OCR A Level Physics

Kinematics

Your notes

Contents

Your notes

Displacement, Speed, Velocity & Acceleration

Scalar quantities

- Scalar quantities only have a magnitude (size)
  - **Distance:** the total length between two points
  - **Speed:** the total distance travelled per unit of time

Vector quantities

- Vector quantities have both magnitude and direction
  - **Displacement:** the distance of an object from a fixed point in a specified direction
  - **Velocity:** the rate of change of displacement of an object
  - **Acceleration:** the rate of change of velocity of an object

Equations for Velocity & Acceleration

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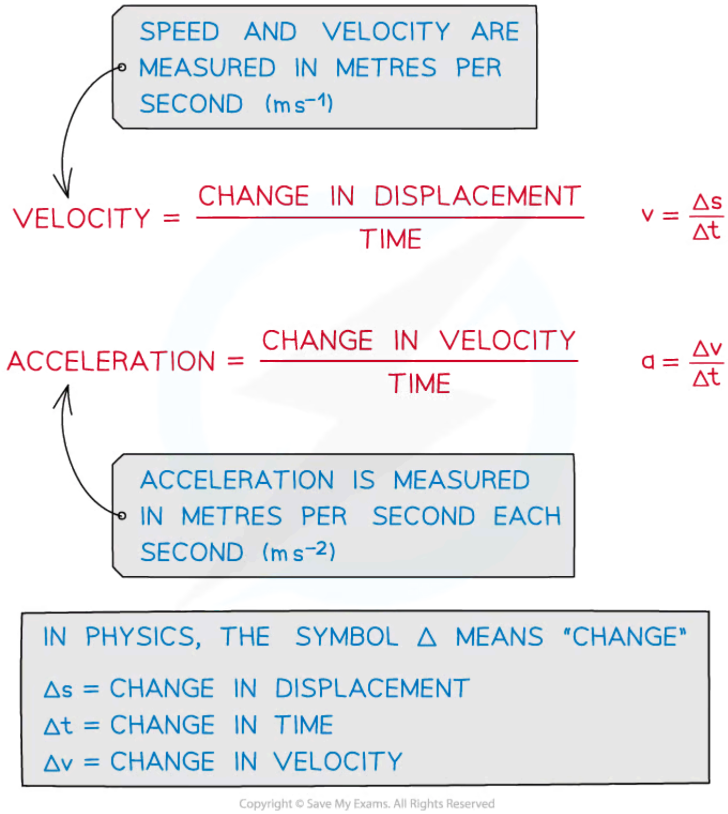

Equations linking displacement, velocity and acceleration

Worked Example

A car accelerates uniformly from rest to a speed of 150 km h^{-1} in 6.2 s. Calculate the magnitude of the acceleration of the car in m s^{-2}.

Answer:

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Step 1: Convert the speed from km h^{-1} to m s^{-1}

$$150 \text{ km h}^{-1} = 150 \times 10^3 \text{ m h}^{-1}$$

$$3600 \text{ s} = 1 \text{ h}$$

$$\frac{150 \times 10^3}{3600} = 41.67 \text{ m s}^{-1}$$

Step 2: Write down the equation for acceleration

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

Step 3: Calculate the acceleration

$$a = \frac{41.67}{6.2} = 6.7 \text{ m s}^{-2}$$

Instantaneous Speed / Velocity

- The instantaneous speed (or velocity) is the speed (or velocity) of an object at any given point in time
- This could be for an object moving at a constant velocity or accelerating
  - An object accelerating is shown by a **curved line** on a displacement – time graph
  - An accelerating object will have a changing velocity
- To find the instantaneous velocity on a displacement-time graph:
  - Draw a **tangent** at the required time
  - Calculate the **gradient** of that tangent

