

ESAT

Physics

Forces and Newton's laws

Free lesson notes

Covers	P3.2, P3.3, P3.4, P3.5
Format	Lesson, worked examples, self-check
Price	Free

About this lesson

A *force* is a push or a pull. Forces are why things start moving, stop moving, change direction, stretch, squash and break, so almost every mechanics question on the ESAT is really a question about forces. The good news is that the whole subject rests on a handful of ideas: forces are vectors that can be added (the *resultant*); the resultant force decides how the motion changes (Newton's laws); and the weight of an object, the stretch of a spring and the drag on a falling skydiver are all special cases of the same story.

This lesson teaches everything from scratch. We start by listing the kinds of force and learning to draw *free-body diagrams*. We then meet Newton's three laws, using $F = ma$ to connect force to the *kinematics* of the previous lesson. We separate mass from weight and follow a skydiver to terminal velocity, and we finish with springs and Hooke's law, including the energy stored in a stretched spring.

Conventions. There is no calculator in the ESAT, so all numbers are friendly. The gravitational field strength is taken as $g = 10 \text{ N/kg}$ ($= 10 \text{ m/s}^2$); the specification says "about 10". Specification codes covered: P3.2 (types of force, free-body diagrams, resultant in one dimension), P3.3 (force and extension, Hooke's law, limit of proportionality, $E = \frac{1}{2}kx^2$), P3.4 (Newton's laws, $F = ma$) and P3.5 (mass and weight, $w = mg$, free fall, terminal velocity). Momentum is the next lesson.

How to use it. Draw a diagram for every problem. In forces, a clear free-body diagram removes most of the difficulty before any algebra starts.

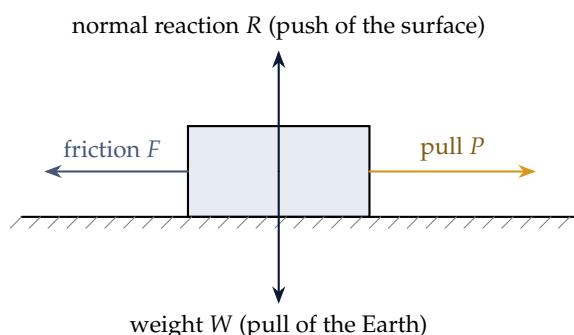
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1 What is a force?

A **force** is an interaction between two objects that can change the motion or the shape of an object. It is a *vector*: it has a size (measured in **newtons**, N) and a direction. A medium-sized apple weighs roughly 1 N, so the unit is not a huge one. A force is measured with a newton-meter, which is a spring (see section 7) with a scale.

Forces fall into two families.

- **Contact forces** act where two objects touch: *friction* (a surface resisting sliding), *normal reaction* (the push of a surface perpendicular to it, supporting a weight), *tension* (a pull along a string or rope), *air resistance* or *drag* (the resistance of a fluid to motion through it), *upthrust* (the upward push of a fluid), and *driving* or *thrust* forces (a tyre pushing on the road, a jet engine pushing gas out).
- **Non-contact forces** act across empty space: *weight* (the gravitational pull of a planet), and the electric and magnetic forces.



The diagram shows a box pulled along a rough floor. Notice how each force is named by *what is pushing or pulling what*, never just "the force". The weight W is the pull of the Earth *on the box*. The normal reaction R is the push of the floor *on*

the box. "Normal" is a mathematician's word meaning *at right angles to the surface*. Friction F opposes the sliding of the box over the floor, so it points against the direction the box is moving (or trying to move).

What forces do. A resultant force can change an object's speed, direction or shape. A force on its own does not make an object move at a steady speed: it makes the velocity *change*. That is the idea of Newton's laws, below.

Worked example: naming forces

A bus travels at a constant speed along a straight, level road. Name four forces acting on it and say what each is the push or pull of.

Weight (pull of the Earth, downwards); normal reaction (push of the road on the tyres, upwards); driving force (push of the road on the tyres forwards, produced by the engine turning the wheels); and air resistance and friction in the bearings (pushes of the air and of the mechanism, backwards).

Common mistakes

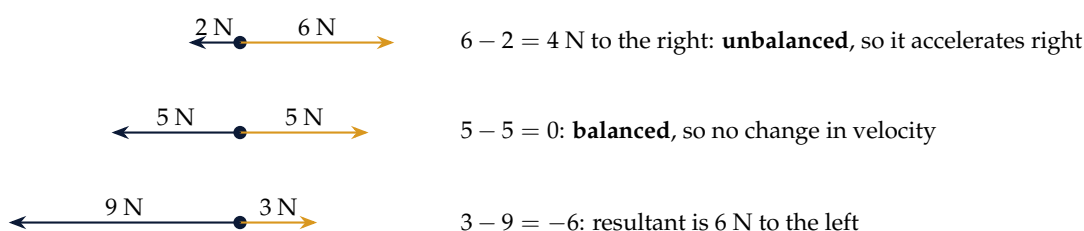
- Writing "gravity" or "force of motion" on a diagram. Every arrow must be a real push or pull by something named: weight, tension, friction... There is no "force of motion".
- Confusing mass and weight. Mass is in kilograms; weight is a force in newtons (section 6).
- Drawing friction in the direction of motion. Friction resists sliding: it points *against* the motion (or against the push, if the object is not yet moving).

