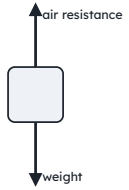
4.5 Forces

AQA GCSE Physics 8463
Paper 2 · Physics only (PO) · Higher (HT)
All equations are on the Physics Equations Sheet

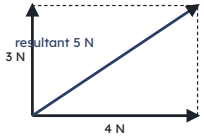
FORCES

- **Scalar:** size only (speed, distance, mass, energy). **Vector:** size and direction (velocity, displacement, force, acceleration, momentum).
- **Contact forces:** friction, air resistance, tension, normal contact force. **Non-contact:** gravitational, electrostatic, magnetic.
- **Weight** is the force acting on an object due to gravity; it acts at the centre of mass. g = 9.8 N/kg.
- **Resultant force:** a single force with the same effect as all the forces acting. Work done = energy transferred.

FREE BODY AND VECTOR DIAGRAMS

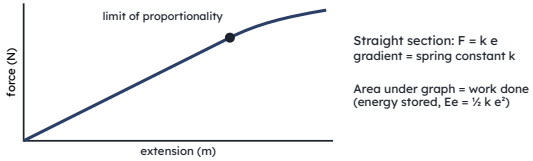


Free body diagram: skydiver



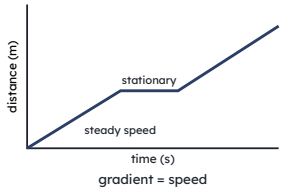
Vector diagram: forces added tip-to-tail (Higher)

ELASTICITY (RP6)

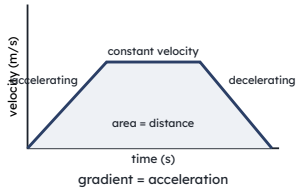


- Elastic deformation: returns to original shape. Extension ∝ force up to the limit of proportionality.
- Measure extension with a pointer, reading at eye level.

MOTION



gradient = speed



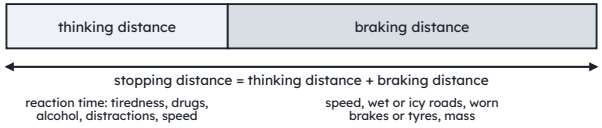
gradient = acceleration

- Speed of sound ≈ 330 m/s; walking ≈ 1.5 m/s; running ≈ 3 m/s; cycling ≈ 6 m/s.
- Acceleration in free fall near Earth's surface ≈ 9.8 m/s².

NEWTON'S LAWS

- **First:** if the resultant force is zero, a stationary object stays still and a moving object keeps the same velocity.
- **Second:** acceleration ∝ resultant force and inversely ∝ mass (F = ma). (HT) Inertial mass = force ÷ acceleration.
- **Third:** whenever two objects interact, the forces they exert on each other are equal and opposite.
- **Terminal velocity:** air resistance increases with speed until it equals weight; resultant force zero.
- **RP7:** vary force at constant mass (move masses from trolley to hanger), and mass at constant force; light gates.

STOPPING DISTANCE



Reaction time 0.2–0.9 s. Large decelerations can overheat brakes or cause loss of control.

MOMENTUM (HT) · MOMENTS AND PRESSURE (PO)

- In a closed system, total momentum before = total momentum after.
- Airbags, seat belts and crumple zones increase the time to stop, reducing the force.
- Balanced when clockwise moments = anticlockwise moments. Gears and levers transmit rotational effects.
- Pressure in a fluid increases with depth and density; upthrust causes floating.

MODEL EXPLANATIONS (GRADE 7+ ANSWERS)

Explain how a skydiver reaches terminal velocity.
At first weight is bigger than air resistance, so there is a resultant force downwards and the skydiver accelerates. As speed increases, air resistance increases, so the resultant force and acceleration decrease; when air resistance = weight, resultant force is zero: terminal velocity.

Explain why an airbag reduces injury in a crash. (Higher)
The airbag increases the time taken for the driver to stop. So the force on the driver is smaller. Force = change in momentum ÷ time; the same change in momentum over a longer time gives a smaller force.

Explain why driving faster makes the braking distance much longer.
Kinetic energy depends on speed squared, so doubling the speed gives four times the kinetic energy. The brakes must transfer more energy. Work done by brakes = braking force × distance; with the same maximum braking force, the distance must be about four times longer.

RP7: ACCELERATION

Aim: Investigate how force and mass affect the acceleration of an object.

