# 2. Kinematics

## 2.1 Equations of motion

## Paper 1

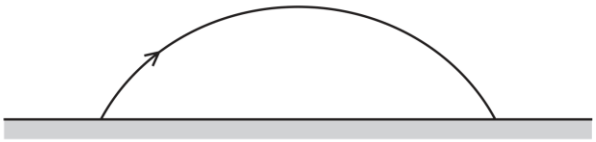
Question Paper

**1** An object is moving with initial velocity $u$. The object then moves with uniform acceleration $a$ for time $t$ until it reaches final velocity $v$.

Which equation describes the motion of the object?

**A** $u = v - 2at$ **B** $u = v - at$ **C** $v = u + at^2$ **D** $v = u + 2at^2$

**2** The diagram shows the path of a golf ball.



Which row describes changes in the horizontal and vertical components of the golf ball's velocity when air resistance is ignored?

| | horizontal | vertical |
|---|---|---|
| **A** | constant deceleration | constant acceleration downwards |
| **B** | constant deceleration | acceleration decreases upwards then increases downwards |
| **C** | constant velocity | constant acceleration downwards |
| **D** | constant velocity | acceleration decreases upwards then increases downwards |

**3** Which statement is **not** correct?

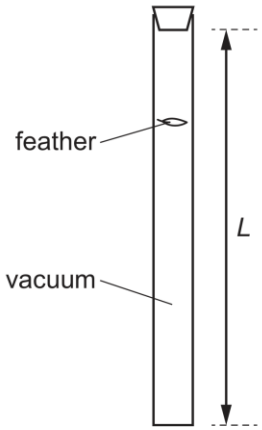
**A** Acceleration can be determined from the gradient of a velocity–time graph.

**B** Acceleration is the rate of change of velocity.

**C** Displacement can be determined from the area under a velocity–time graph.

**D** Velocity is the rate of change of distance.

**4** The diagram shows a laboratory experiment in which a feather falls from rest in a long evacuated vertical tube of length *L*.

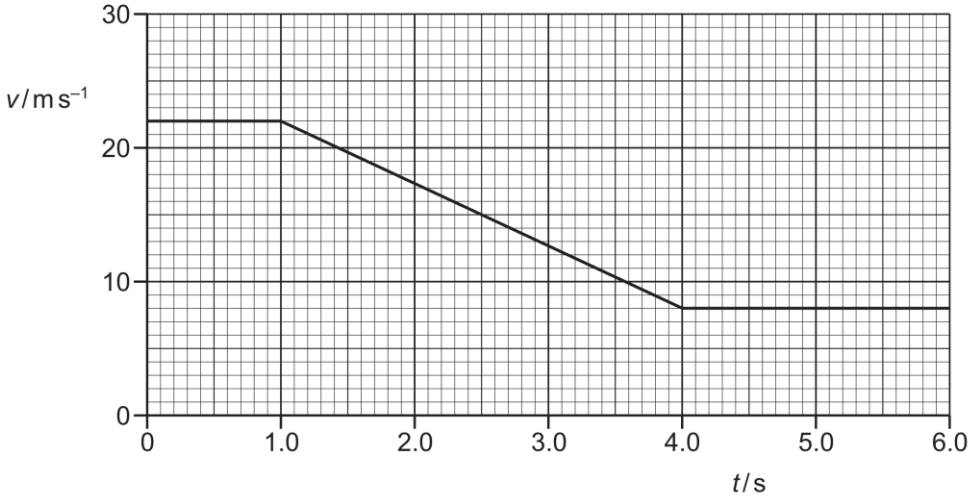



The feather takes time *T* to fall from the top to the bottom of the tube.

How far does the feather fall from the top of the tube in time 0.50*T*?

**A** 0.13*L* **B** 0.25*L* **C** 0.38*L* **D** 0.50*L*

**5** A car travels along a straight horizontal road. The graph shows the variation of the velocity *v* of the car with time *t* for 6.0 s of its journey.




The brakes of the car are applied from $t = 1.0$ s to $t = 4.0$ s.

How far does the car travel while the brakes are applied?

**A** 21 m **B** 45 m **C** 67 m **D** 83 m

**6** An object is projected from horizontal ground at a velocity of magnitude $u$ and angle $\theta$ to the horizontal. It hits the ground at a time $t$ after it is projected. Assume air resistance is negligible.




Which statement does **not** describe the motion of this object?

**A** The horizontal component of the object's velocity is constant and has the value $u\cos\theta$.

**B** The horizontal distance travelled by the object is $tu\cos\theta$.

**C** The time taken for the object to reach maximum height is $\frac{t}{2}$.

**D** The vertical component of the object's velocity is constant and has the value $u\sin\theta$.

**7** A person, travelling on a motorway a total distance of 200 km, travels the first 90 km at an average speed of 80 km h$^{-1}$.

Which average speed must be obtained for the rest of the journey if the person is to reach the destination in a total time of 2 hours 0 minutes?

**A** 110 km h$^{-1}$ **B** 120 km h$^{-1}$ **C** 122 km h$^{-1}$ **D** 126 km h$^{-1}$

**8** An object is dropped from rest on the Earth from a height of 2.0 m.

The same object is dropped from rest on the Moon from twice the height.

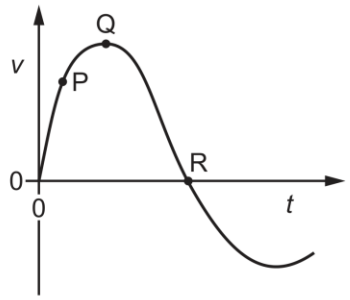
The acceleration of free fall on the Moon is approximately 16% of the value on the Earth.

Assume that there are no resistive forces acting on the object.

What is the ratio $\frac{\text{speed of the object just before hitting the surface on the Earth}}{\text{speed of the object just before hitting the surface on the Moon}}$?

**A** 1.8 **B** 2.5 **C** 3.1 **D** 3.5

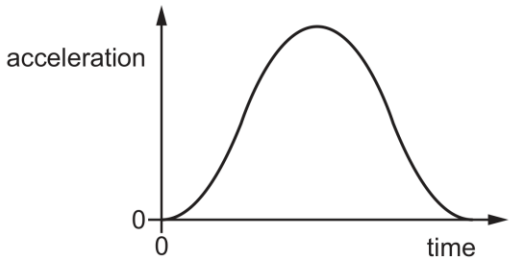
**9** The graph shows how velocity $v$ varies with time $t$ for a bungee jumper.