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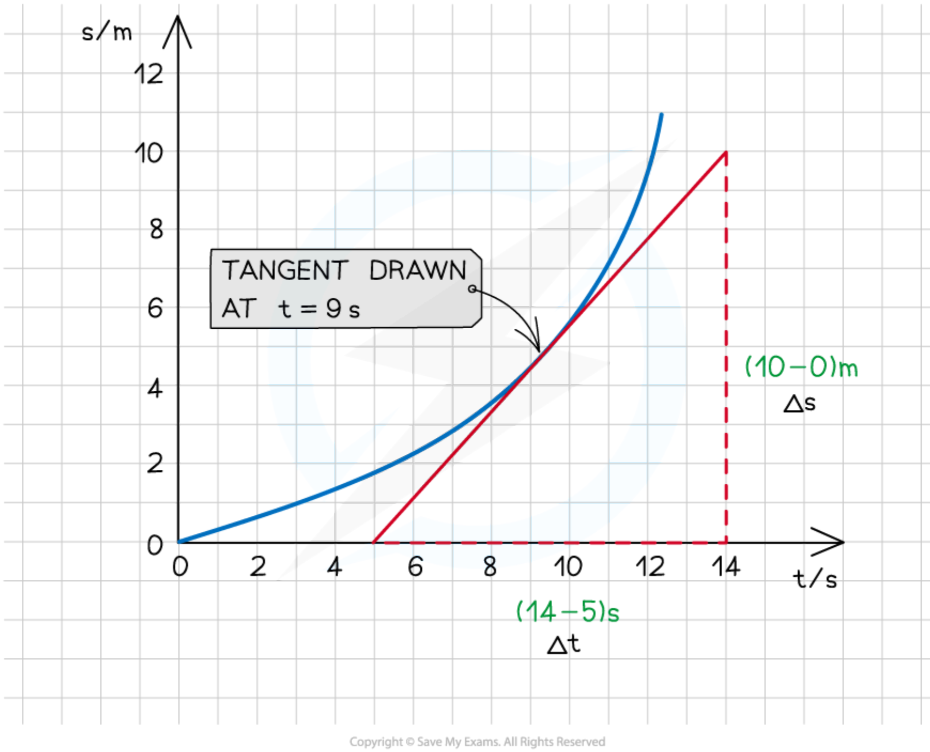

The instantaneous velocity is found by drawing a tangent on the displacement time graph

Average Speed / Velocity

- The average speed (or velocity) is the **total distance** (or displacement) divided by the **total time**
- To find the average velocity on a displacement-time graph, divide the **total displacement** (on the y-axis) by the **total time** (on the x-axis)
    - This method can be used for both a curved or a straight line on a displacement-time graph

Worked Example

A cyclist travels a distance of 20 m at a constant speed then decelerates to a traffic light 5 m ahead. The whole journey takes 3.5 s. Calculate the average speed of the cyclist.

Answer:

Step 1: Write the average speed equation

Average speed = total distance ÷ total time

Step 2: Calculate the total distance

Total distance = 20 + 5 = 25 m

Step 3: Calculate the average speed

Average speed = 25 ÷ 3.5 = 7.1 m s^{-1}

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Motion Graphs

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Motion Graphs

- Three types of graph that can represent motion are displacement-time graphs, velocity-time graphs and acceleration-time graphs

Displacement-Time Graph

- On a **displacement-time graph:**
  - The **gradient** (or slope) equals **velocity**
  - The **y-intercept** equals the **initial displacement**
  - A diagonal **straight** line represents a **constant** velocity
    - A **positive slope** represents motion in the **positive direction**
    - A **negative slope** represents motion in the **negative direction**
  - A **curved** line represents an **acceleration**
  - A **horizontal line** (zero slope) represents a state of **rest**
  - The area under the curve is meaningless
- Remember the displacement-time graph can have positive or negative values on the displacement axis. However, a distance-time graph only has positive