2 Free-body diagrams and the resultant force

To understand the motion of a single object we draw it *on its own* and add an arrow for every force acting *on it* (and only on it). This is a **free-body diagram**. The rules:

1. Isolate the object. Draw it as a box or a dot.
2. Draw one arrow for each force acting on the object, starting at the object (weights and reactions are often drawn from the centre).
3. Each arrow points in the direction of the force, and its length is roughly proportional to its size. Label every arrow with its name (and value, if known).
4. Do not draw forces that the object exerts on *other* things.

The **resultant force** is the single force with the same effect as all the forces together. In one dimension it is easy: choose a positive direction, give forces that point that way a plus sign and the others a minus sign, and add. For example, with right as positive, a 6 N force to the right and a 2 N force to the left give a resultant of $+6 - 2 = 4$ N to the right.



Balanced and unbalanced. If the resultant force is zero the forces are **balanced**: the object is unaffected, in the sense that its velocity does not change. If the resultant is not zero the forces are **unbalanced**, and the object accelerates in the direction of the resultant. Opposite directions *subtract*; the same direction *adds*. (We are not asked to combine forces at an angle in this specification.)

Worked example: a hanging lamp and a rocket

A lamp of weight 30 N hangs at rest from a cable. What is the tension? A rocket of weight 50 000 N has an engine thrust of 80 000 N upwards. Find the resultant force on the rocket (ignore air resistance).

The lamp is at rest, so the resultant is zero: tension up = weight down, $T = 30$ N. For the rocket take up as positive: $80000 - 50000 = 30000$ N upwards, unbalanced, so it accelerates upwards.

Worked example: three forces on a sledge

A sledge is pulled forwards by two ropes, with forces 40 N and 30 N, against a friction force of 50 N. What is the resultant force?

Forwards positive: $40 + 30 - 50 = 20$ N forwards.

Common mistakes

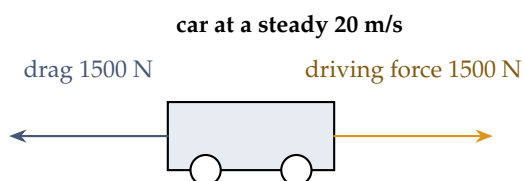
- Adding forces without signs: $6 + 2$ instead of $6 - 2$ when the forces oppose.
- Including a force that the object exerts on something else, such as the push of the box *on* the floor, in the free-body diagram of the box.
- Saying "balanced forces mean it is not moving". Balanced forces mean the velocity is *constant* (which may be zero, or may not).

3 Newton's first law and why things slow down

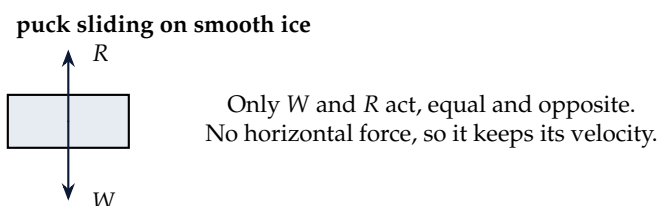
Everyday experience seems to say that a push is needed to *keep* something moving: a trolley you stop pushing comes to a halt. Newton's insight was that this is because of an *unseen* force, friction, and that with no resultant force an object would carry on for ever. That is his **first law**:

An object stays at rest, or keeps moving at constant velocity (the same speed in the same straight line), unless a resultant force acts on it.

Put the other way round: a constant velocity (including rest) means the resultant force is zero, and a changing velocity means there is a resultant force. The tendency of an object to resist changes in its motion is called **inertia**; the more mass an object has, the more inertia it has.

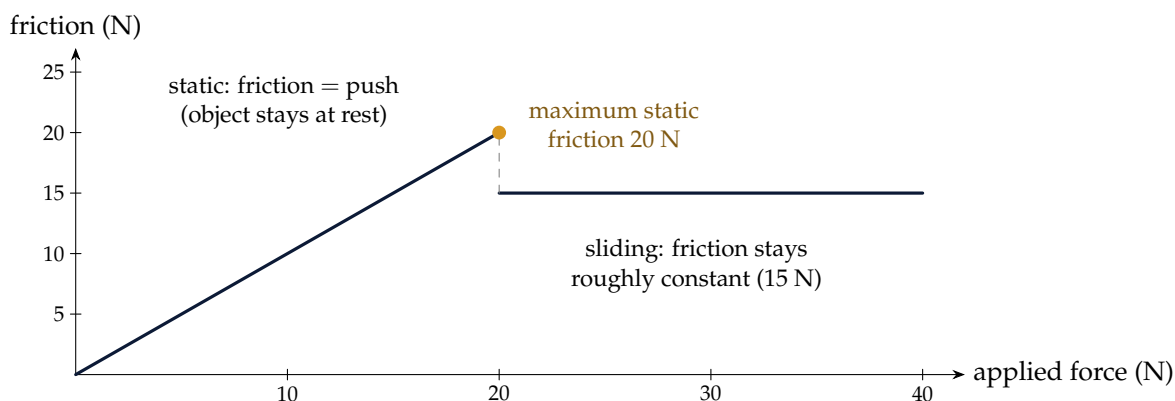


Resultant = 0, so the velocity does not change: no force is needed to *keep* it moving.