At which point is the bungee jumper momentarily at rest and at which point does she have zero acceleration?

| | jumper at rest | jumper with zero acceleration |
|---|---|---|
| **A** | Q | P |
| **B** | Q | R |
| **C** | R | Q |
| **D** | R | R |

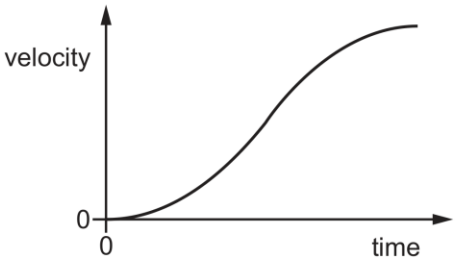
**10** The graph shows how the acceleration of an object moving in a straight line varies with time.



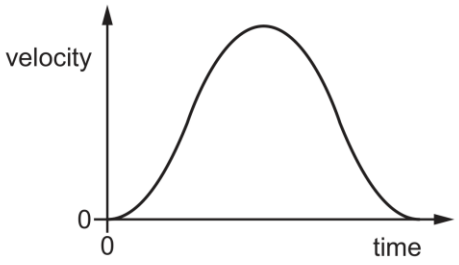

The object starts from rest.

Which graph shows the variation with time of the velocity of the object over the same time interval?

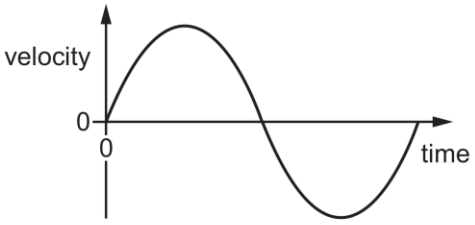
**A**



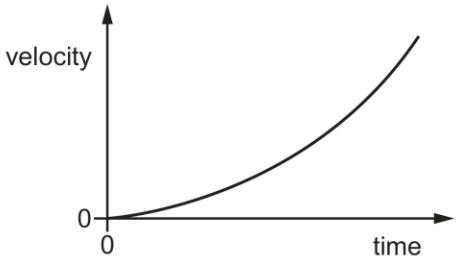

**B**




**C**




**D**



**11** A stone falls vertically from rest. Air resistance is negligible.

What is the speed of the stone when it has fallen through a distance of 0.40 m?

**A** $2.0\,m\,s^{-1}$ **B** $2.8\,m\,s^{-1}$ **C** $3.9\,m\,s^{-1}$ **D** $7.8\,m\,s^{-1}$

**12** A ball is thrown horizontally off a tall building. The ground is horizontal. Air resistance is negligible.

Which statement about the motion of the ball is correct?

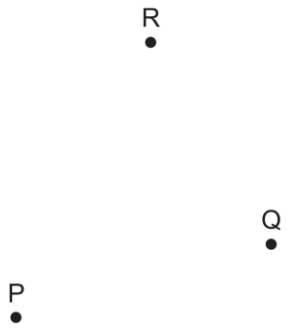
**A** The acceleration of the ball is always at right angles to the path of the ball.

**B** The ball follows a circular path until it hits the ground.

**C** The ball has constant acceleration.

**D** The ball's time in the air is proportional to the velocity at which the ball is thrown.

**13** One object moves directly from P to R.




In a shorter time, a second object moves from P to Q to R.

Which statement about the two objects is correct for the journey from P to R?

**A** They have the same average speed.

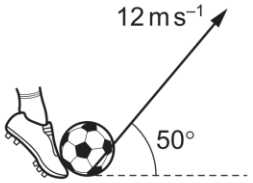
**B** They have the same average velocity.

**C** They have the same displacement.

**D** They travel the same distance.

**14** A ball is kicked so that it has an initial velocity of $12\,m\,s^{-1}$ at an angle of 50° to horizontal ground.

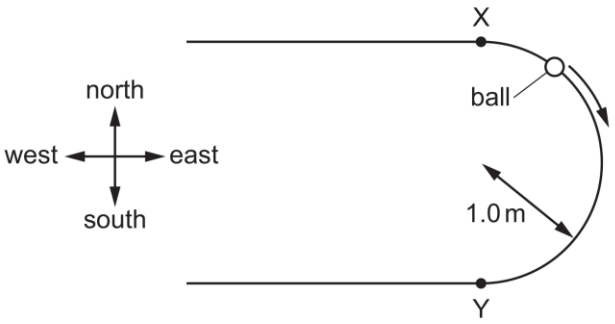
Assume that air resistance is negligible.




What is the maximum height above the ground that is reached by the ball?

**A** 0.47 m **B** 3.0 m **C** 4.3 m **D** 7.3 m

**15** A ball travels from point X to point Y around a semicircular track of radius 1.0 m, as shown.




What is the displacement of the ball from X to Y?

**A** 2.0 m

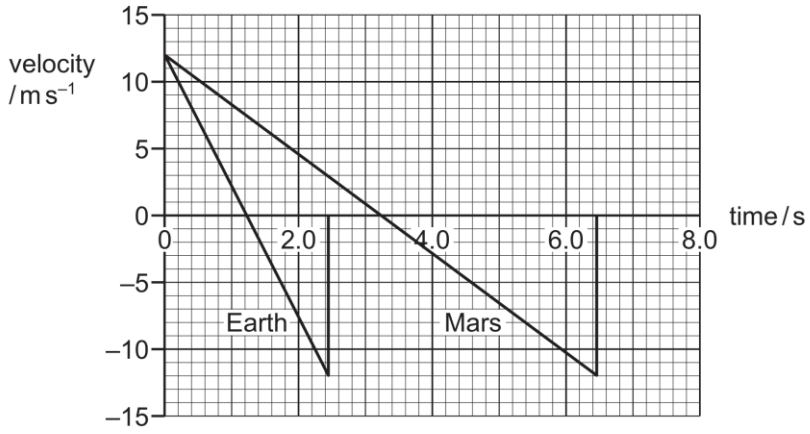
**B** 2.0 m due south

**C** 3.1 m

**D** 3.1 m due south

**16** A rock is launched vertically upwards from the surface of the Earth and an identical rock is launched vertically upwards from the surface of Mars. Each rock is launched with an initial velocity of $12\,m\,s^{-1}$.

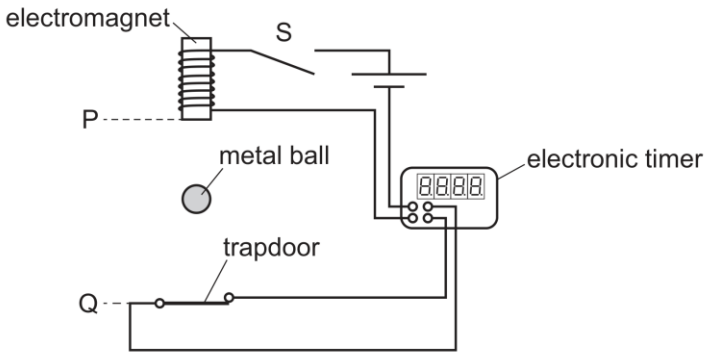
Each rock then reaches its maximum height above the surface before returning back down to the surface. The velocity–time graph for each rock is shown. In both cases, air resistance is negligible.




