

Forces and their effects

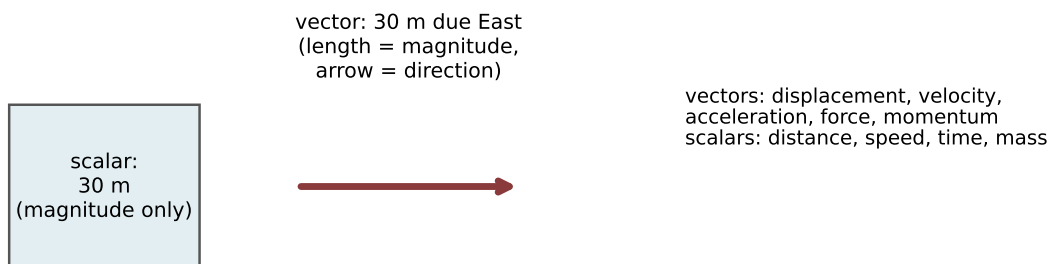
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Every push, pull and hold in the world is a force – and OxfordAQA’s first topic organises them: contact and non-contact interactions, scalars against vectors, Newton’s three laws, vehicle safety, and the P-extension ideas of momentum, terminal velocity, centre of mass and moments.

OxfordAQA International GCSE Physics 9203, topic 3.1 (Version 5.1, exams 2018 onwards). Statements marked (P) are Paper-2-only; paper details are in the specification’s scheme of assessment. The specimen components on file are 9203-92031 and 9203-92032 – specimen practice in this package is always labelled as such.

Forces and their interactions

Objects interact by **non-contact field forces** (gravity, electrostatics, magnetism) and **contact forces** (friction, air resistance, tension, normal contact force). **Friction** acts between two surfaces, impedes motion and may heat them; air resistance is friction with a fluid.



Scalars have magnitude only (distance, speed, time); **vectors** add direction (displacement, velocity, acceleration, force, momentum) and can be drawn as arrows.

Weight is the force of gravity: $W = m \times g$.

Forces can **change shape** – stretching, bending, compressing. Elastic distortions recover; inelastic ones do not (P). A stretched spring stores **elastic potential energy**, and below the **limit of proportionality**:

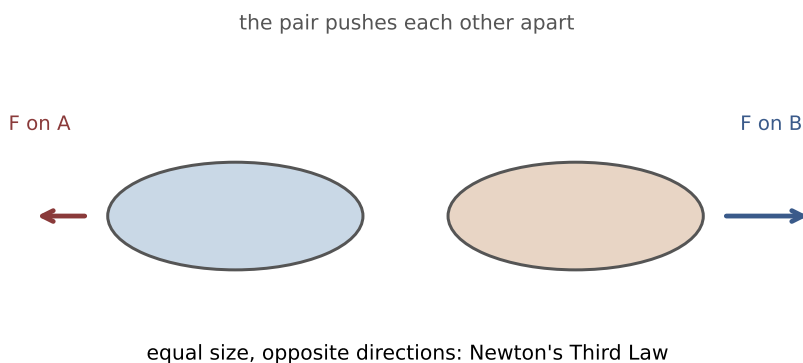
$$F = k \times e$$

Required practical: investigate force against extension for a spring (hang masses,

plot the line, gradient = k).

Motion and Newton's laws

Speed is the gradient of a distance–time graph; velocity adds direction: $v = s/t$ (usable for average speeds too). Acceleration is the rate of change of velocity: $a = \Delta v/t$ – from the gradient of a velocity–time graph, whose **area gives distance travelled**. Changing direction at constant speed is still acceleration.



- **Newton's First Law:** zero resultant force $\rightarrow$ rest stays rest, motion keeps its velocity.
- **Newton's Second Law:** $F = m \times a$ in the direction of the resultant.
- **Newton's Third Law:** interacting objects exert equal, opposite forces on each other.

Resultants: opposite or parallel forces add along a line; two coplanar forces combine by **scale drawing** (drawn to scale, head to tail).