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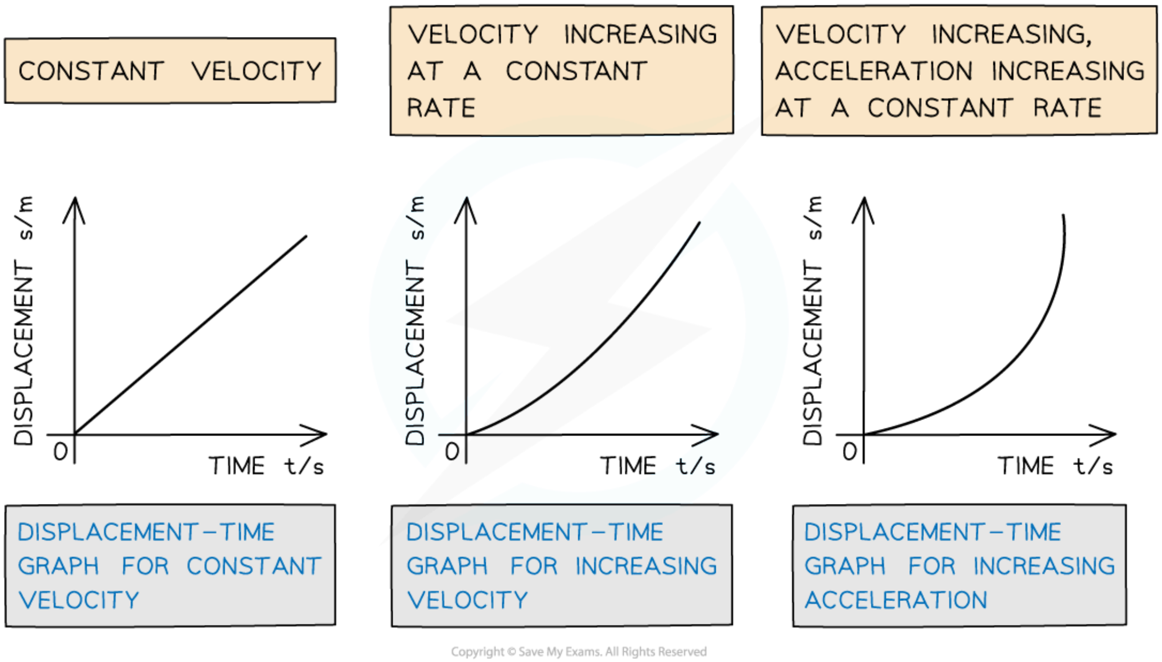
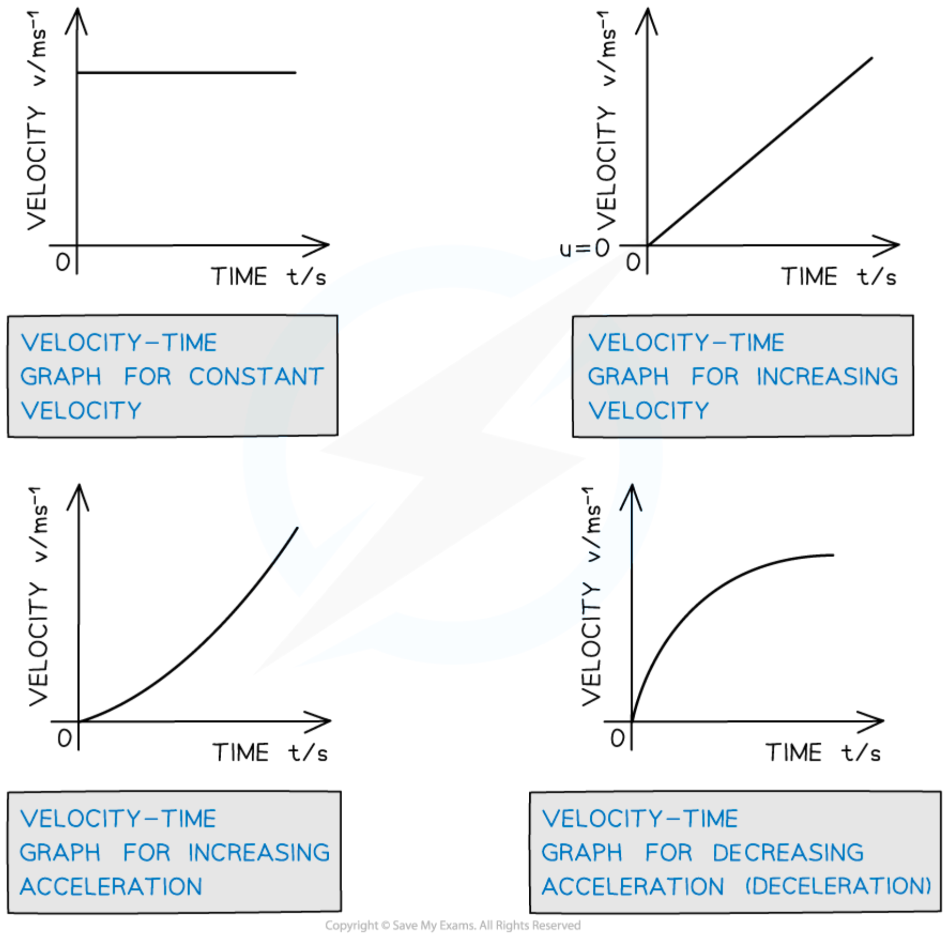


