

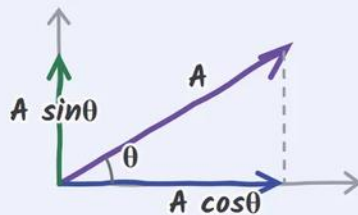


the three laws, the momentum they are really about, and why forces come in pairs



The first law, and what inertia means

- a body stays at rest, or moves in a straight line at constant speed, unless an unbalanced force acts on it
- inertia is that resistance to any change in the state of motion, and mass is the measure of inertia
- so a heavier body has more inertia and is harder both to start moving and to stop
- inertia of rest: dust flies off a beaten carpet because the carpet moves and the dust does not
- inertia of motion: a passenger lurches forward when a bus brakes, because the body keeps moving
- balanced forces produce no change in motion, so a body can move at constant speed with forces acting, provided they cancel



a body with two opposing forces of equal size drawn on it: they cancel, so nothing about the motion changes. A change of speed or direction requires the arrows to be unequal

Momentum, and the second law

- momentum is mass times velocity, $p = mv$, measured in kg m s^{-1} , and it is a vector
- so a heavy slow body can carry the same momentum as a light fast one
- the second law: the rate of change of momentum is proportional to the applied force and happens in its direction
- for constant mass this reduces to the familiar $F = ma$
- one newton is the force giving a mass of 1 kg an acceleration of 1 m s^{-2}
- the same change of momentum spread over a longer time needs a smaller force, which is why airbags, crumple zones and bending the knees on landing all work

The relations of this chapter *

momentum

$$p = mv$$

the second law, in its general form

$$F = \frac{mv - mu}{t}$$

and for constant mass

$$F = ma$$

conservation of momentum in a collision

$$m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$$

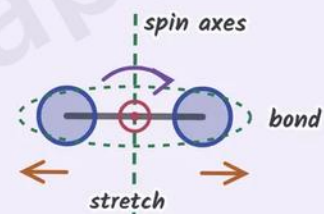
the third law

$$F_{AB} = -F_{BA}$$

the second line is the more fundamental one: $F = ma$ is what it becomes when the mass does not change, and questions about a rocket or a leaking cart need the general form

The third law, and the pair of forces

- to every action there is an equal and opposite reaction
- the two forces are equal in size and opposite in direction, and they act on two different bodies
- that last point is everything: because they act on different bodies, they never cancel each other
- if they acted on the same body, nothing could ever accelerate, which is the usual confusion
- walking works this way: the foot pushes back on the ground and the ground pushes forward on the foot
- a gun recoils, a rocket rises by throwing gases backwards, and a boat moves when the oar pushes water back



two bodies with the force each exerts on the other drawn as arrows pointing opposite ways: the arrows are the same length but they sit on different bodies, which is exactly why they do not cancel