In the figure the car's driving force equals the drag, so the resultant is zero and it cruises at 20 m/s without speeding up or slowing down. If the driver lifted off the accelerator, the drag would be unbalanced, and the car would slow down. A puck on smooth ice has only its weight and the support of the ice, which cancel, so it keeps sliding at constant velocity.

Friction. Friction is a contact force that opposes sliding (or the tendency to slide) between two surfaces. When you push a heavy crate and it does not move, friction exactly matches your push, so the resultant is zero. If you push harder, friction increases to match, up to a maximum value; beyond that the crate starts to slide, and the friction while it slides is usually a little less.



Seat belts. A passenger in a braking car continues moving forward at the car's old velocity, because nothing is pulling them back: it is the car that slows. The seat belt supplies the backward force that slows the passenger together with the car.

Worked example: steady speed

A cyclist travels at a steady 6 m/s along a level road. The air resistance on the rider is 30 N. How large is the forward force from the tyres on the road?

Steady speed means zero resultant force, so the driving force equals the resistive force: 30 N.

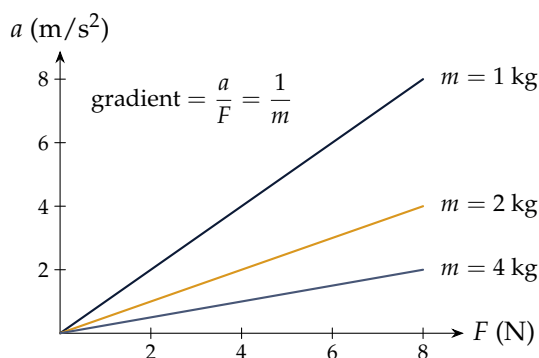
Common mistakes

- Believing a constant force is needed to keep a constant velocity. It is a constant force that produces a constant *acceleration*.
- Thinking that an object moving forward must have a resultant force forward. Moving forward at a steady speed needs a resultant of zero.
- Drawing the friction force with a fixed value when the object is not moving. Static friction *matches* the push, up to its maximum.

4 Newton's second law: $F = ma$

What does a resultant force actually do? Experiment gives a clear answer. Pull a trolley along a smooth track with a steady force and measure its acceleration (with light gates, or a ticker-tape).

- Keep the mass fixed and increase the force: the acceleration is **proportional** to the resultant force: $a \propto F$. Doubling the force doubles the acceleration.
- Keep the force fixed and increase the mass: the acceleration is **inversely proportional** to the mass: $a \propto \frac{1}{m}$. Doubling the mass halves the acceleration.



The graph shows a against F for three masses: each is a straight line through the origin, and the gradient is $\frac{a}{F} = \frac{1}{m}$. Combining the two results gives $a \propto \frac{F}{m}$, and the unit of force is defined to make the constant of proportionality exactly

one. This is **Newton's second law**:

$$F = ma \quad \text{where } F \text{ is the resultant force (N), } m \text{ the mass (kg) and } a \text{ the acceleration (m/s}^2\text{).}$$

One newton is the force that gives a 1 kg mass an acceleration of 1 m/s^2 . The acceleration is in the *same direction* as the resultant force. Two points deserve emphasis. First, F is always the *resultant* (net) force, found from the free-body diagram: it is not the driving force alone. Second, $F = ma$ links force to *kinematics*: once you know a you can use the equations of the previous lesson.

Worked example: force from motion

A 1200 kg car accelerates from rest to 20 m/s in 10 s. The resistive forces are 400 N. What is the driving force?

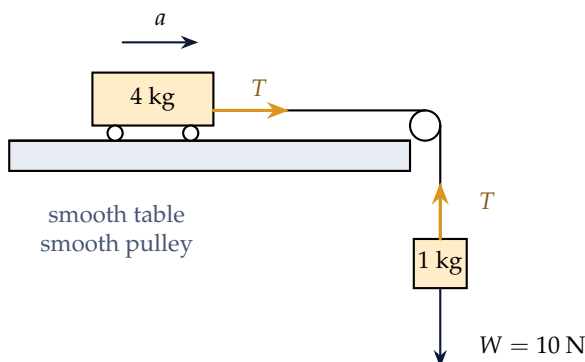
$$a = \frac{20 - 0}{10} = 2 \text{ m/s}^2. \text{ The resultant is } F = ma = 1200 \times 2 = 2400 \text{ N. Resultant} = \text{driving} - \text{resistive, so driving} \\ = 2400 + 400 = 2800 \text{ N.}$$

Worked example: force, then kinematics

A 50 kg skater, initially at rest on smooth ice, is pushed by a steady 100 N force for 3 s. How fast is she moving, and how far has she gone?

