Chapter 9 - Mechanics

Constant Acceleration

Chapter Overview

1. Displacement-Time Graphs

2. Velocity-Time Graphs

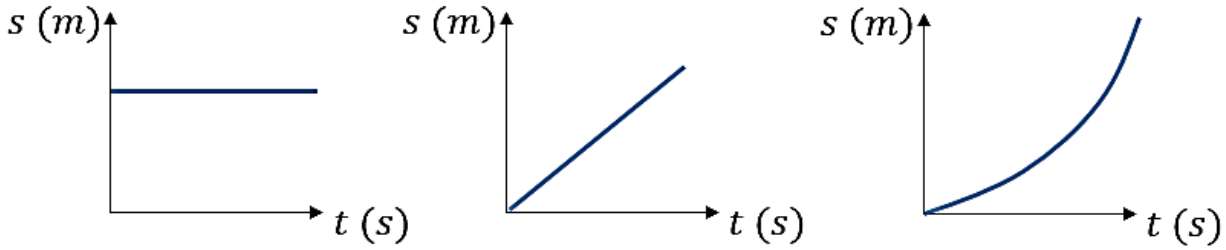
3. Constant Acceleration Formulae (SUVAT)

4. Vertical Motion Under Gravity

Topics	What students need to learn:		
	Content		Guidance
7 Kinematics	7.1	Understand and use the language of kinematics: position; displacement; distance travelled; velocity; speed; acceleration.	
	7.2	Understand, use and interpret graphs in kinematics for motion in a straight line: displacement against time and interpretation of gradient; velocity against time and interpretation of gradient and area under the graph.	Derivation may use knowledge of Sections 7.2 and/or 7.4 Understand and use *suvat* formulae for constant acceleration in 2D.
7 Kinematics *continued*	7.3	Understand, use and derive the formulae for constant acceleration for motion in a straight line.	Derivation may use knowledge of sections 7.2 and/or 7.4 Understand and use *suvat* formulae for constant acceleration in 2D.
	7.4	Use calculus in kinematics for motion in a straight line: $v = \frac{dr}{dt}$, $a = \frac{dv}{dt} = \frac{d^2r}{dt^2}$ $r = \int v \ dt$, $v = \int a \ dt$	The level of calculus required will be consistent with that in Sections 7 and 8 in Paper 1.

1. Displacement-Time Graphs

Describe the motion of each object:



Velocity is the rate of change of displacement
(i.e. gradient of displacement-time graph)

Average Velocity = _____

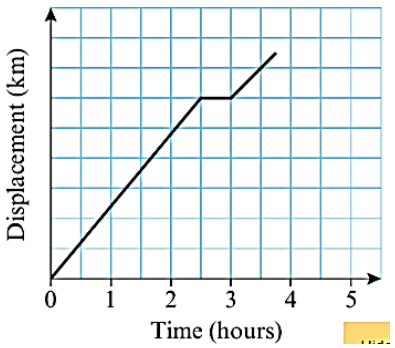
Average Speed = _____

Example *(Exercise 9A Question 2)*

Khalid drives from his home to a hotel. He drives for $2\frac{1}{2}$ hours at an average velocity of $60\,\text{km}\,\text{h}^{-1}$. He then stops for lunch before continuing to his hotel. The diagram shows a displacement–time graph for Khalid's journey.

a Work out the displacement of the hotel from Khalid's home.

b Work out Khalid's average velocity for his whole journey.



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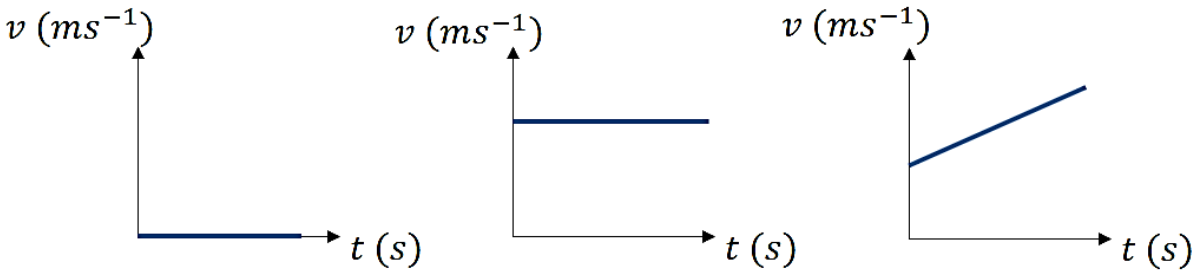
2. Velocity-Time Graphs

Describe the motion of each object:



Acceleration the rate of change of velocity
(i.e. gradient of velocity-time graph)

The **area** under a velocity-time graph gives the **distance travelled.**

Example

The velocity-time graph shown is for a body which starts from rest, accelerates uniformly to a velocity of $8ms^{-1}$ in 2 seconds, maintains that velocity for a further 5 seconds then decelerates uniformly to rest. The entire journey takes 11 seconds. Find:

a) The acceleration of the body during the initial part of the motion
b) The deceleration of the body during the final part of the motion
c) The total distance travelled by the body

Algebraic Example

A particle moves along a straight line. The particle accelerates uniformly from rest to a velocity of 8 ms^{-1} in T seconds. The particle then travels at a constant velocity of 8 ms^{-1} for $5T$ seconds. The particle then decelerates uniformly to rest in a further 40 s.