What is the difference in the maximum heights of the two rocks?

**A** 12 m **B** 15 m **C** 19 m **D** 24 m

**17** A student determines the acceleration of free fall by using a small metal ball, as shown.




When switch S is opened, the ball is released from an electromagnet and an electronic timer is started. The ball then falls vertically downwards. The timer stops when the ball hits a trapdoor. The student measures the distance PQ between the electromagnet and the trapdoor. This distance and the reading on the timer are then used to calculate the acceleration of free fall.

Which statement about errors in the experiment is correct?

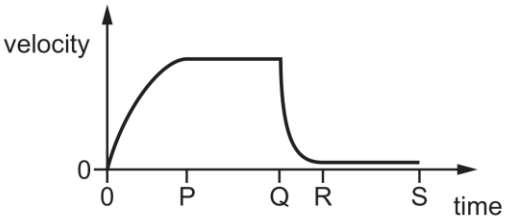
**A** The random error can be reduced by adding the diameter of the ball to the distance PQ.

**B** The random error can be reduced by subtracting the diameter of the ball from the distance PQ.

**C** The systematic error can be reduced by adding the diameter of the ball to the distance PQ.

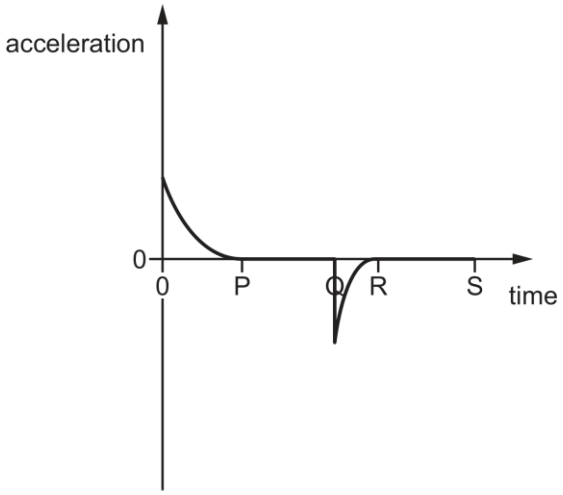
**D** The systematic error can be reduced by subtracting the diameter of the ball from the distance PQ.

**18** A parachutist falls from a stationary balloon at time $t = 0$. The velocity–time graph for the parachutist from time $t = 0$ until the time when he is just above the ground is shown.

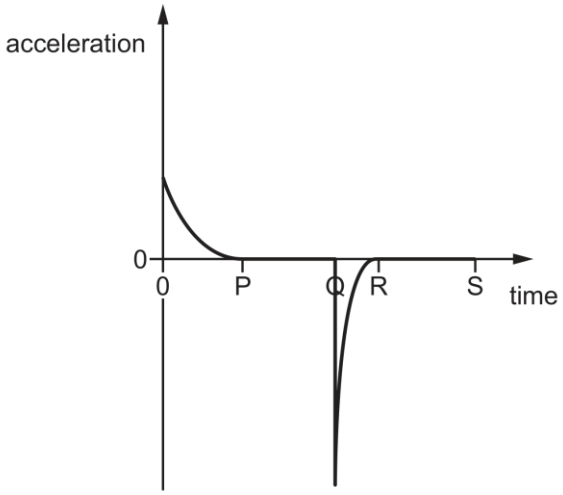



Which graph best shows the variation with time of the acceleration of the parachutist?

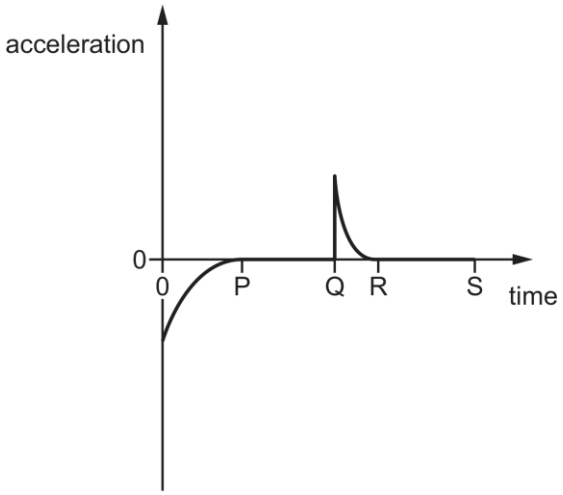
**A**



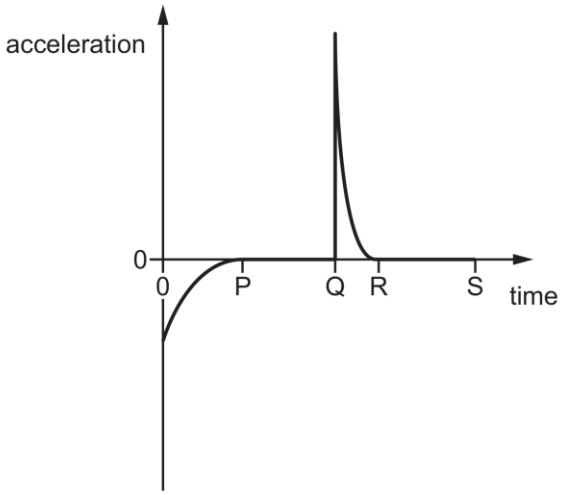

**B**



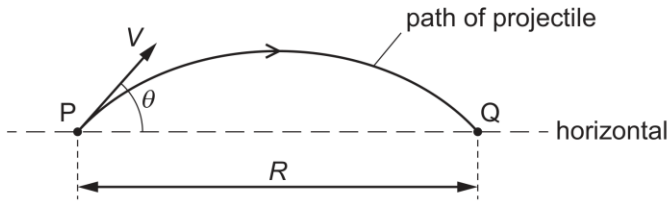

**C**




**D**



**19** A projectile is fired from point P with velocity $V$ at an angle $\theta$ to the horizontal. It lands at point Q, a horizontal distance $R$ from P, after time $T$.




The acceleration of free fall is $g$. Air resistance is negligible.

Which equation is correct?

