Newton's second law: force, mass and acceleration

Physics · Grade 11 · Lesson handout · Sample lesson written for the DocReel demo

The big idea

Push an empty shopping cart and it speeds up quickly. Push a full one just as hard and it speeds up much more slowly. Newton's second law explains why: how quickly an object's velocity changes depends on two things, the **net force** acting on it and its **mass**.

> **Newton's second law.** The acceleration of an object is directly proportional to the net force on it and inversely proportional to its mass. The acceleration is in the same direction as the net force.
>
> $$F_{net} = m \times a \quad \text{or} \quad a = F_{net} \div m$$

- $\mathbf{F_{net}}$ is the net (total) force, in newtons (N). If several forces act, add them as vectors first.
- **m** is the mass, in kilograms (kg).
- **a** is the acceleration, in metres per second squared (m/s²).

One newton is the net force that gives a 1 kg mass an acceleration of 1 m/s². So 1 N = 1 kg·m/s².

Same force, different masses

When the net force stays the same, doubling the mass halves the acceleration. Here a net force of 60 N acts on three different carts:

Mass (kg)	Net force (N)	Acceleration (m/s²)
10	60	6
20	60	3
30	60	2

Worked example 1: finding the acceleration

A student pushes a 40 kg crate across the floor with a force of 200 N. Friction pushes back with 80 N. What is the crate's acceleration?

Net force: 200 N − 80 N = 120 N, in the direction of the push.
Acceleration: a = F_{net} ÷ m = 120 N ÷ 40 kg = **3 m/s²**.

The common mistake is to use the 200 N push instead of the net force. Friction is a force too, so it has to be included.

Worked example 2: finding the force

A 1,200 kg car speeds up from rest to 15 m/s in 6 seconds. What net force acts on it?

Acceleration: a = change in velocity ÷ time = 15 m/s ÷ 6 s = 2.5 m/s².
Net force: F_{net} = m × a = 1,200 kg × 2.5 m/s² = **3,000 N**.

Why do heavy and light objects fall at the same rate?

Gravity pulls harder on a heavier object: the force of gravity is F = m × g, where g is about 9.8 m/s² near Earth's surface. But a heavier object also has more mass to speed up. Put the two together: a = F ÷ m = (m × g) ÷ m = g. The mass cancels, so without air resistance every object falls with the same acceleration, about 9.8 m/s². A feather falls slowly in air only because air resistance is large compared with its tiny weight.

Two common misconceptions

- **"A moving object needs a force to keep it moving."** No. An object moving at a constant velocity has a net force of zero. A force is needed to *change* velocity: to speed up, slow down or turn.
- **"A bigger force always means a bigger speed."** No. Force sets the acceleration, the rate at which velocity changes, not the speed itself.

Practice questions

1. A net force of 15 N acts on a 5 kg box. What is its acceleration?
2. A 0.15 kg baseball accelerates at 40 m/s² when it is thrown. What net force acts on it?
3. Two people push an 800 kg car with a combined force of 2,400 N. Friction is 400 N. What is the car's acceleration?
4. The same net force acts on a 2 kg ball and on a 6 kg ball. How does the acceleration of the 6 kg ball compare with that of the 2 kg ball?

Answers: 1. 3 m/s². 2. 6 N. 3. Net force 2,000 N, so 2.5 m/s². 4. One third as large.

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