(a) Sketch a velocity-time graph to illustrate the motion of the particle.

Give then the total displacement of the particle is 600m.

(b) find the value of T.

Test Your Understanding *(EdExcel M1 May 2013 Q5)*

A car is travelling along a straight horizontal road. The car takes 120 s to travel between two sets of traffic lights which are 2145 m apart. The car starts from rest at the first set of traffic lights and moves with constant acceleration for 30 s until its speed is 22 m s^{-1}. The car maintains this speed for T seconds. The car then moves with constant deceleration, coming to rest at the second set of traffic lights.

(a) Sketch, in the space below, a speed-time graph for the motion of the car between the two sets of traffic lights.

(2)

(b) Find the value of T.

(3)

A motorcycle leaves the first set of traffic lights 10 s after the car has left the first set of traffic lights. The motorcycle moves from rest with constant acceleration, a m s^{-2}, and passes the car at the point A which is 990 m from the first set of traffic lights. When the motorcycle passes the car, the car is moving with speed 22 m s^{-1}.

(c) Find the time it takes for the motorcycle to move from the first set of traffic lights to the point A.

(4)

(d) Find the value of a.

(2)

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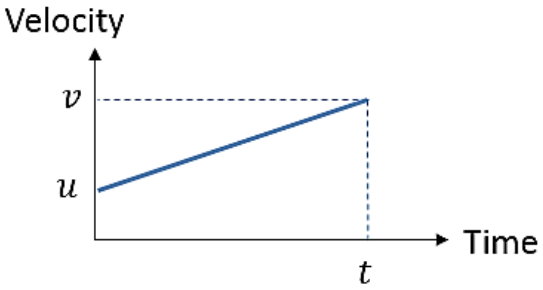
3-4. Constant Acceleration Formulae (SUVAT Equations)

These formulae are used to solve problems where the object is moving in a **straight line with constant acceleration for a specific period of time**. You should memorise these and know how to derive them.



$$Acceleration = \frac{change\ in\ velocity}{time}$$

$$v =$$

(Equation 1)

For uniform acceleration, the average velocity is the average of v and u. Using the area of the graph (which we know gives distance):

$$s =$$

(Equation 2)

Eliminating v - sub for v from equation 1 into equation 2:

$s =$

(Equation 3)

Eliminating t - sub for t from equation 1 into equation 2:

$v^2 =$

(Equation 4)

Eliminating u – sub for u from equation 1 into equation 2:

$s =$

(Equation 5)

- Work out what you know
- Work out what you need
- Choose the appropriate equation
- Diagrams help!
- Work out which direction will be positive
- Check that your units are consistent

Example

A stone slides in a straight line across a horizontal sheet of ice. It passes a point, A with velocity $14ms^{-1}$ and a point, B 2.5 seconds later. Assuming the deceleration is uniform and that AB = 30m, find:

a) The deceleration

b) The velocity at B

c) How long after passing A the stone comes to rest

Example – Deceleration Leading to a Change in Direction

A particle travels with uniform deceleration $2ms^{-2}$ in a horizontal line. The points A and B lie on the line and AB = 32m. At time t = 0, the particle passes through A with velocity $12ms^{-1}$ in the direction AB. Find:

a) The values of t when the particle is at B

b) The velocity of the particle for each of these values of t.

Test Your Understanding *(EdExcel M1 May 2013 Q4)*

A lorry is moving along a straight horizontal road with constant acceleration. The lorry passes a point A with speed u m s^{-1}, ($u < 34$), and 10 seconds later passes a point B with speed 34 m s^{-1}. Given that $AB = 240$ m, find

(a) the value of u,

(3)

(b) the time taken for the lorry to move from A to the mid-point of AB.

(6)

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Exercise 9D Page 145

5. Vertical Motion Under Gravity

The downwards acceleration under gravity is $g = 9.8$ ms^{-2}.
ALWAYS state the positive direction in your calculations.
Quote final answers to 2 or 3 s.f. – you may be penalised if you quote more.

Example

A ball is thrown vertically upwards with a velocity of 14.7ms^{-1} from a platform 19.6m above the ground. Find:

a) The time taken for the ball to reach the ground

b) The velocity of the ball when it hits the ground

Example

A ball is projected vertically upwards from ground level at a speed of 20 ms^{-1}.
Determine the amount of time the ball is at least 10m above ground level.

Example – When Two Particles are in Motion

Two stones are thrown from the same point at the same time - one vertically upwards with speed $30ms^{-1}$ and one vertically downwards at $30ms^{-1}$. Find how far apart the stones are after 3 seconds.

Test Your Understanding *(EdExcel M1 May 2013 (R) Q4)*

At time $t = 0$, two balls A and B are projected vertically upwards. The ball A is projected vertically upwards with speed 2 m s^{-1} from a point 50 m above the horizontal ground. The ball B is projected vertically upwards from the ground with speed 20 m s^{-1}. At time $t = T$ seconds, the two balls are at the same vertical height, h metres, above the ground. The balls are modelled as particles moving freely under gravity. Find

(a) the value of T,

(5)

(b) the value of h.

(2)

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Mixed Exercise 9 Page 152