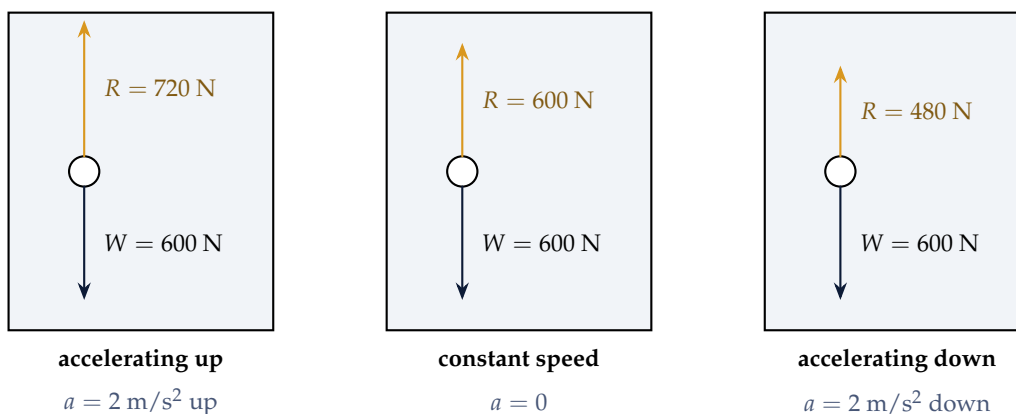
$$a = F/m = 100/50 = 2 \text{ m/s}^2. \text{ Then } v = u + at = 0 + 2 \times 3 = 6 \text{ m/s, and } s = \frac{1}{2}at^2 = \frac{1}{2}(2)(9) = 9 \text{ m.}$$

Connected objects. When two objects move together they have the same acceleration, so we can treat them as one object of combined mass for the *whole system*, then go back to one object to find an internal force such as a tension. Here a 4 kg trolley on a smooth table is pulled by a string over a smooth pulley, with a 1 kg mass hanging on the end.



The only force driving the whole system is the weight of the hanging mass, 10 N; the mass being accelerated is $4 + 1 = 5 \text{ kg}$. So $a = \frac{10}{5} = 2 \text{ m/s}^2$. The tension acts on the trolley alone: $T = ma = 4 \times 2 = 8 \text{ N}$. Check with the hanging mass: weight – tension = $10 - 8 = 2 = 1 \times 2$. (checks) Notice that the tension (8 N) is *less* than the weight of the hanging mass: if it were equal, the hanging mass would not accelerate at all.

Apparent weight in a lift. A person standing on scales feels (and the scale reads) the *normal reaction* R , not the weight. If the lift accelerates, the resultant force is ma , so R differs from W . Taking a 60 kg person ($W = 600 \text{ N}$) and $a = 2 \text{ m/s}^2$:



Accelerating up: $R - W = ma$, so $R = 600 + 60 \times 2 = 720$ N (heavier feeling). *Constant speed:* $R = W = 600$ N. *Accelerating down:* $W - R = ma$, so $R = 600 - 120 = 480$ N (lighter). Note that the scale reading depends on the *acceleration*, not the velocity: a lift moving upwards but slowing down has a downward acceleration, so it gives the lower reading.

Worked example: a lift that slows

A 60 kg passenger stands on scales in a lift moving upwards at 4 m/s. The lift then brakes to rest in 2 s. What do the scales read while it brakes?

$a = \frac{0 - 4}{2} = -2$ m/s² (downwards). Taking up as positive, $R - 600 = 60 \times (-2)$, so $R = 600 - 120 = 480$ N.

Exam tip

For a vertical problem write “(up force) – (down force) = ma ” with the direction of the acceleration as positive. For an object on a table, the resultant and ma are in a line, so one equation is enough.

Common mistakes

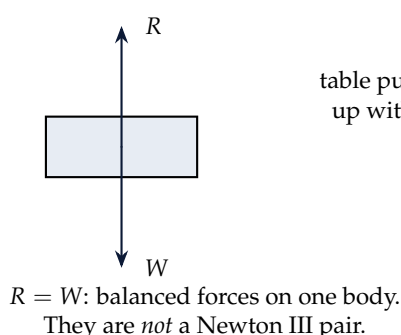
- Putting a single force into $F = ma$ when several act. The F is the *resultant*.
- Thinking the tension equals the weight of the hanging mass: it is true only if the mass is stationary or moving at constant velocity.
- Using the *mass of one object* for the whole connected system when finding the acceleration (or the other way round).
- Confusing velocity with acceleration for the scale reading in a lift.

5 Newton's third law: pairs of forces

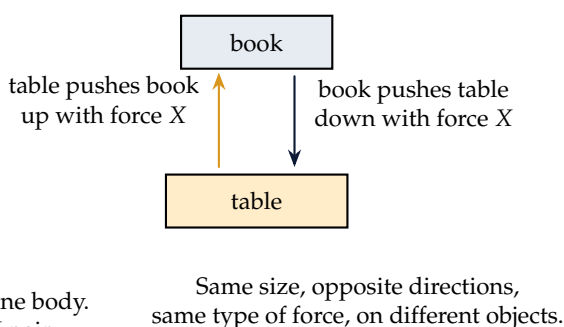
Forces never come singly. When object A pushes on object B, B pushes back on A. **Newton's third law:** *if object A exerts a force on object B, then B exerts an equal and opposite force on A.* The two forces of such a **pair** are

- equal in size,
- opposite in direction,
- the *same type* of force (both gravitational, both contact...),
- and, crucially, they act on **different objects**.