**A** $R = VT\cos\theta$

**B** $R = VT\sin\theta$

**C** $R = VT\cos\theta - \frac{1}{2}gT^2$

**D** $R = VT\sin\theta - \frac{1}{2}gT^2$

**20** What is the definition of acceleration?

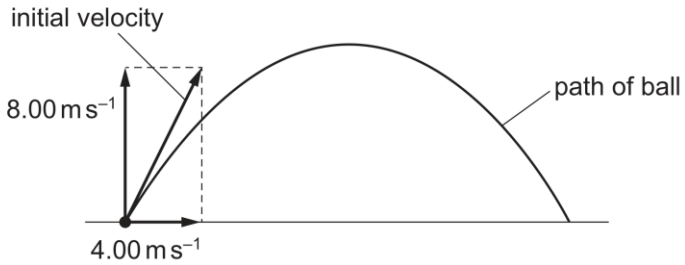
**A** the rate of change of displacement

**B** the rate of change of kinetic energy

**C** the rate of change of momentum

**D** the rate of change of velocity

**21** An astronaut on the Moon, where there is no air resistance, throws a ball. The ball's initial velocity has a vertical component of $8.00\,m\,s^{-1}$ and a horizontal component of $4.00\,m\,s^{-1}$, as shown.

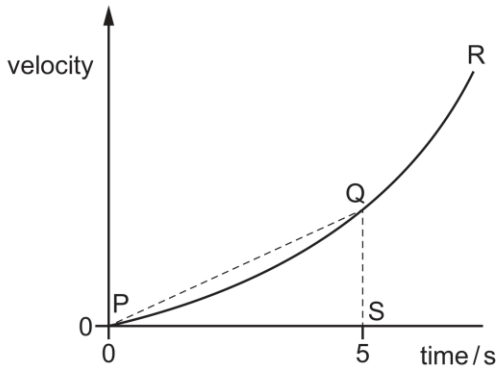



The acceleration of free fall on the Moon is $1.62\,m\,s^{-2}$.

What is the speed of the ball 9.00 s after being thrown?

**A** $6.58\,m\,s^{-1}$ **B** $7.70\,m\,s^{-1}$ **C** $10.6\,m\,s^{-1}$ **D** $14.6\,m\,s^{-1}$

**22** The curved line PQR is the velocity–time graph for a car starting from rest.




What is the average acceleration of the car over the first 5 s?

**A** the area below the curve PQ

**B** the area of the triangle PQS

**C** the gradient of the straight line PQ

**D** the gradient of the tangent at Q

**23** A ball is thrown horizontally with a speed of $10.0\,m\,s^{-1}$ above horizontal ground. The ball hits the ground after a time of 3.0 s.

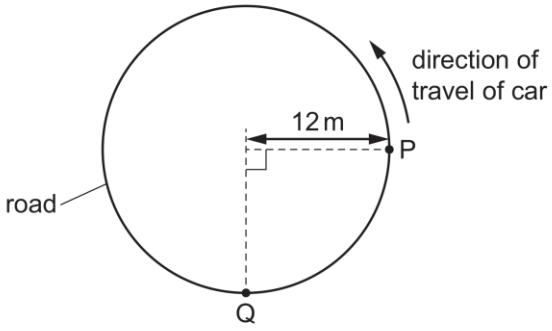
Air resistance is negligible.

What is the speed of the ball just before it hits the ground?

**A** $10\,m\,s^{-1}$ **B** $29\,m\,s^{-1}$ **C** $31\,m\,s^{-1}$ **D** $39\,m\,s^{-1}$

**24** A car travels anticlockwise along a horizontal circular road of radius 12 m, as shown.

The car takes a time of 4.0 s to move from position P to position Q.




What is the magnitude of the average velocity of the car for the journey from P to Q?

**A** $4.2\,m\,s^{-1}$ **B** $4.7\,m\,s^{-1}$ **C** $6.0\,m\,s^{-1}$ **D** $14\,m\,s^{-1}$

**25** The water surface in a deep well is 78.0 m below the top of the well. A person at the top of the well drops a heavy stone down the well.

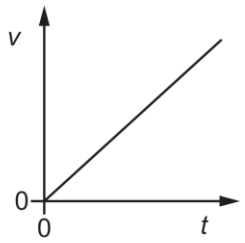
Air resistance is negligible. The speed of sound in the air is 330 m s$^{-1}$.

What is the time interval between the person dropping the stone and hearing it hitting the water?

**A** 3.75 s **B** 3.99 s **C** 4.19 s **D** 4.22 s

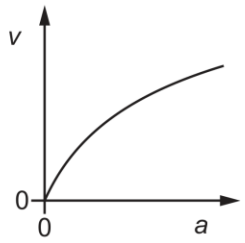
**26** A particle accelerates from rest.

The graph shows the variation of the velocity $v$ of the particle with time $t$.

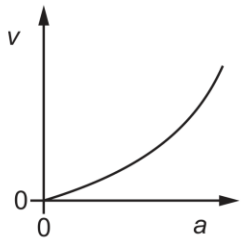



Which graph shows the variation of the velocity $v$ with the acceleration $a$ of the particle?

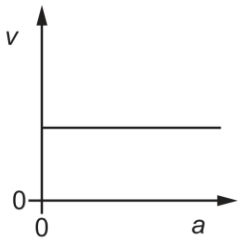
**A**



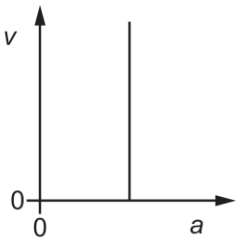

**B**



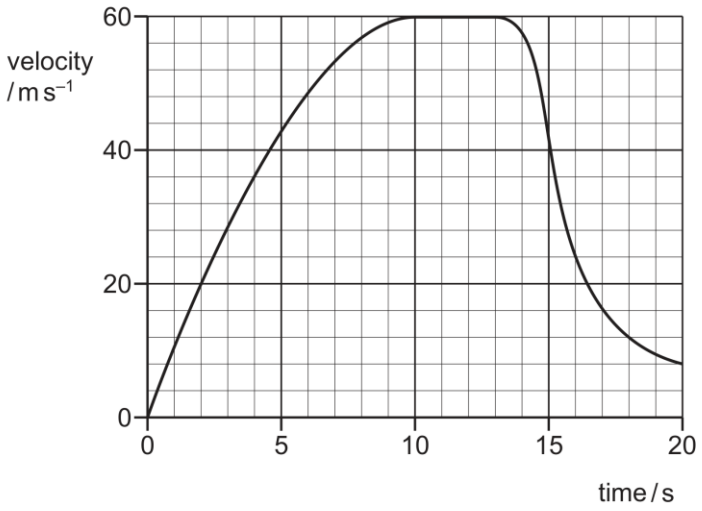

**C**




**D**



**27** The graph shows the vertical velocity of a parachutist during the first 20 s of her jump.




Approximately how far does she fall **before** opening the parachute?