Displacement-time graph for different scenarios

Velocity-Time Graph

- On a **velocity-time graph:**
  - **Slope** equals **acceleration**
  - The **y-intercept** equals the **initial velocity**
  - A **straight** line represents **uniform** acceleration
    - A **positive** slope represents an **increase** in **velocity** (acceleration) in the **positive direction**
    - A **negative** slope represents an **increase** in **velocity** (acceleration) in the **negative direction**
  - A **curved** line represents the **non-uniform acceleration**
  - A **horizontal** line (zero slope) represents motion with **constant velocity**
  - The **area** under the curve equals the **displacement** or **distance** travelled
- Remember the velocity-time graph can have positive or negative values on the displacement axis. However, a speed-time graph only has positive



Velocity-time graph for different scenarios

Acceleration-Time Graph

- On an **acceleration-time graph:**
  - The slope is meaningless
  - The **y-intercept** equals the **initial acceleration**
  - A horizontal line (zero slope) represents an object undergoing **constant acceleration**
  - The **area** under the curve equals the **change in velocity**

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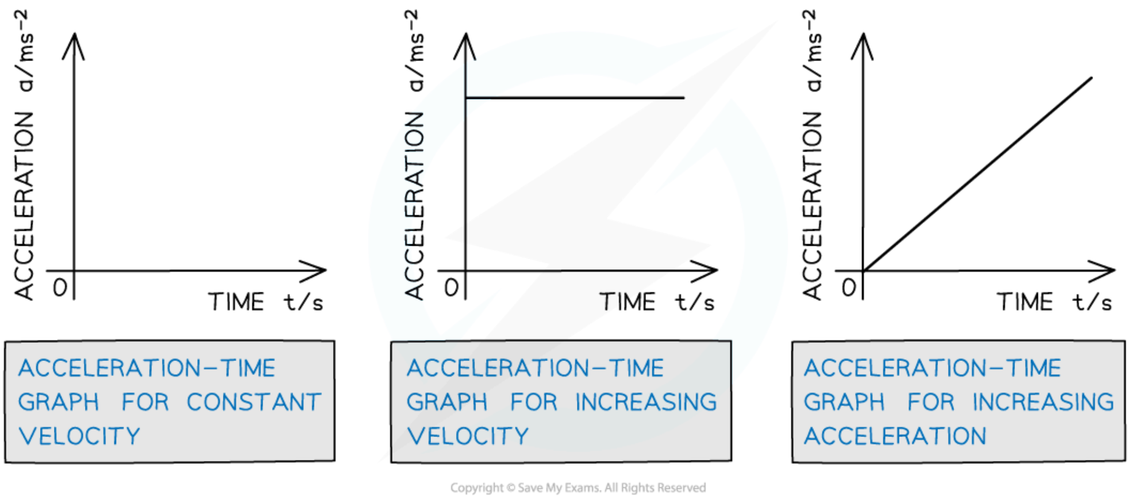

Acceleration-time graphs for different velocity scenarios

Displacement & Velocity-Time Graphs

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Displacement-Time Graphs

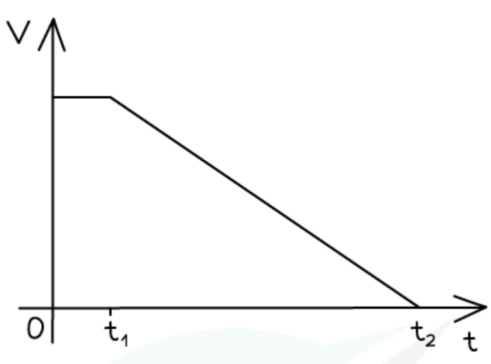
- Displacement-time graphs show the changing position of an object in motion
- They also show whether an object is moving forwards (positive displacement) or backwards (negative displacement)

Velocity = Gradient of a displacement-time graph

- The greater the slope, the **greater the velocity**
- A negative gradient = a negative velocity (the object is moving backwards)

Worked Example

A car driver sees a hazard ahead and applies the brakes to bring the car to rest. What does the displacement-time graph look like?