Forces on one object (the book)



A Newton III pair (two objects)



The last point is the one that catches people. In the left diagram the weight of a book and the normal reaction of the table are equal and opposite, but they are both forces *on the book*, and they are different types of force (gravity and contact): they are *not* a third-law pair. They are equal only because the book is in equilibrium. The partner of the table's push up on the book is the book's push down on the table (right-hand diagram). The partner of the Earth's pull on the book is the book's pull on the Earth.

Since the two forces of a pair act on different objects they never cancel, even though they are equal. Cancelling happens only between forces on the same object. Whether an object accelerates depends on the forces *on it*.

Worked example: skaters pushing apart

Skater A has mass 60 kg and skater B has mass 40 kg. They stand on smooth ice, A pushes B, and B accelerates at 3 m/s^2 . What is the acceleration of A?

Force on B: $F = ma = 40 \times 3 = 120 \text{ N}$. By the third law, B pushes A with 120 N in the opposite direction. So $a_A = \frac{120}{60} = 2 \text{ m/s}^2$, in the opposite direction. The lighter skater accelerates more.

Worked example: a car and a heavy lorry collide

A small car collides head-on with a heavy lorry. Compare the forces each exerts on the other, and their accelerations. The forces are equal and opposite (third law), whatever their masses. But the accelerations differ: $a = F/m$, so the car, having the smaller mass, suffers the larger acceleration.

Common mistakes

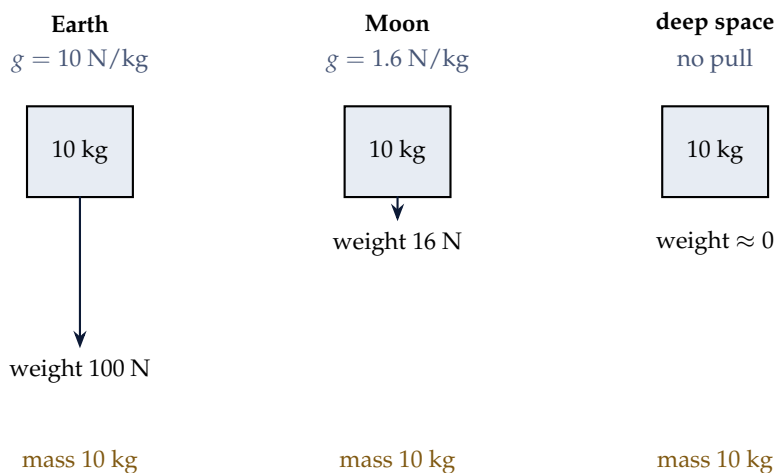
- Saying "the heavier object pushes harder". The forces in a pair are always equal.
- Calling the weight and the normal reaction a third-law pair.
- Thinking equal and opposite forces mean nothing can ever accelerate: the two forces act on different objects.

6 Mass, weight, free fall and terminal velocity

Mass is the amount of matter in an object, measured in kilograms. It is the same everywhere. **Weight** is the gravitational force on the object, measured in newtons. It depends on where the object is. The two are linked by the **gravitational field strength** g , which is the weight per kilogram:

$$W = mg.$$

Near the Earth's surface $g \approx 10 \text{ N/kg}$, so a 10 kg object weighs about 100 N. On the Moon $g \approx 1.6 \text{ N/kg}$, so the same object weighs 16 N; in deep space, far from any planet, its weight is almost zero. Its mass is 10 kg in all three places.



Why g is also an acceleration. If gravity is the only force on an object, $F = ma$ with $F = mg$ gives $ma = mg$, so $a = g$. The mass cancels: a heavier object is pulled harder but also has more inertia, and the two effects cancel exactly, so all objects in free fall have the same acceleration 10 m/s^2 . That is why g may be quoted in N/kg or m/s^2 : the units are the same thing.

Worked example: weight and mass on another planet

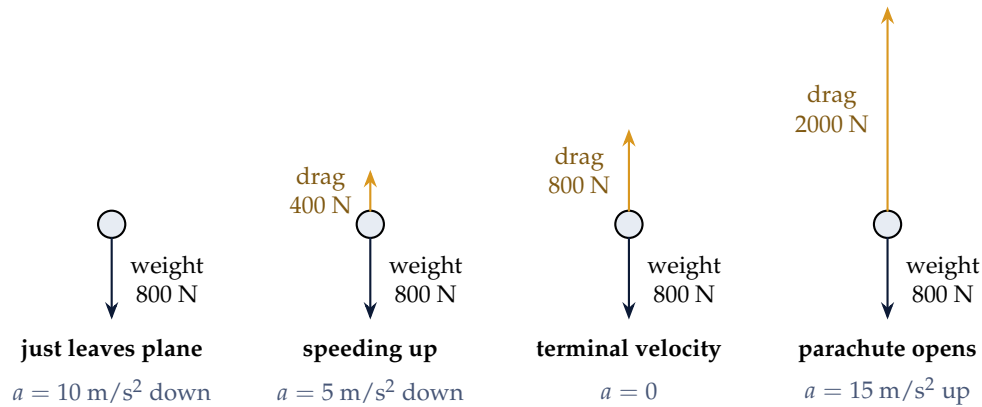
An astronaut has mass 75 kg with kit. Find the weight on Earth and the weight on Mars, where $g = 4 \text{ N/kg}$ (rounded).

