Forces and Acceleration

You must be able to:

- Apply Newton's second law to situations where objects are accelerating
- Estimate the magnitude of everyday accelerations
- Draw and interpret velocity–time graphs.

Acceleration

- The **acceleration** of an object is a measure of how quickly it speeds up, slows down or changes direction.

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$$\text{acceleration} = \frac{\text{change in velocity}}{\text{time taken}}$$

$$a = \frac{\Delta v}{t}$$

Acceleration (a) is measured in metres per second squared (m/s²). Change in velocity (Δv) is found by subtracting initial velocity from final velocity ($v - u$) and is measured in metres per second (m/s). Time (t) is measured in seconds (s).

- When an object slows down, the change in velocity is negative, so it has a negative acceleration.
- Acceleration can also be can be calculated using the equation:

$$(\text{final velocity})^2 - (\text{initial velocity})^2 = 2 \times \text{acceleration} \times \text{distance}$$

$$v^2 - u^2 = 2as$$

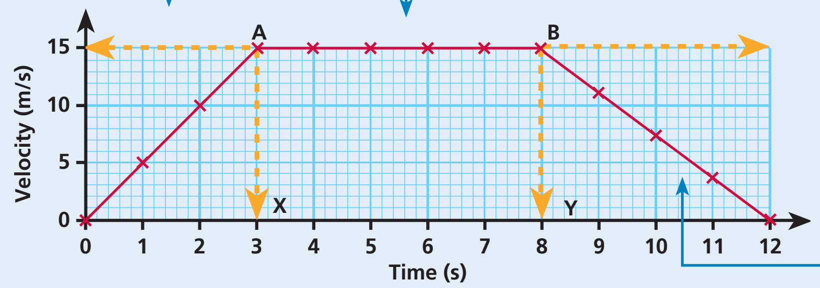
Final velocity (v) is measured in metres per second (m/s). Initial velocity (u) is measured in metres per second (m/s). Acceleration (a) is measured in metres per second squared (m/s²). Distance (s) is measured in metres (m).

Key Point

Acceleration is a measure of change in velocity.

Velocity–Time Graphs

- The **gradient** of a velocity–time graph can be used to find the acceleration of an object.
- The total distance travelled is equal to the area under the graph.



The change in velocity is 15m/s over a 3 second period, so the acceleration is $\frac{15}{3}$ = 5m/s²

The velocity is constant, so the acceleration is zero.

The change in velocity is –15m/s over a 4 second period, so the acceleration is $\frac{-15}{4}$ = –3.75m/s². The negative value shows that the object is slowing down.

Distance travelled:

First section: $\frac{1}{2}$ × 3 × 15 = 22.5m

Break down the area under the graph into smaller shapes.

Middle section: 15 × 5 = 75m

Final section: $\frac{1}{2}$ × 4 × 15 = 30m

Total distance = 22.5 + 75 + 30

= 127.5m

Add together all of the areas to find the total distance.

Newton's Second Law

- Newton's second law is often stated as: the acceleration of an object is **proportional** to the resultant force acting on the object and **inversely proportional** to the mass of the object, i.e.
  - if the resultant force is doubled, the acceleration will be doubled
  - if the mass is doubled, the acceleration will be halved.
- This law can be summarised with the equation:

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force = mass × acceleration

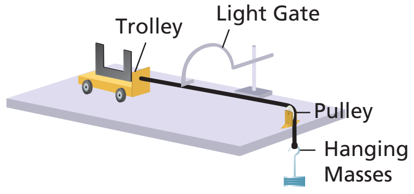
$$F = ma$$

Force (F) is measured in newtons (N). Mass (m) is measured in kilograms (kg). Acceleration (a) is measured in metres per second squared (m/s²).

HT Mass is a measure of **inertia**.
HT It describes how difficult it is to change the velocity of an object.
HT This inertial mass is given by the ratio of force over acceleration, i.e. $m = \frac{F}{a}$.
HT The larger the mass, the bigger the force needed to change the velocity.

REQUIRED PRACTICAL

Investigate the effect of varying the force and / or the mass on the acceleration of an object.



Sample Method	**Considerations, Mistakes and Errors**
1. Set up the equipment as shown. 2. Release the trolley and use light gates or a stopwatch to take the measurements needed to calculate acceleration. 3. Move 100g (1N) from the trolley onto the mass holder. 4. Repeat steps 2 and 3 until all the masses have been moved from the trolley onto the mass holder. If investigating the mass, keep the force constant by removing a mass from the trolley but not adding it to the holder.	• When changing the force it is important to keep the mass of the system constant. Masses are taken from the trolley to the holder. No extra masses are added. • Fast events often result in timing errors. Repeating results and finding a mean can help reduce the effect of these errors. • If the accelerating force is too low or the mass too high, then frictional effects will cause the results to be inaccurate.
Variables	**Hazards and Risks**
• The independent variable is the force or the mass. • The control variable is kept the same. In this case, the force if the mass is changed or the mass if the force is changed.	• The biggest hazard in this experiment is masses falling onto the experimenter's feet. To minimise this risk, masses should be kept to the minimum needed for a good range of results.

Key Point

Calculating a mean helps to reduce the effect of random errors.

A result that is accurate is close to the true value.

Quick Test

1. An object accelerates from 2m/s to 6m/s over a distance of 8m. Use the equation $v^2 - u^2 = 2as$ to find the acceleration of the object.
2. Comparing two velocity–time graphs, it can be seen that graph A is twice as steep as graph B. What does this indicate?
3. Why is it important to carryout repeat readings during an experiment?

Key Words

acceleration
gradient
proportional
inversely proportional
HT inertia