

9) Constant acceleration

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Worked example

A cyclist is travelling along a straight road.
She accelerates at a constant rate from a velocity of 5 ms^{-1} to a velocity of 7.4 ms^{-1} in 50 seconds.

Find:

- (a) the distance she travels in these 50 seconds
- (b) her acceleration in these 50 seconds.

Your turn

A cyclist is travelling along a straight road.
She accelerates at a constant rate from a velocity of 4 ms^{-1} to a velocity of 7.5 ms^{-1} in 40 seconds.

Find:

- (a) the distance she travels in these 40 seconds
- (b) her acceleration in these 40 seconds.

a) 230 m

b) 0.0875 ms^{-2}

Worked example

A particle moves in a straight line from a point A to a point B with a constant deceleration 3 ms^{-2} . The velocity of the particle at A is 16 ms^{-1} and the velocity of the particle at B is 4 ms^{-1} . Find:

- (a) the time taken for the particle to move from A to B .
- (b) the distance from A to B .

After reaching B the particle continues to move along the straight line with constant deceleration 3 ms^{-2} .

The particle is at the point C 12 seconds after passing through the point A . Find:

- (c) the velocity of the particle at C .
- (d) The distance from A to C .

Your turn

A particle moves in a straight line from a point A to a point B with a constant deceleration 1.5 ms^{-2} . The velocity of the particle at A is 8 ms^{-1} and the velocity of the particle at B is 2 ms^{-1} . Find:

- (a) the time taken for the particle to move from A to B .
- (b) the distance from A to B .

After reaching B the particle continues to move along the straight line with constant deceleration 1.5 ms^{-2} .

The particle is at the point C 6 seconds after passing through the point A . Find:

- (c) the velocity of the particle at C .
- (d) The distance from A to C .

a) 4 s

b) 20 m

c) 1 ms^{-1} in the direction \overrightarrow{BA}

d) 21 m

Worked example

A car moves from traffic lights along a straight road with constant acceleration.

The car starts from rest at the traffic lights and 20 seconds later the car passes a speed-trap where it is registered as travelling at 54 km h^{-1} . Find:

- (a) the acceleration of the car
- (b) the distance between the traffic lights and the speed-trap.

Your turn

A car moves from traffic lights along a straight road with constant acceleration.

The car starts from rest at the traffic lights and 30 seconds later the car passes a speed-trap where it is registered as travelling at 45 km h^{-1} . Find:

- (a) the acceleration of the car
- (b) the distance between the traffic lights and the speed-trap.

a) $\frac{5}{12} \text{ ms}^{-2} = 0.417 \text{ ms}^{-2} \text{ (3 sf)}$

b) 187.5 m

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Worked example

Use the equations $v = u + at$ and $s = \left(\frac{u+v}{2}\right)t$ to derive:

$$v^2 = u^2 + 2as$$

$$s = vt - \frac{1}{2}at^2$$

Your turn

Use the equations $v = u + at$ and $s = \left(\frac{u+v}{2}\right)t$ to derive:

$$s = ut + \frac{1}{2}at^2$$

Shown

Worked example

A particle is moving along a straight line from A to B with constant acceleration 3 ms^{-2} .

The velocity of the particle is 5 ms^{-1} in the direction \overrightarrow{AB} .

The velocity of the particle at B is 81 ms^{-1} in the same direction.

Find the distance from A to B .

Your turn

A particle is moving along a straight line from A to B with constant acceleration 5 ms^{-2} .

The velocity of the particle is 3 ms^{-1} in the direction \overrightarrow{AB} .

The velocity of the particle at B is 18 ms^{-1} in the same direction.

Find the distance from A to B .

31.5 m

Worked example

A particle is moving in a straight horizontal line with constant deceleration 6 ms^{-2} .

At time $t = 0$ the particle passes through a point O with speed 23 ms^{-1} travelling towards a point A , where $OA = 40 \text{ m}$. Find:

- (a) the times when the particle passes through A
- (b) the value of t when the particle returns to O .

Your turn

A particle is moving in a straight horizontal line with constant deceleration 4 ms^{-2} .

At time $t = 0$ the particle passes through a point O with speed 13 ms^{-1} travelling towards a point A , where $OA = 20 \text{ m}$. Find:

- (a) the times when the particle passes through A
- (b) the value of t when the particle returns to O .

a) $t = 2.5 \text{ s}, t = 4 \text{ s}$

b) $t = 6.5 \text{ s}$

Worked example

A particle is moving in a straight horizontal line with constant deceleration 6 ms^{-2} .

At time $t = 0$ the particle passes through a point O with speed 23 ms^{-1} .

Find the total distance travelled by the particle between when it first passes O and returns to O

Your turn

A particle is moving in a straight horizontal line with constant deceleration 4 ms^{-2} .

At time $t = 0$ the particle passes through a point O with speed 13 ms^{-1} .

Find the total distance travelled by the particle between when it first passes O and returns to O

42.25 m

Worked example

Two particles P and Q are moving along the same straight horizontal line with constant accelerations 2 and 4 ms^{-2} respectively. At time $t = 0$, P passes through a point A with speed 12 ms^{-1} . One second later Q passes through A with speed 6 ms^{-1} , moving in the same direction as P .