Earth: $75 \times 10 = 750 \text{ N}$. Mars: $75 \times 4 = 300 \text{ N}$. The mass is 75 kg on both.

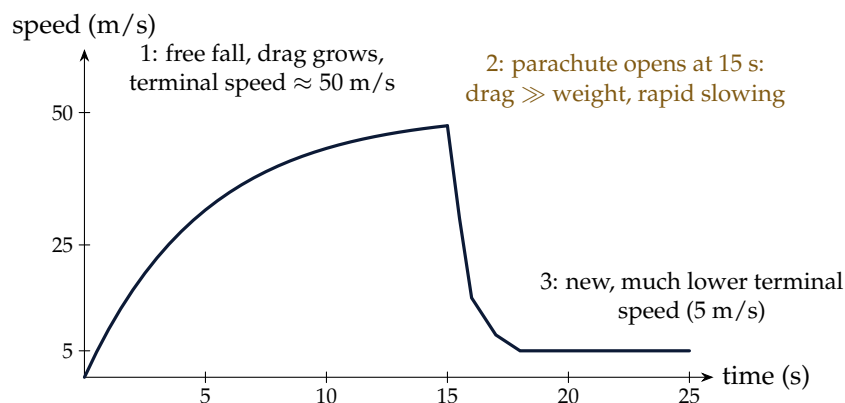
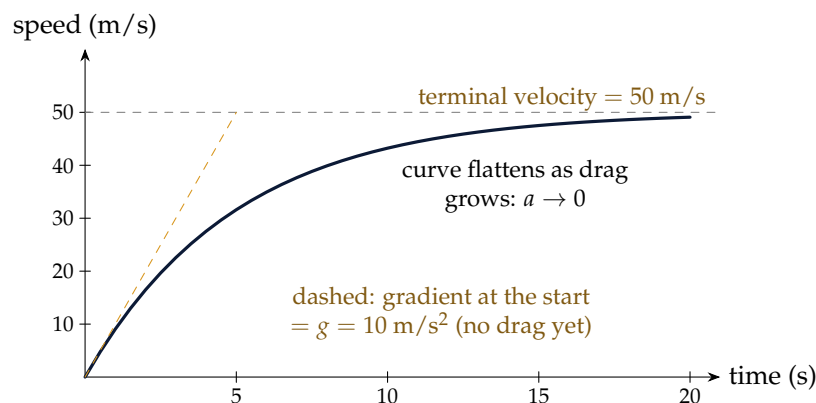
Falling through air: terminal velocity. In real life, air resistance (drag) opposes motion through air, and it *increases with speed*. Follow a skydiver of mass 80 kg (weight 800 N):

1. At the instant of leaving the plane the speed is zero, so there is no drag. The resultant is the whole weight: $a = g = 10 \text{ m/s}^2$.

- As speed grows, drag grows. The resultant (weight – drag) shrinks, so the acceleration falls (the speed still rises, but more slowly).
- Eventually the drag equals the weight. The resultant is zero, so $a = 0$ and the speed stays constant: this is the **terminal velocity**.
- Opening a parachute suddenly increases the drag far above the weight. The resultant is now *upward*, so the skydiver *decelerates*; as the speed falls the drag falls, until it again equals the weight, at a much lower terminal velocity.



The speed–time graph follows the story. The gradient is the acceleration: it starts at g (steepest), then decreases to zero as the curve levels off at the terminal velocity.



Terminal velocity is not about reaching “zero acceleration” by magic: it is the speed at which drag has *grown to match the weight*. A larger or more spread-out object has a bigger drag at a given speed, which is why a parachute lowers the terminal velocity.

Worked example: acceleration with partial drag

The skydiver above (mass 80 kg) is falling with a drag of 600 N. What is the acceleration?

Weight = 800 N down. Resultant = 800 – 600 = 200 N down. $a = \frac{200}{80} = 2.5 \text{ m/s}^2$ downwards.