**A** 390 m **B** 570 m **C** 710 m **D** 770 m

**28** A toy car travels on a circular track at a constant speed of 0.50 m s$^{-1}$. It passes a point on the track at time $t = 0$ and takes a time of 40 s to travel once around the track.

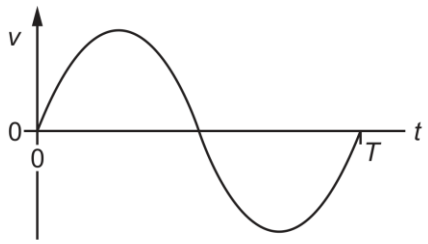
The magnitude of the average velocity of the car between $t = 0$ and $t = 20$ s is $v_{20}$.

The magnitude of the average velocity of the car between $t = 0$ and $t = 40$ s is $v_{40}$.

What are $v_{20}$ and $v_{40}$?

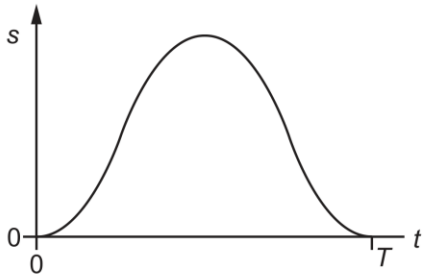
| | $v_{20}$ / m s$^{-1}$ | $v_{40}$ / m s$^{-1}$ |
|---|---|---|
| **A** | 0.32 | 0 |
| **B** | 0.32 | 0.32 |
| **C** | 0.50 | 0 |
| **D** | 0.50 | 0.50 |

**29** The graph shows how the velocity $v$ of an object moving in a straight line varies with time $t$ from $t = 0$ to $t = T$.

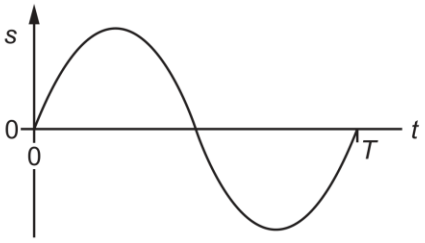



Which graph could represent the displacement $s$ of the object from time $t = 0$ to $t = T$?

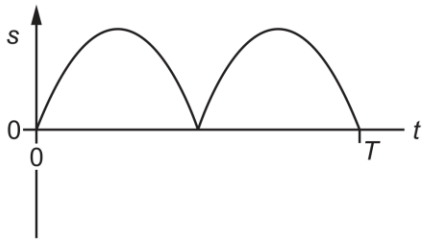
**A**



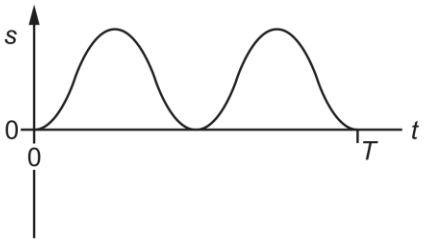

**B**




**C**




**D**

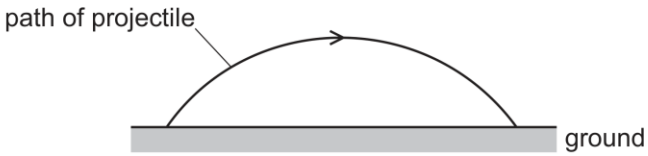



**30** A goods train passes through a station at a steady speed of $10\,m\,s^{-1}$ at time $t = 0$. An express train is at rest at the station. The express train leaves the station with a uniform acceleration of $0.5\,m\,s^{-2}$ just as the goods train goes past. Both trains move in the same direction on straight, parallel tracks.

At which time $t$ does the express train overtake the goods train?

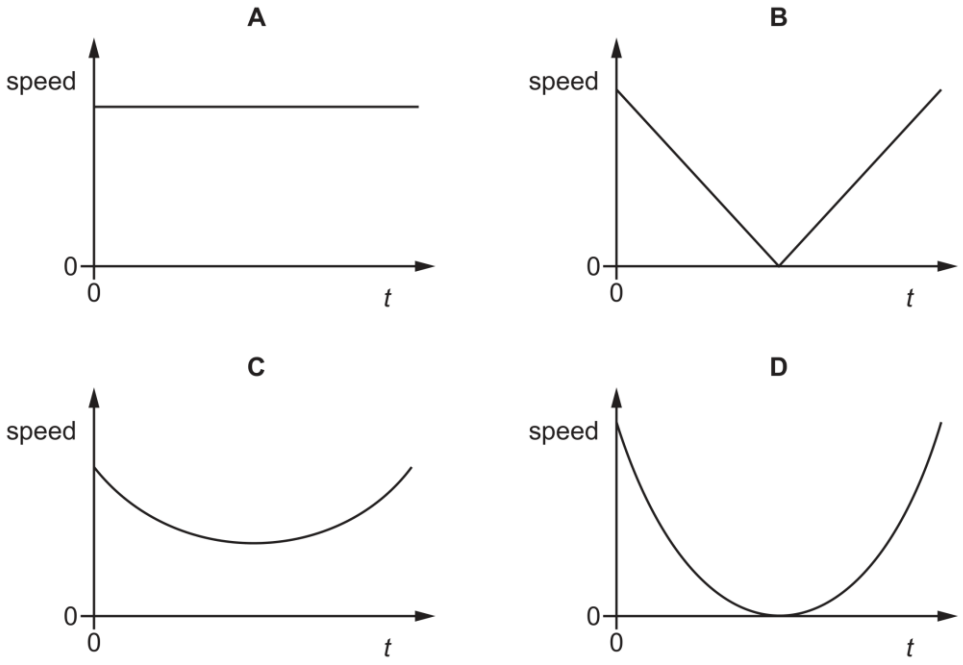
**A** 6 s **B** 10 s **C** 20 s **D** 40 s

**31** A projectile is launched at an angle to the horizontal at time $t = 0$. It travels over horizontal ground, as shown.




Air resistance is negligible.

Which graph best shows the variation with $t$ of the speed of the projectile from when it is launched to when it lands on the ground?