- Find the value of t where the particles meet.
- Find the distance of A from the point where the particles meet.

Your turn

Two particles P and Q are moving along the same straight horizontal line with constant accelerations 6 and 8 ms^{-2} respectively. At time $t = 0$, P passes through a point A with speed 10 ms^{-1} . One second later Q passes through A with speed 5 ms^{-1} , moving in the same direction as P .

- Find the value of t where the particles meet.
- Find the distance of A from the point where the particles meet.

a) $t = 13.1 \text{ s}$ (3 sf)

b) 644 m (3 sf)

Worked example

A particle moves in a straight horizontal line with constant acceleration from A to B, then B to C.

$AB = 3 \text{ km}$ and $BC = 12 \text{ km}$.

It takes 2 hour from A to B and 4 hours from B to C.

Find:

- The acceleration of the particle
- The particle's speed as it passes A

Your turn

A particle moves in a straight horizontal line with constant acceleration from A to B, then B to C.

$AB = 4 \text{ km}$ and $BC = 12 \text{ km}$.

It takes 2 hours from A to B and 3 hours from B to C.

Find:

- The acceleration of the particle
- The particle's speed as it passes A

a) $0.8 \text{ km h}^{-2} = 6.1728 \times 10^{-5} \text{ ms}^{-2}$ (3 sf)

b) $1.2 \text{ km h}^{-1} = 0.333 \text{ ms}^{-1}$ (3 sf)

9.5) Vertical motion under gravity

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Worked example

A book falls off the top shelf of a bookcase. The shelf is 2.8 m above a wooden floor. Find:
(a) the time the book takes to reach the floor,
(b) the speed with which the book strikes the floor.

Your turn

A book falls off the top shelf of a bookcase. The shelf is 1.4 m above a wooden floor. Find:
(a) the time the book takes to reach the floor,
(b) the speed with which the book strikes the floor.

a) 0.53 s

b) 5.2 ms^{-1}

Worked example

A ball is projected vertically upwards, from a point X which is 5m above the ground, with speed 15 ms^{-1} . Find

- (a) the greatest height above the ground reached by the ball,
- (b) the time of flight of the ball

Your turn

A ball is projected vertically upwards, from a point X which is 7m above the ground, with speed 21 ms^{-1} . Find

- (a) the greatest height above the ground reached by the ball,
- (b) the time of flight of the ball

a) 30 m (2 sf)

b) 4.6 s (2 sf)

Worked example

A ball is projected vertically upwards from ground level at a speed of 40 ms^{-1} .

Determine the amount of time the ball is at least 20m above ground level.

Your turn

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.

2.9 s (2 sf)

Worked example

A ball is projected vertically upwards with initial speed of 20 ms^{-1} .

It hits the ground 5 s later.

Find the height above the ground from which the ball was thrown.

Your turn

A ball is projected vertically upwards with initial speed of 15 ms^{-1} .

It hits the ground 5 s later.

Find the height above the ground from which the ball was thrown.

47.5 m

Worked example

A stone is thrown vertically upward from a point which is 8 m above the ground with speed 5 ms^{-1} .

Find:

- The time of flight of the stone
- The total distance travelled by the stone

Your turn

A stone is thrown vertically upward from a point which is 5 m above the ground with speed 8 ms^{-1} .

Find:

- The time of flight of the stone
- The total distance travelled by the stone

a) 2.1 s (2 sf)

b) 12 m (2 sf)

Worked example

Ball A falls vertically from rest from the top of a tower 48 m high. At the same time as A begins to fall, another ball B is projected vertically upwards from the bottom of the tower with speed 24 ms^{-1} . The balls collide. Find the distance to the point where the balls collide from the bottom of the tower.

Your turn

Ball A falls vertically from rest from the top of a tower 63 m high. At the same time as A begins to fall, another ball B is projected vertically upwards from the bottom of the tower with speed 21 ms^{-1} . The balls collide. Find the distance to the point where the balls collide from the bottom of the tower.

19 m (2 sf)

Worked example

At time $t = 0$, two balls A and B are projected vertically upwards. Ball A is projected upwards with speed 3 ms^{-1} from a point 40 m above the horizontal ground. Ball B is projected vertically upwards from the ground with speed 30 ms^{-1} . The balls are modelled as particles moving freely under gravity. Find the time and the height at which the balls are at the same vertical height.

Your turn

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

$$t = 2.8 \text{ s (2 sf)}$$

$$h = 18 \text{ m (2 sf)}$$

Worked example

A ball is released from rest at a point which is 20 m above a wooden floor. Each time the ball strikes the floor, it rebounds with $\frac{2}{3}$ of the speed with which it strikes the floor.

Find the greatest height above the floor reached by the ball:

- a) The first time it rebounds from the floor
- b) The second time it rebounds from the floor.

Your turn

A ball is released from rest at a point which is 10 m above a wooden floor. Each time the ball strikes the floor, it rebounds with $\frac{3}{4}$ of the speed with which it strikes the floor.

Find the greatest height above the floor reached by the ball:

- a) The first time it rebounds from the floor
- b) The second time it rebounds from the floor.

a) 5.6 m (2 sf)

b) 3.2 m (2 sf)