Change	Force (or mass)
Measure	Acceleration
Control	Mass (when changing force), force (when changing mass), surface

Must include:

- Investigate both effects: varying force at constant mass, and varying mass at constant force
- Identify which variable is changed and which is kept constant
- Keep the total mass constant when changing force
- Measure acceleration with light gates or timings
- Repeat and average

Common mistake: Adding masses to the hanger without removing them from the trolley.

4.5 Forces

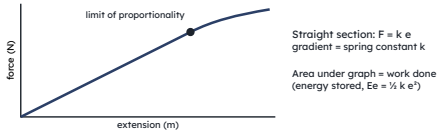
KEY EQUATIONS (ALL ON THE PHYSICS EQUATIONS SHEET)

Equation	Quantities (units)	Watch out
W = m g	weight (N), mass (kg), gravitational field strength (N/kg)	g = 9.8 N/kg on Earth
W = F s	work done (J), force (N), distance moved along the line of the force (m)	1 J = 1 N m
F = k e	force (N), spring constant (N/m), extension (m)	Only up to the limit of proportionality
M = F d	moment (N m), force (N), perpendicular distance from the pivot (m) (Physics only)	Perpendicular distance
p = F ÷ A	pressure (Pa), force normal to the surface (N), area (m^2) (Physics only)	1 Pa = 1 N/m^2
p = h ρ g	pressure (Pa), height of column (m), density (kg/m^3), g (N/kg) (Physics only, Higher)	Pressure increases with depth
s = v t	distance (m), speed (m/s), time (s)	km → m, minutes → s
a = Δv ÷ t	acceleration (m/s^2), change in velocity (m/s), time (s)	Negative a = deceleration
$v^2 - u^2 = 2as$	final velocity (m/s), initial velocity (m/s), acceleration (m/s^2), distance (m)	Square the velocities
F = m a	resultant force (N), mass (kg), acceleration (m/s^2)	Use the resultant force
p = m v	momentum (kg m/s), mass (kg), velocity (m/s) (Higher)	Momentum has a direction
F = m Δv ÷ Δt	force (N) = rate of change of momentum (Higher)	Longer time → smaller force

KEY WORDS

Scalar: size only (speed, distance, mass, energy, time).
Vector: size and direction (velocity, displacement, force, acceleration, momentum).
Weight: the force acting on an object due to gravity; acts at the centre of mass.
Resultant force: a single force that has the same effect as all the original forces acting together.
Work done: energy transferred when a force moves an object through a distance.
Limit of proportionality: the point beyond which extension is no longer proportional to force.
Terminal velocity: the constant velocity reached when the resultant force on a falling object is zero.
Newton's First Law: if the resultant force is zero, a stationary object stays still and a moving object continues at the same velocity.
Newton's Second Law: acceleration is proportional to the resultant force and inversely proportional to the mass (F = ma).
Newton's Third Law: whenever two objects interact, the forces they exert on each other are equal and opposite.
Inertia (Higher): the tendency of objects to continue in their state of rest or of uniform motion.
Stopping distance: thinking distance (during reaction time) + braking distance (under the braking force).

RP6: FORCE AND EXTENSION



Aim: Investigate how adding weights affects the extension of a spring.

Change	Force (weight added)
Measure	Extension
Control	Same spring

Must include:
- Measure the original length
- Calculate extension, not just length
- Add equal force steps
- Plot force against extension
- Determine k from the gradient

Common mistake: Plotting length instead of extension.

MISCONCEPTIONS

× A moving object needs a resultant force.	✓ Constant velocity means zero resultant force (Newton's First Law).
× Mass and weight are the same.	✓ Mass (kg) doesn't change; weight (N) depends on g.
× Third Law pairs cancel out.	✓ They act on different objects, so they can't cancel.

AIM FOR GRADE 7+

- $v^2 - u^2 = 2as$ for braking distances; F = mΔv ÷ Δt for collisions (Higher).
- Explain terminal velocity in steps: forces → resultant → acceleration.
- Describe RP7 with how to keep the investigation valid (constant total mass).

COMMAND WORDS

State	a short answer, no explanation
Describe	say what happens, in order
Explain	say what and why: use "because" and "so"
Calculate	equation, substitution, answer, unit
Evaluate	both sides, then a justified conclusion

QUICK-FIRE QUIZ: COVER THE ANSWERS

Unit of momentum?	**kg m/s**
Gradient of a distance–time graph?	**Speed**
Area under a v–t graph? (Higher)	**Distance travelled**
g on Earth?	**9.8 N/kg**
Typical reaction time?	**0.2–0.9 s**
Newton's First Law, in a few words?	**Zero resultant force: velocity doesn't change**