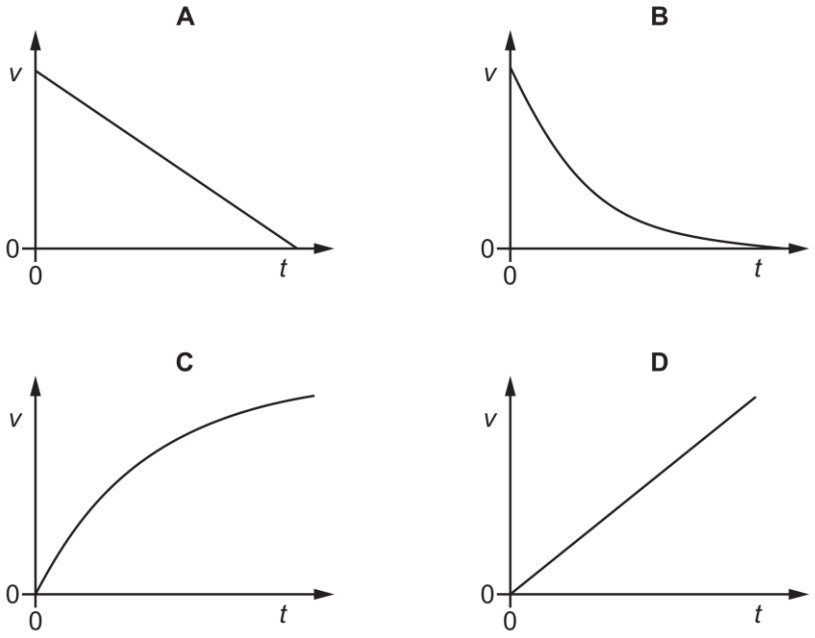



**32** A train, initially at rest at a station, has a uniform acceleration of $0.20\,m\,s^{-2}$ until it reaches a speed of $20\,m\,s^{-1}$. It travels for a time at this constant speed and then has a uniform deceleration of $0.40\,m\,s^{-2}$ until it comes to rest at the next station. The distance between the two stations is 3000 m.

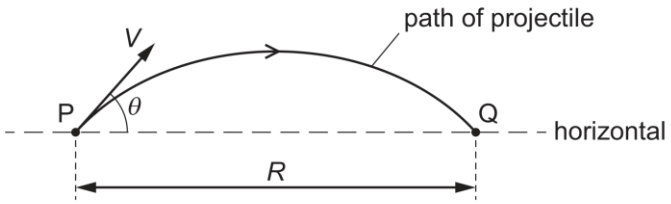
What is the time taken by the train to travel between the two stations?

**A** 75 s **B** 150 s **C** 230 s **D** 300 s

**33** Which graph shows the variation with time $t$ of the velocity $v$ of an object falling vertically downwards in a vacuum?




**34** A projectile is fired from point P with velocity $V$ at an angle $\theta$ to the horizontal. It lands at point Q, a horizontal distance $R$ from P. Air resistance is negligible.




The acceleration of free fall is $g$.

Which equation for $R$ is correct?

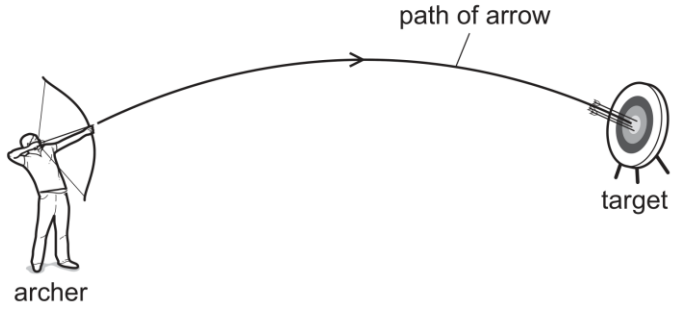
**A** $R = \dfrac{V^2 \sin\theta \cos\theta}{g}$

**B** $R = \dfrac{2V^2 \sin\theta \cos\theta}{g}$

**C** $R = \dfrac{V^2 \sin\theta \cos\theta}{2g}$

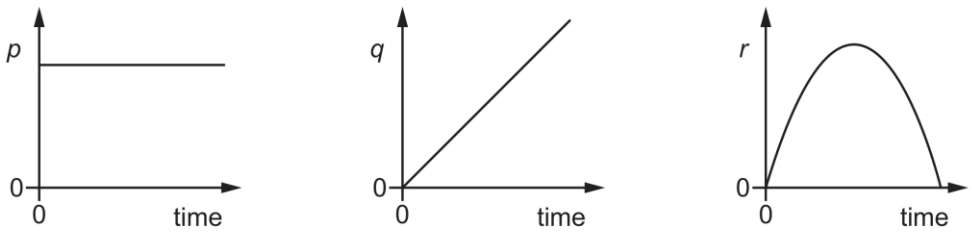
**D** $R = \dfrac{V^2 g \sin\theta \cos\theta}{2}$

**35** An archer shoots an arrow at a target. The diagram shows the path of the arrow.




Air resistance is negligible.

The graphs show how three different quantities *p*, *q* and *r* vary with time.



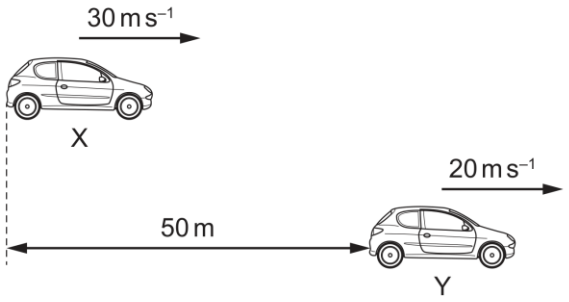

Which quantity could be the horizontal component of displacement and which quantity could be the vertical component of displacement of the arrow?

| | horizontal component of displacement | vertical component of displacement |
|---|---|---|
| **A** | *p* | *q* |
| **B** | *q* | *r* |
| **C** | *r* | *p* |
| **D** | *r* | *q* |

**36** Two cars X and Y are positioned as shown at time $t = 0$.

They are travelling in the same direction.

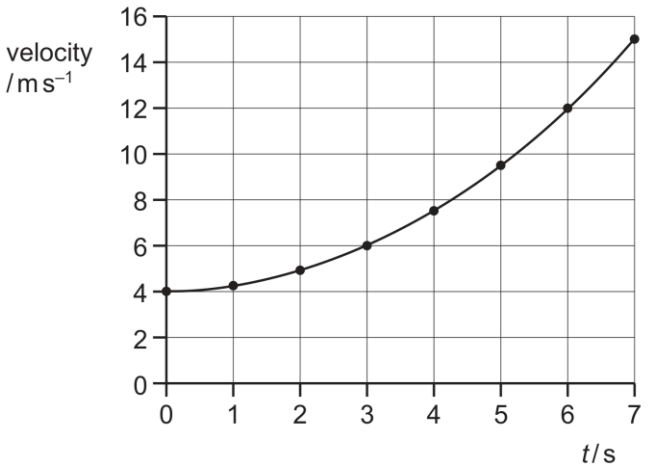
X is 50 m behind Y and has a constant velocity of $30\,m\,s^{-1}$. Y has a constant velocity of $20\,m\,s^{-1}$.




What is the value of $t$ when X is level with Y?

