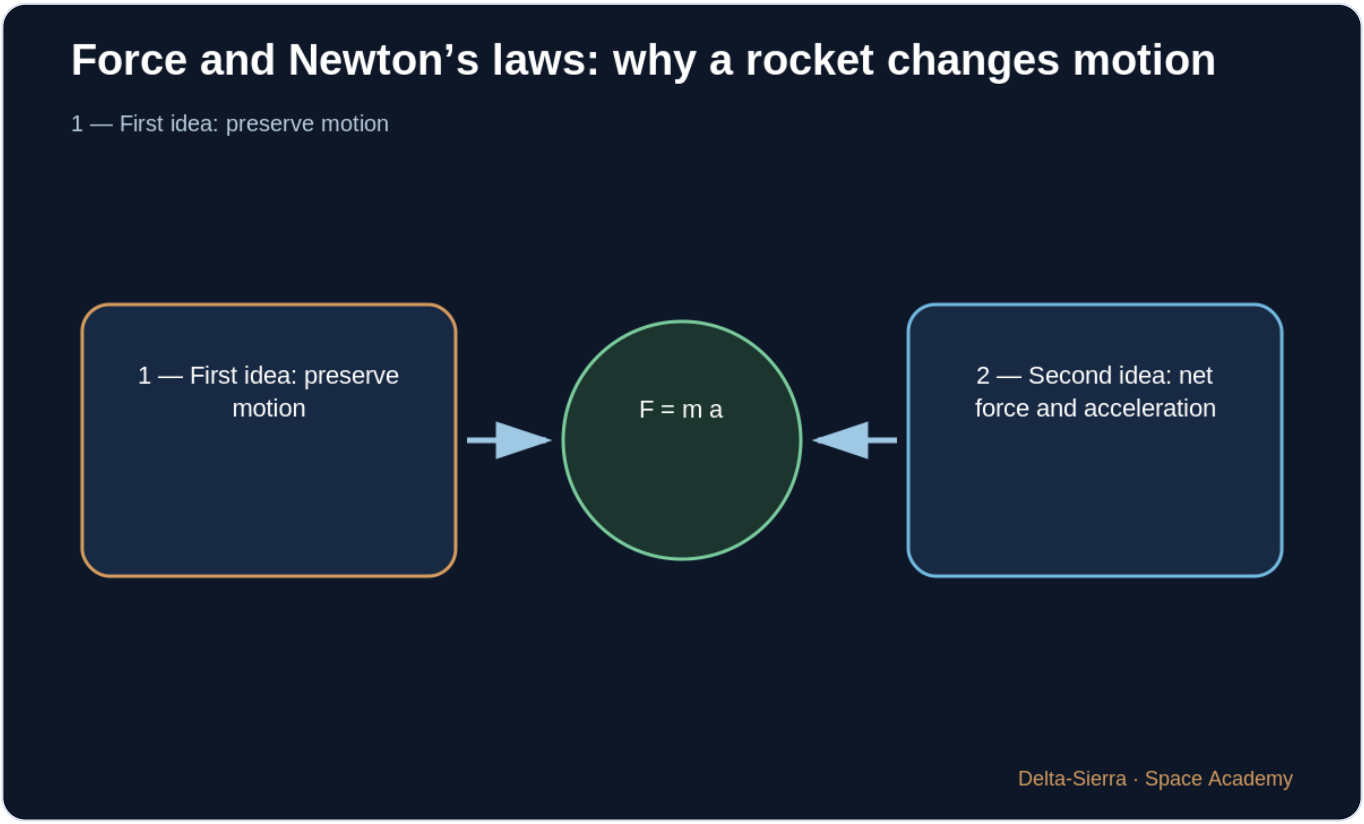
---

3 — Several forces combine into a net force

Engine force: +500 N east. Resistance: −200 N west.

```
F net = 500 − 200 = +300 N
```

Why subtract? The forces point in opposite directions.



Opposing forces can cancel fully or partly.

4 — Newton's first law: zero net force means no change in velocity

In the ideal model, an object at rest stays at rest and an object in uniform straight-line motion keeps that motion when net force is zero.

This is inertia.