Exam tip

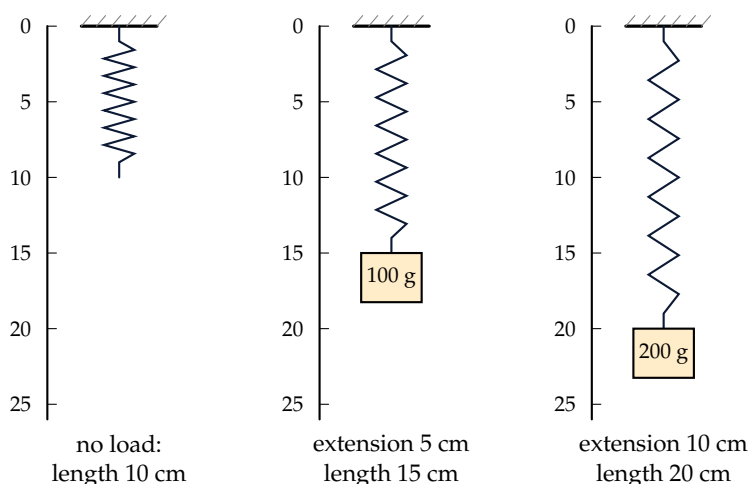
At terminal velocity the *speed* is constant but the skydiver is still moving: do not say they have stopped. And never say “weight disappears”: the weight is the same, the resultant is zero.

Common mistakes

- Using “mass” and “weight” interchangeably (“my weight is 60 kg”).
- Saying a heavier object falls faster in a vacuum. With no air resistance all objects accelerate at g .
- Saying the acceleration is zero “at the start” of a fall; it is the largest then. It is zero at terminal velocity.
- Believing that after the parachute opens the skydiver goes *upwards*: the resultant is upwards, so the velocity decreases, but the direction is still downwards until the speed reaches the new terminal velocity.

7 Springs: force and extension, Hooke's law

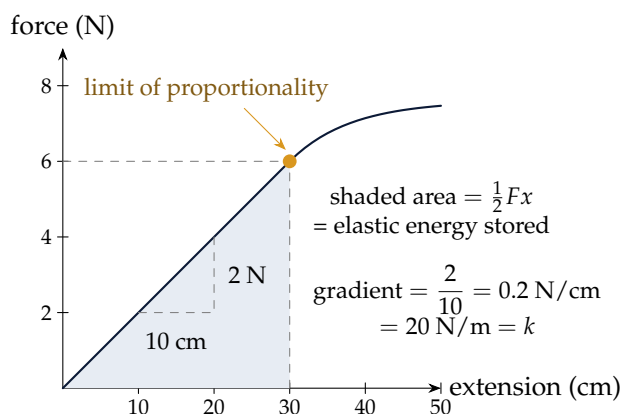
A force can also change the *shape* of an object. If the object returns to its original shape when the force is removed, the deformation is **elastic**. A spring is the standard example. Hang masses on a spring and measure its length.



The **extension** is the increase in length over the natural (unloaded) length: here 10 cm → 15 cm → 20 cm, so the extensions are 0, 5 and 10 cm. The load goes 0, 1 N (100 g × 10) and 2 N: doubling the force doubles the extension. This is **Hooke's law**: the extension is proportional to the force applied, up to the *limit of proportionality*.

$$F = kx$$

where x is the extension (always in metres in $F = kx$ when k is in N/m) and k is the **spring constant**, in N/m. The stiffer the spring, the larger k . From the rig: $k = \frac{1 \text{ N}}{0.05 \text{ m}} = 20 \text{ N/m}$. The same law holds for compression, with x the decrease in length.



On the force–extension graph the straight section has gradient k . (Here $0.2 \text{ N/cm} = 20 \text{ N/m}$.) Beyond the **limit of proportionality** the graph curves: extension grows faster than the force and Hooke's law no longer applies. Stretch further and the spring passes its *elastic limit*: it no longer returns to its original length when unloaded.

Energy stored. To stretch a spring you do work. The force rises steadily from 0 to F as the extension rises from 0 to x , so the *average* force is $\frac{1}{2}F$ and the work done is $\frac{1}{2}Fx$: the shaded area under the graph, a triangle. Using $F = kx$:

$$E = \frac{1}{2}Fx = \frac{1}{2}kx^2.$$

This energy is stored as elastic potential energy. For the spring of the figure, stretched 0.30 m with $F = 6 \text{ N}$: $E = \frac{1}{2} \times 6 \times 0.30 = 0.9 \text{ J}$, and also $\frac{1}{2} \times 20 \times 0.3^2 = 0.9 \text{ J}$. Because of the x^2 , doubling the extension stores *four* times the energy.

Worked example: finding k and an unknown extension

A spring extends by 8 cm under a load of 2 N . Find k , then the extension under 5 N and the length if its natural length is 30 cm (assuming Hooke's law holds).

$k = \frac{2}{0.08} = 25 \text{ N/m}$. Extension under 5 N : $x = \frac{F}{k} = \frac{5}{25} = 0.20 \text{ m} = 20 \text{ cm}$ (or by proportion: $8 \times \frac{5}{2} = 20$). Length = $30 + 20 = 50 \text{ cm}$.

Worked example: energy in a spring

A spring with $k = 400 \text{ N/m}$ is compressed by 5 cm . How much energy is stored?

$x = 0.05 \text{ m}$. $E = \frac{1}{2}kx^2 = \frac{1}{2} \times 400 \times 0.0025 = 0.5 \text{ J}$.