**A** 1.0 s **B** 1.7 s **C** 2.5 s **D** 5.0 s

**37** The graph shows the variation with time $t$ of the velocity of a vehicle moving in a straight line.




The vehicle, moving at $4.0\,m\,s^{-1}$, begins to accelerate at time $t = 0$.

What is the vehicle's acceleration at time $t = 3.0$ s?

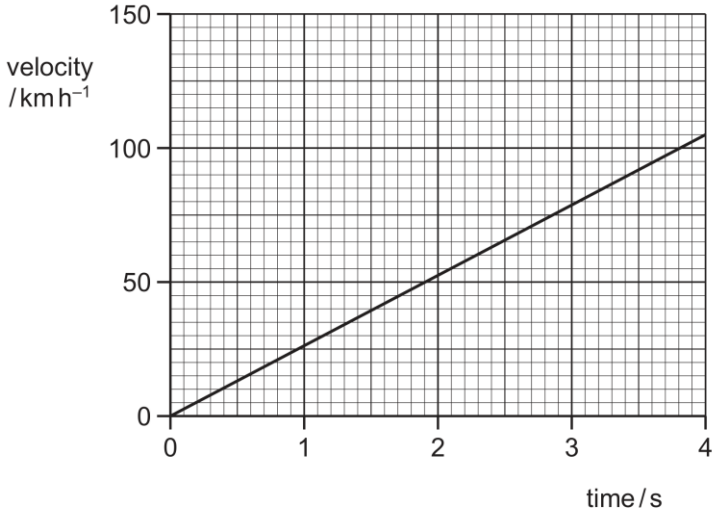
**A** $0.67\,m\,s^{-2}$ **B** $1.0\,m\,s^{-2}$ **C** $1.3\,m\,s^{-2}$ **D** $2.0\,m\,s^{-2}$

**38** A stone is projected vertically upwards from the ground at an initial speed of $15\,m\,s^{-1}$. Air resistance is negligible.

What is the maximum height reached by the stone?

**A** 0.76 m **B** 11 m **C** 23 m **D** 110 m

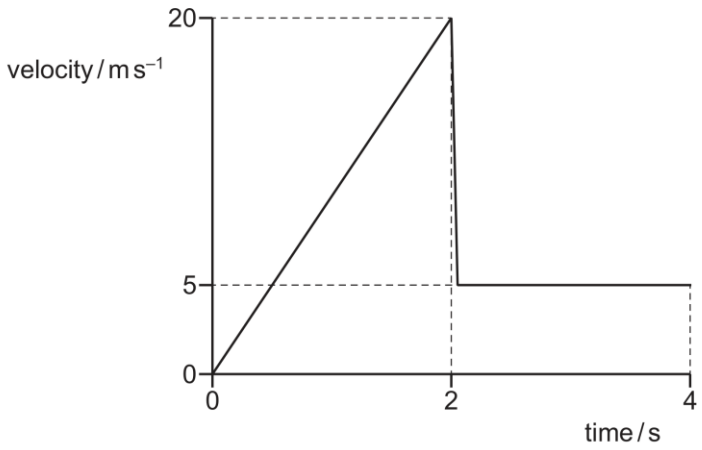
**39** The velocity of an electric car changes as shown.




What is the acceleration of the car?

**A** $210\,m\,s^{-2}$ **B** $58\,m\,s^{-2}$ **C** $26\,m\,s^{-2}$ **D** $7.3\,m\,s^{-2}$

**40** A stone is dropped from a height of 20 m above water. The graph shows the variation with time of the velocity of the stone.




Which statement describes the approximate position of the stone four seconds after it is dropped?

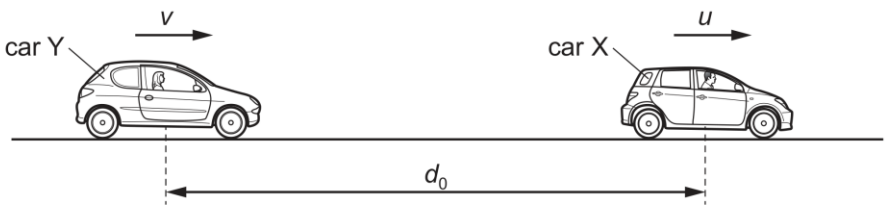
**A** It is at a distance of 10 m above the surface of the water.

**B** It is at a distance of 10 m below the surface of the water.

**C** It is at a distance of 20 m below the surface of the water.

**D** It is at a distance of 30 m below the surface of the water.

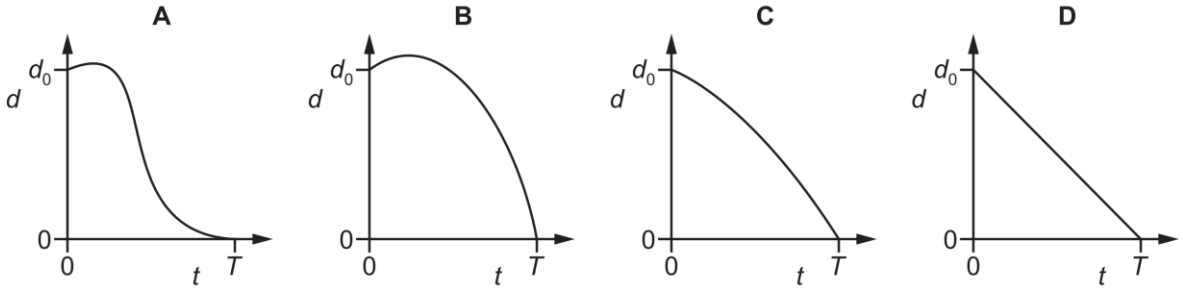
**41** A car X is travelling at a constant speed $u$ along a straight road. At time $t = 0$ a second car Y is a distance $d_0$ behind car X and travelling at a speed $v$ in the same direction. Speed $v$ is less than speed $u$.




At time $t = 0$ car Y begins to accelerate with a constant acceleration.

Car Y overtakes car X at time $t = T$.

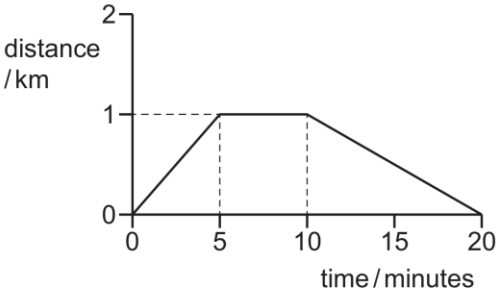
Which graph could best show the variation with time $t$ of the distance $d$ between the cars?