Answer:

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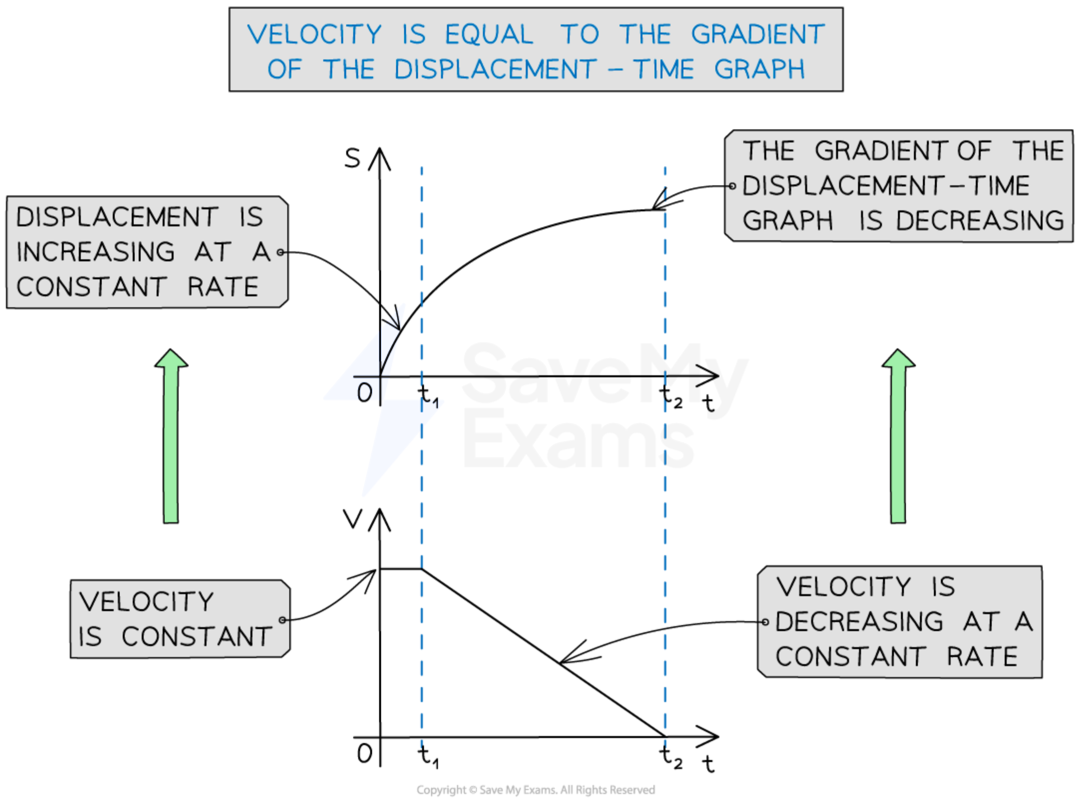

Velocity–Time Graphs

- Velocity-time graphs show the speed and direction of an object in motion over a specific period of **time**
- The area under a velocity-time graph is equal to the **displacement** of a moving object

Displacement = Area under a velocity-time graph

- **Acceleration** is any change in the velocity of an object in a given time
- As velocity is a vector quantity, this means that if the **speed** of an object **changes**, or its **direction changes**, then it is accelerating
  - An object that slows down tends to be described as 'decelerating'

Acceleration = Gradient of a velocity-time graph

Motion of a Bouncing Ball

- For a bouncing ball, the acceleration due to gravity is **always** in the same direction (in a uniform gravitational field such as the Earth's surface)