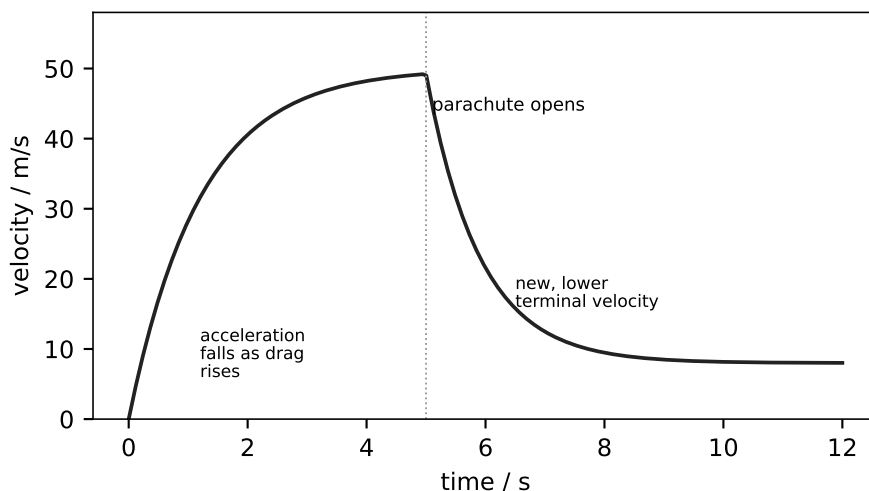
(P) Momentum, safety and terminal velocity

$$p = m \times v \qquad F = \frac{\Delta p}{t}$$

Momentum is conserved in a closed system – collisions and explosions share a fixed total. Car safety: airbags, seat belts, side-impact bars, crumple zones, crash mats, cushioned playground surfaces and cycle helmets all **lengthen the time** of impact, so for the same momentum change the force is smaller.

At a steady speed the driving force balances resistive forces. Stopping distance = **thinking + braking** distance; reaction time grows with tiredness, distraction, drugs and alcohol; braking force must grow with speed, and large decelerations overheat

brakes. Braking converts the vehicle's kinetic energy into heating the brakes (friction work); braking distance lengthens on wet or icy roads and with worn brakes or tyres. An object falling through a fluid accelerates until drag equals weight – **terminal velocity**; parachutes raise drag to cut the terminal velocity, and streamlining (a shark's shape, a car's design) reduces drag to raise the maximum speed.

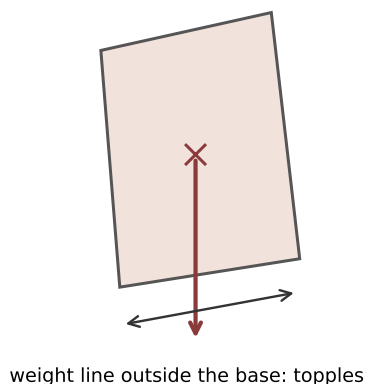
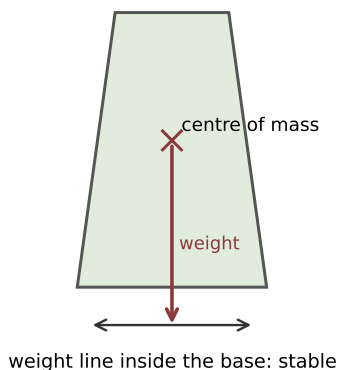


(P) Centre of mass and moments

The **centre of mass** is where an object's mass may be thought concentrated; a freely suspended object rests with it below the suspension point, and a symmetrical object's centre of mass lies on the axis of symmetry. Find it for an irregular lamina by suspending it from two points and drawing plumb lines.

$$M = F \times d$$

A balanced object has equal total clockwise and anticlockwise **moments**; levers are force multipliers. If the weight's line of action falls outside the base, the resultant moment topples the object (vehicles, balancing toys).



Check yourself

1. Give one example each of a contact and a non-contact force.
2. Which of these are vectors: speed, displacement, time, force?
3. State the spring equation and the name of its constant.
4. State Newton's three laws in one sentence each.
5. A 900 kg car accelerates at 2 m/s^2 . Calculate the resultant force.
6. Name two factors that lengthen thinking distance and two that lengthen braking distance.
7. (P) Explain how a crumple zone protects passengers, using $F = \Delta p/t$.
8. (P) Why does a parachutist reach a lower terminal velocity after opening the parachute?
9. (P) Where is the centre of mass of a symmetrical object?
10. (P) A 250 N force acts 0.4 m from a pivot. Calculate its moment.

Answers: 1 contact – friction/tension/air resistance/normal; non-contact – gravity/electrostatic/magnetic; 2 displacement and force; 3 $F = ke$, the spring constant (N/m); 4 first – no resultant force means no change in velocity; second – $F = ma$ in the resultant's direction; third – interactions give equal and opposite forces; 5 $F = 900 \times 2 = 1800 \text{ N}$; 6 thinking – tiredness, distractions, drugs/alcohol (any two); braking – wet or icy roads, worn brakes or tyres (any two); 7 (P) the crumple zone lengthens the collision time; for the same momentum change, $F = \Delta p/t$ is smaller, so less force reaches the passengers; 8 (P) the parachute greatly increases drag, so drag balances weight at a much lower speed; 9 (P) on its axis of symmetry; 10 (P) $M = 250 \times 0.4 = 100 \text{ N m}$.