5 — Newton's second law: F = m × a

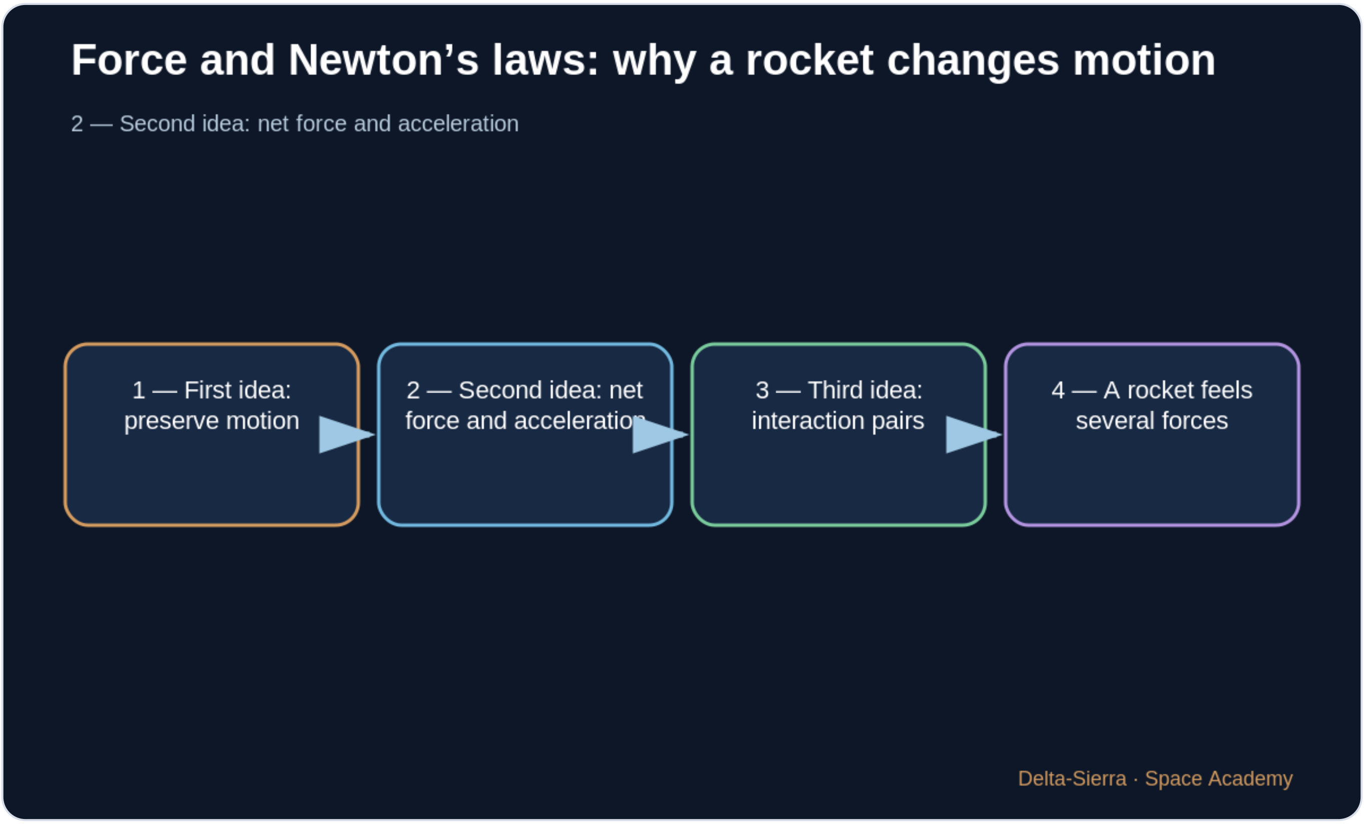
$$F = m \times a$$

Read: "F equals m times a".

A 150 kg rover has a net force of 300 N east.

```
a = F ÷ m = 300 ÷ 150 = 2 m/s²
```

Why divide by mass? For the same force, more mass changes velocity more slowly.