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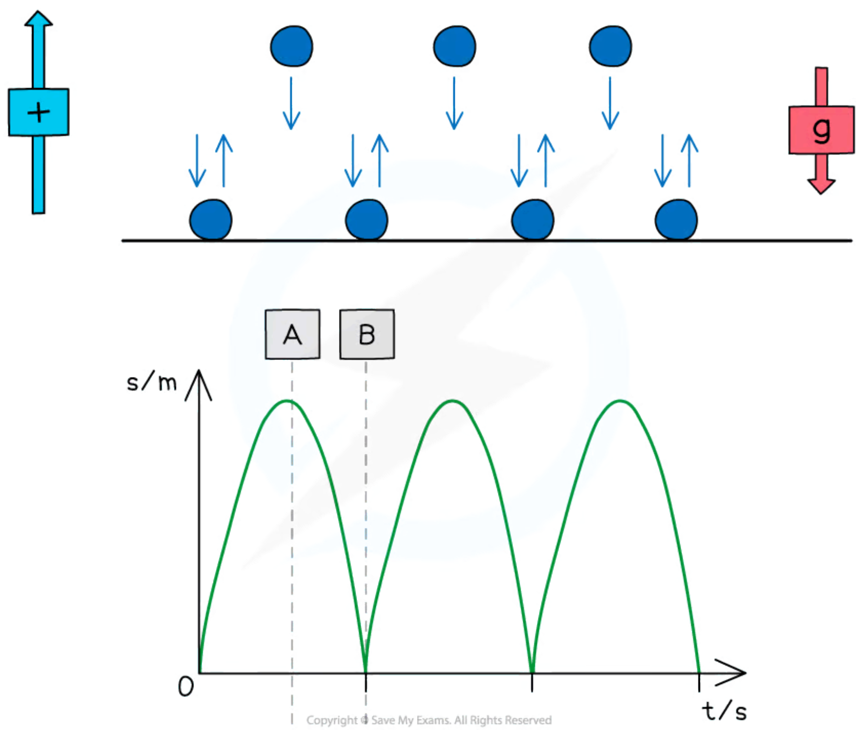
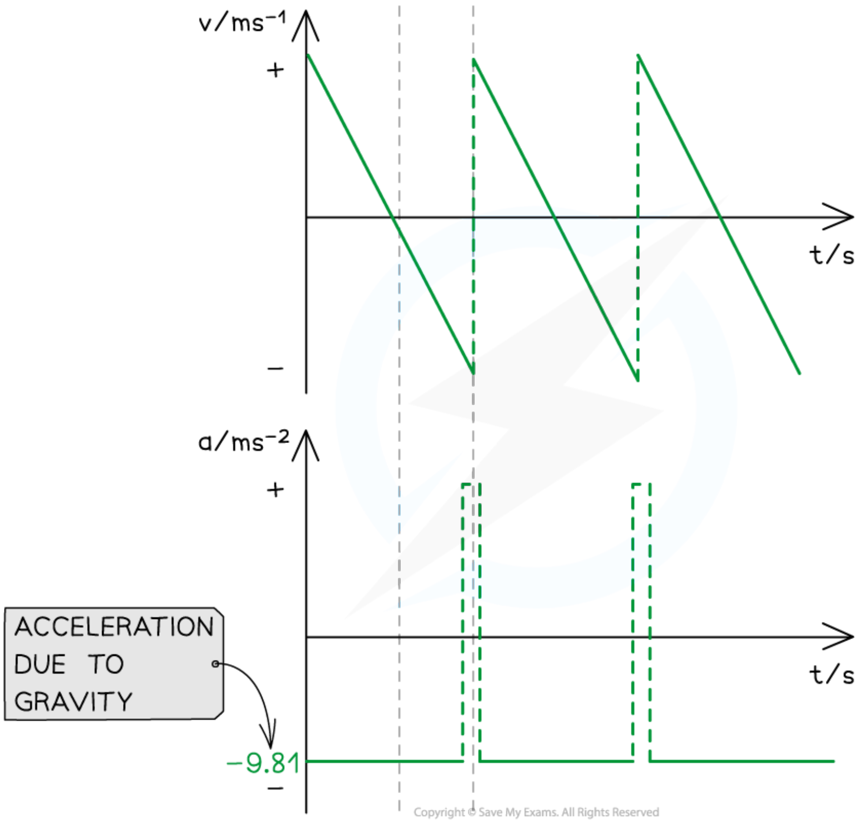
    - This is assuming there are no other forces on the ball, such as air resistance
- Since the ball changes its direction when it reaches its highest and lowest point, the direction of the velocity will change at these points
- The vector nature of velocity means the ball will sometimes have a:
    - **Positive velocity** if it is travelling in the positive direction
    - **Negative velocity** if it is travelling in the negative direction
- An example could be a ball bouncing from the ground back upwards and back down again
    - The positive direction is taken as upwards
    - This will be either stated in the question or can be chosen, as long as the direction is consistent throughout
- Ignoring the effect of air resistance, the ball will reach the same height every time before bouncing from the ground again
- When the ball is travelling upwards, it has a positive velocity which slowly decreases (decelerates) until it reaches its highest point