Worked example: two springs in a chain

Two identical springs, each with $k = 100 \text{ N/m}$, hang one below the other (in series). A 2 kg mass hangs from the lower one. Find the total extension.

The weight is 20 N . Each spring carries the full 20 N (the lower spring supports the mass; the upper spring supports the lower spring and the mass). Each extends by $\frac{20}{100} = 0.2 \text{ m}$. Total extension = 0.4 m : twice what one spring gives, so the chain behaves like a spring with half the stiffness.

Common mistakes

- Using the *length* of the spring instead of the *extension* in $F = kx$.
- Forgetting to convert centimetres to metres when k is in N/m .
- Applying Hooke's law beyond the limit of proportionality, where the graph curves.
- Writing $E = \frac{1}{2}kx$ or $E = kx^2$: there is both a factor $\frac{1}{2}$ and a *square*.
- Thinking mass hung on two springs in series gets half the force each: each carries the whole weight.

8 Strategy and applied reasoning

Most ESAT force questions are solved by the same short routine.

1. Sketch the object and draw *all* the forces on it. Label values.

2. Choose a positive direction (the direction of the acceleration, if you know it).
3. Find the resultant. If the velocity is constant, it is zero. If the object accelerates, write $F_{\text{res}} = ma$.
4. If the question gives distances or times, use the equations of uniform acceleration from the previous lesson to link a with s , u , v and t .
5. Check the units, the sign, and whether the answer is of a sensible size.

Estimating forces. A force is often found from a speed change and a time: $F = ma = \frac{m(v - u)}{t}$. In a crash, a car of mass 1000 kg going at 15 m/s stops in 0.1 s; the deceleration is 150 m/s^2 and the average force is 150 000 N, fifteen times the car's weight. The same car braking normally to a stop in 5 s needs only 3000 N: a very different experience. Crumple zones work by lengthening the time, and so reducing the force.

Worked example: force, mass and speed together

A 2 kg block slides on a rough table. It is moving at 10 m/s and the friction force is a steady 5 N. How far does it slide before stopping?

Resultant (friction, opposing) = 5 N, so $a = \frac{5}{2} = 2.5 \text{ m/s}^2$ (a deceleration). $v^2 = u^2 + 2as$: $0 = 100 - 2(2.5)s$, so $s = 20 \text{ m}$. Heavier blocks need longer to stop for the same friction.

Worked example: is the answer sensible?

A student calculates that a 60 kg sprinter accelerates from rest to 9 m/s in 1.5 s. Estimate the average horizontal force.

$a = 9/1.5 = 6 \text{ m/s}^2$, so $F = 60 \times 6 = 360 \text{ N}$: about 0.6 of her weight. This is reasonable: the legs push on the track much harder than this, but only the forward part of the push gives the horizontal acceleration.

Exam tip

If the question has numbers that divide nicely under $F = ma$, the intended method is almost always *resultant force first*. Two forces plus an acceleration usually means a third, unknown force to be found by subtraction.

Common mistakes

- Stopping at the acceleration. The question may ask for a distance or a time, which needs the kinematics equations too.
- Using the weight where the *mass* is needed in $F = ma$ (for example dividing 600 N by 2 m/s^2 , instead of 60 kg).

Check yourself

Try these without looking back, then compare with the answers on the next page.

1. A box is pushed with 12 N to the right and friction is 12 N to the left. What happens to its motion?
2. A 4 kg trolley has a resultant force of 10 N. Find its acceleration.
3. A rock has mass 6 kg. What are its mass and weight on the Moon ($g = 1.6 \text{ N/kg}$)?
4. A book rests on a table. Why is the table's upward push not the third-law partner of the book's weight?
5. A skydiver reaches terminal velocity. What can you say about the drag and the weight, and about the acceleration?
6. A spring of natural length 20 cm has length 26 cm under a load of 3 N. Find k .
7. How much energy is stored in the spring of the last question?
8. A 70 kg person in a lift accelerates upwards at 1 m/s^2 . What do the scales read?

Answers to the self-check

1. The resultant is zero, so its velocity does not change (it stays at rest, or moves at constant velocity).
2. $a = 10 \div 4 = 2.5 \text{ m/s}^2$.
3. Mass 6 kg (unchanged); weight $6 \times 1.6 = 9.6 \text{ N}$.
4. Both forces act on the same object (the book), and they are different types of force. The partner of the table's push on the book is the book's push on the table.
5. The drag equals the weight (balanced), so the resultant is zero and the acceleration is zero: the speed is constant.
6. Extension = 6 cm = 0.06 m. $k = 3 \div 0.06 = 50 \text{ N/m}$.
7. $E = \frac{1}{2}Fx = \frac{1}{2} \times 3 \times 0.06 = 0.09 \text{ J}$ (or $\frac{1}{2} \times 50 \times 0.06^2 = 0.09 \text{ J}$).
8. $R - 700 = 70 \times 1$, so $R = 770 \text{ N}$.

Next step

Heurisco's *ESAT Physics: Forces and Newton's Laws Practice Set* has twenty original exam-style questions on this lesson, with diagrams, ordered from gentle to genuinely hard, each with a full worked solution and a note on the commonest trap.