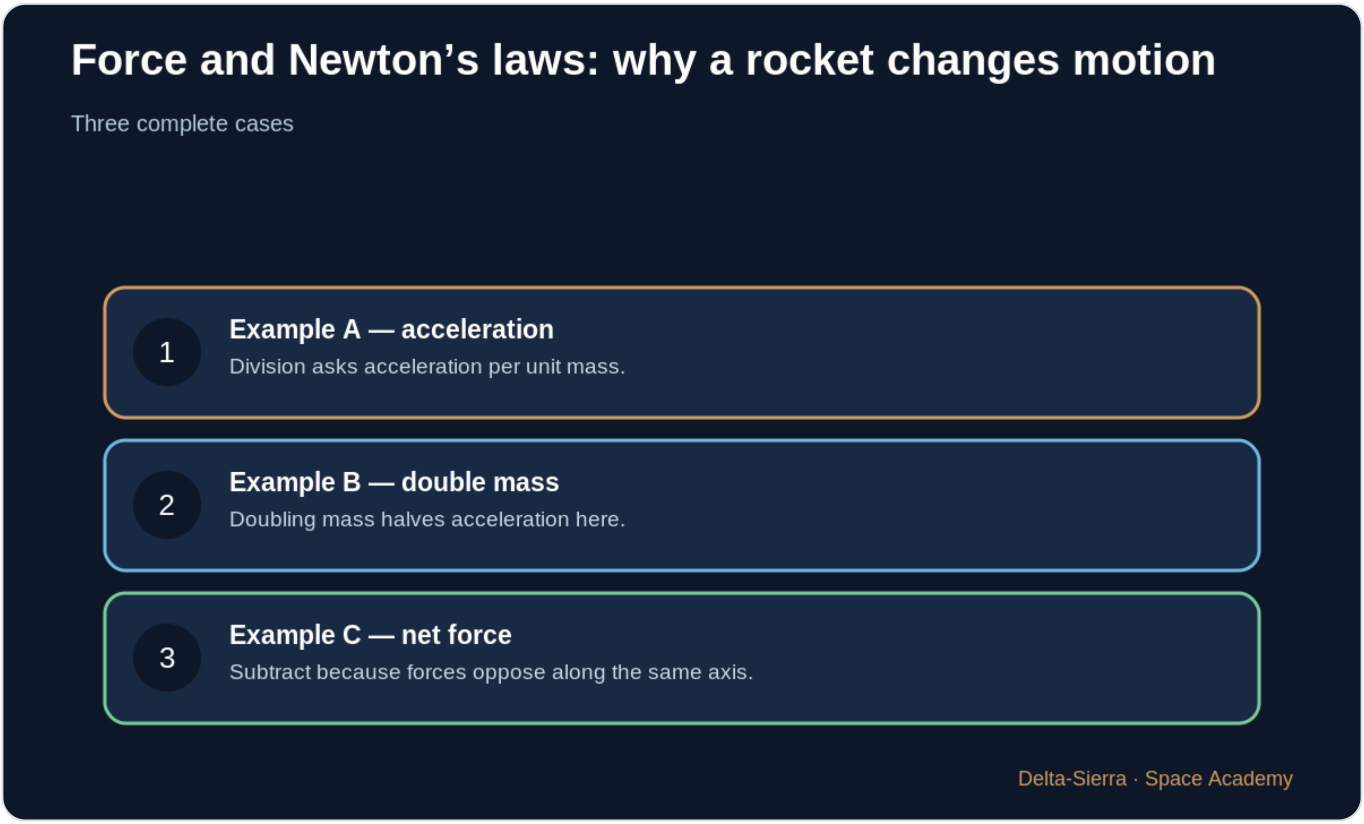
The same force produces less acceleration on a larger mass.

6 — Newton’s third law: action and reaction

If A exerts a force on B, B exerts an equal-magnitude opposite force on A. Rocket exhaust pushed backward pushes the engine forward.

> **Common trap:** action and reaction act on two different objects, so they are not cancelled inside the force balance of one object.

7 — Three guided examples



Rover, cable and thruster applications.