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- At point **A** (the highest point):
  - The ball is at its maximum displacement
  - The ball momentarily has zero velocity
  - The velocity changes from positive to negative as the ball changes direction
  - The acceleration, *g*, is still constant and directed vertically downwards
- At point **B** (the lowest point):
  - The ball is at its minimum displacement (on the ground)
  - Its velocity changes instantaneously from negative to positive, but its speed (magnitude) **remains the same**
  - The change in direction causes a momentary acceleration (since acceleration = change in velocity / time)

Worked Example

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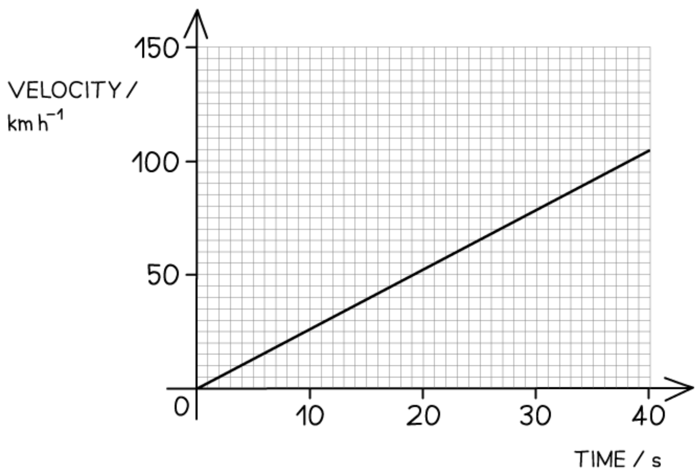
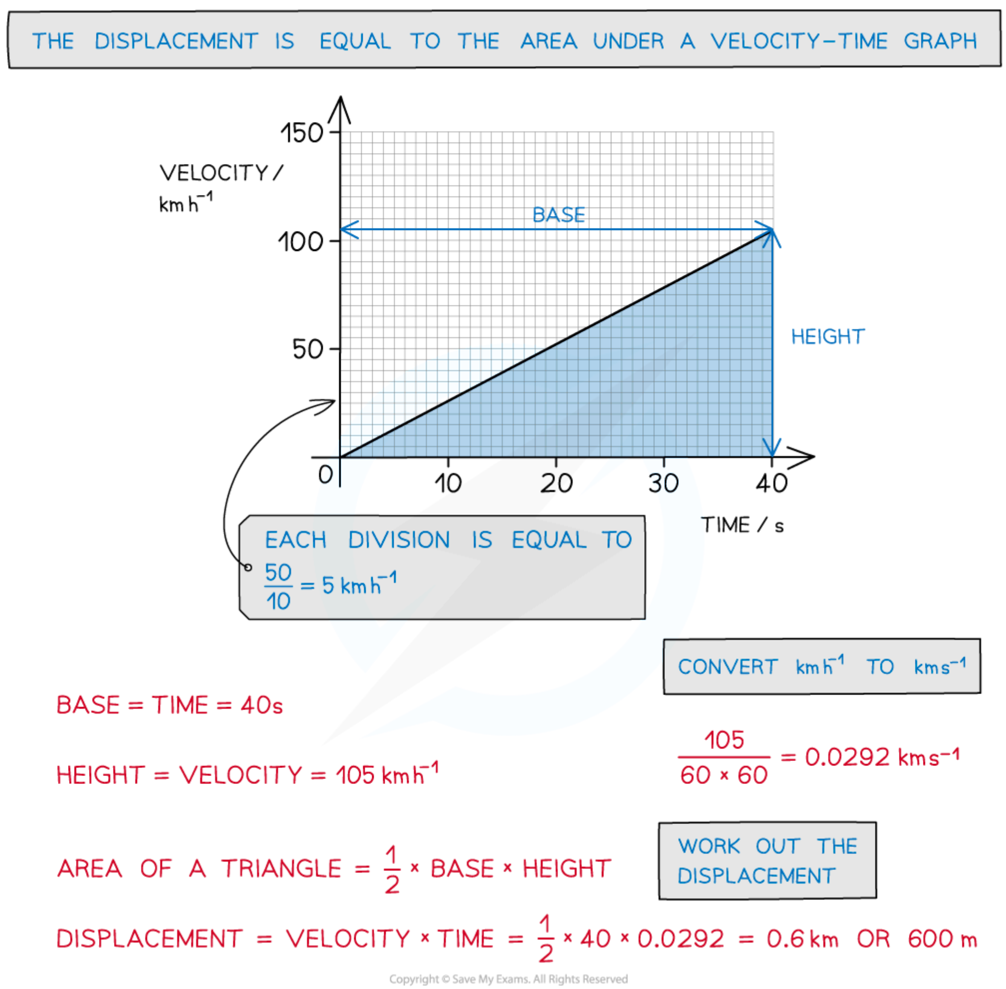
The velocity-time graph of a vehicle travelling with uniform acceleration is shown in the diagram below.



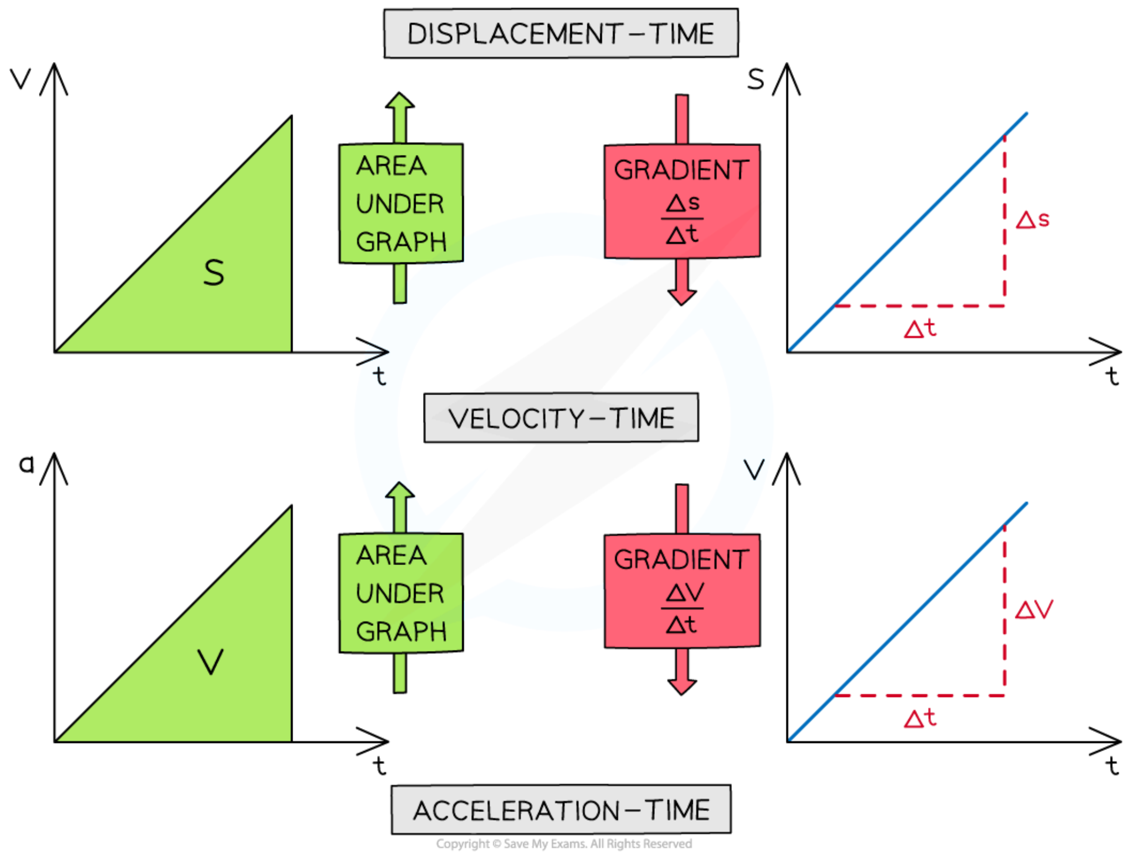
Calculate the displacement of the vehicle at 40 s.

Answer:



Summary of Gradients & Areas

- The gradient of a **displacement**-time graph is the **velocity**
- The gradient of a **velocity**-time graph is the **acceleration**
- The area under a **velocity**-time graph is the **displacement**
- The area under an **acceleration**-time graph is the **velocity**



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Examiner Tips and Tricks

Always check the values given on the y-axis of a motion graph - students often confuse displacement-time graphs and velocity-time graphs. The area under the graph can often be broken down into triangles, squares and rectangles, so make sure you are comfortable with calculating area!