Example A — Accelerate a rover

```
400 N ÷ 200 kg = 2 m/s²
```

Example B — Balanced forces

```
+600 N − 600 N = 0 N
```

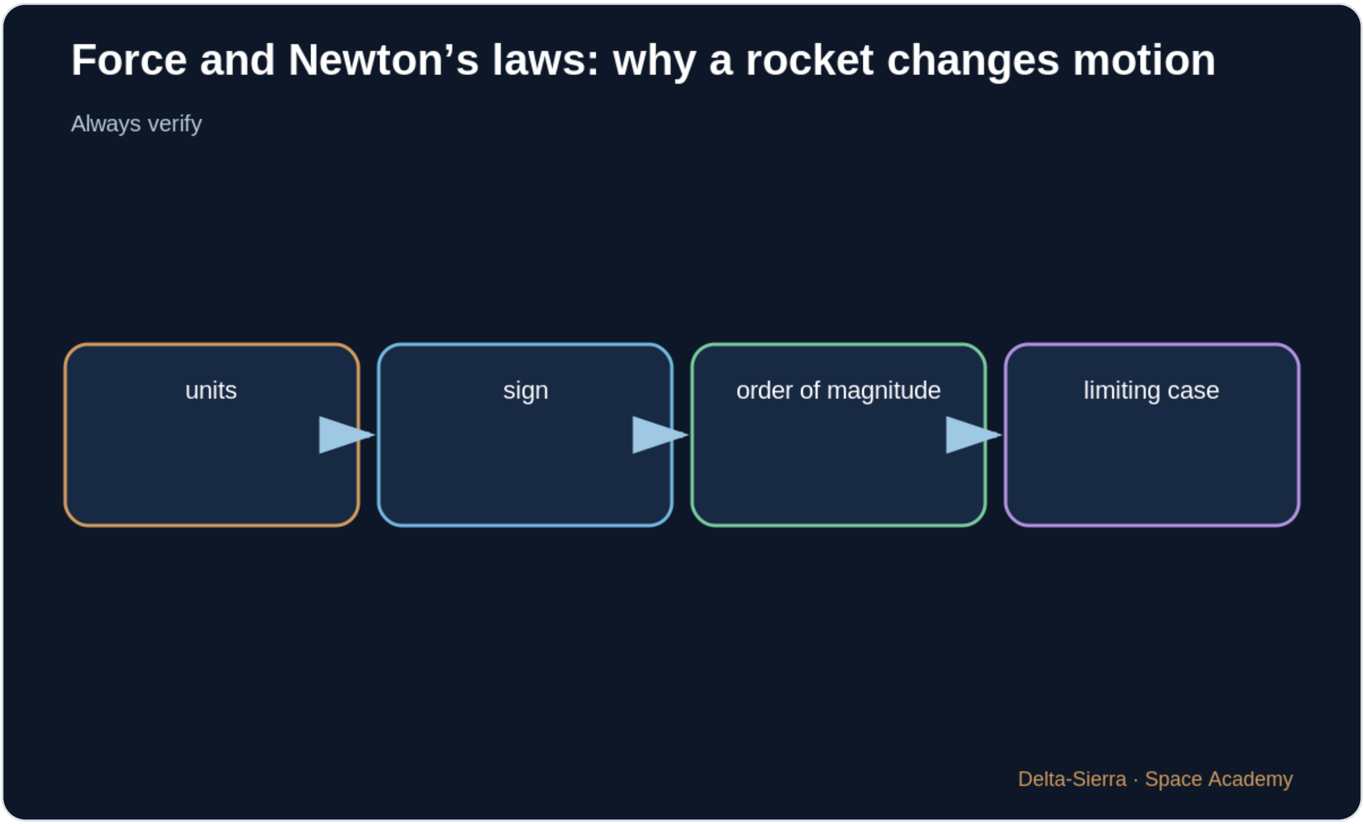
Example C — Required force

1,000 kg at 0.5 m/s^2.

```
F = 1,000 × 0.5 = 500 N
```

8 — Practical method: draw forces before writing equations

1. choose the object;
2. draw all forces acting on it;
3. choose positive direction;
4. sum components;
5. apply F = m × a.



Final check: object, real forces, directions, units and net force.

Beginner checkpoint — choose one object before adding forces

A force diagram becomes much easier when you first decide which single object is being studied. For a rover, include only forces acting on the rover: wheel-ground interaction, resistance, gravity, ground reaction and any cable force. Do not mix in the force that the rover exerts on the ground as though it also acted on the rover; that belongs to the action-reaction partner.

After choosing the object, select a positive direction and give each force a sign. Add the signed forces to obtain the net force. Only then use F = m × a. This order matters because Newton’s second law uses the *net* force, not one convenient force selected from the diagram.

9 — Corrected exercises

Exercise 1

800 N east and 300 N west?

500 N east.

Exercise 2

250 kg accelerating at 1.2 m/s²?

300 N net force.

Primary and educational sources

- NASA Glenn - Four Forces on a Rocket
- NASA Glenn - Rocket Thrust
- NASA Science - Basics of Space Flight: Gravity & Mechanics