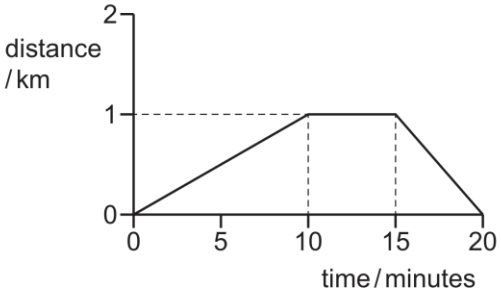
**42** A student cycles uphill from home to a shop, taking 10 minutes. The student then spends 5 minutes in the shop, before cycling home downhill at twice the initial speed.

Which graph could show the variation with time of the distance travelled by the cyclist?

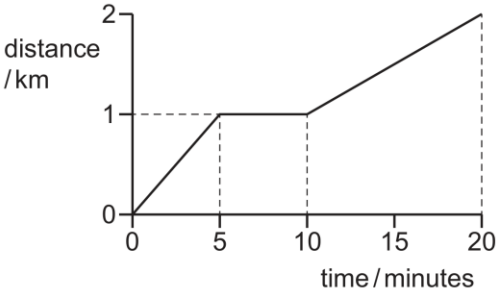
**A**



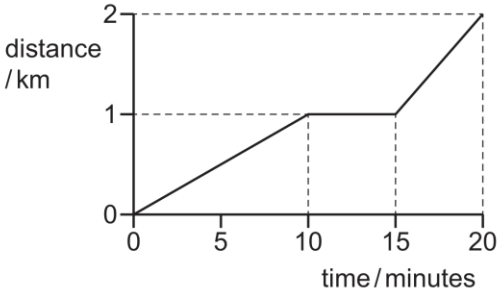

**B**




**C**

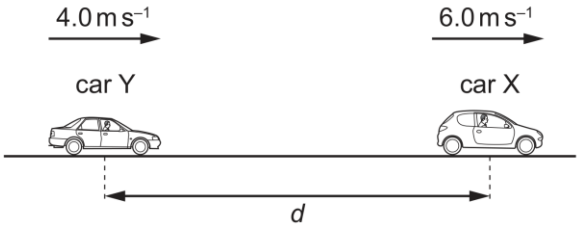



**D**




**43** Two cars X and Y are travelling along the same straight road. Car X is travelling at a constant speed of $6.0\,m\,s^{-1}$. Car Y has a constant acceleration of $0.50\,m\,s^{-2}$.

At the instant shown, car X is a distance *d* ahead of car Y. Car Y is travelling at a speed of $4.0\,m\,s^{-1}$.



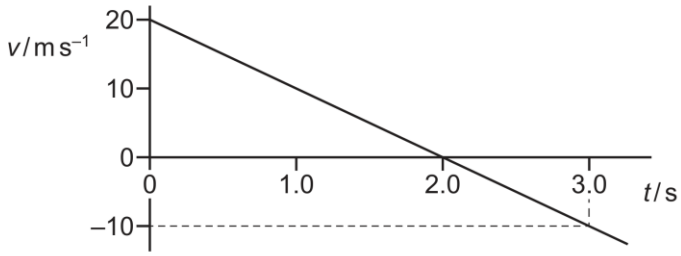

Car Y is level with car X after a time of 20 seconds.

What is the distance *d*?

**A** 40 m **B** 60 m **C** 180 m **D** 300 m

**44** A stone is thrown vertically upwards from a point X at time $t = 0$.

The variation with time $t$ of the velocity $v$ of the stone is shown.




What is the displacement of the stone from point X at time $t = 3.0$ s?

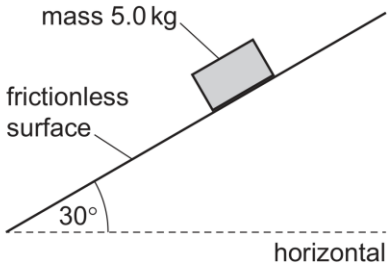
**A** 15 m above X

**B** 15 m below X

**C** 25 m above X

**D** 25 m below X

**45** A mass of 5.0 kg is released from rest on a frictionless surface inclined at 30° to the horizontal. Air resistance is negligible.



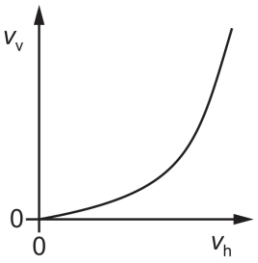

How far does the mass travel in a time of 0.80 s?

**A** 1.6 m **B** 2.0 m **C** 2.7 m **D** 3.1 m

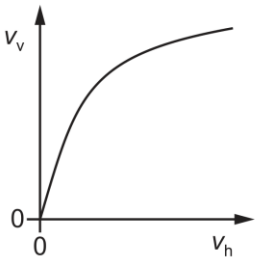
**46** A stone is thrown horizontally from the top of a cliff and falls into the sea some time later. Air resistance is negligible.

Which graph shows how the vertical component $v_v$ of velocity of this stone varies with its horizontal component $v_h$ of velocity as it moves through the air?

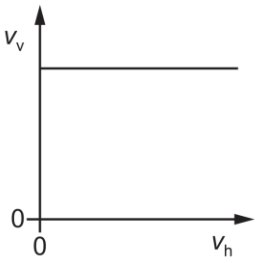
**A**



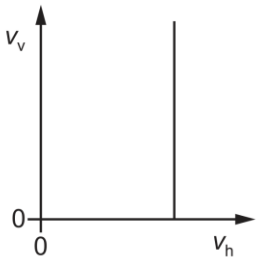

**B**




**C**




**D**



**47** A ball is thrown vertically upwards from ground level and reaches a maximum height of 12.7 m before falling back to ground level.

Assume air resistance is negligible.

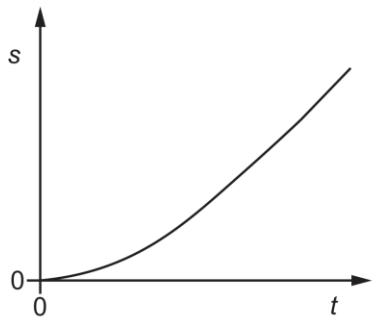
What is the total time for which the ball is in the air?

**A** 1.61 s **B** 3.22 s **C** 3.88 s **D** 5.18 s

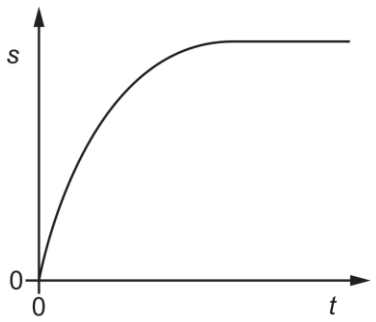
**48** A tennis ball falls freely, in air, from the top of a tall building.

Which graph best represents the variation with time *t* of the distance *s* fallen?

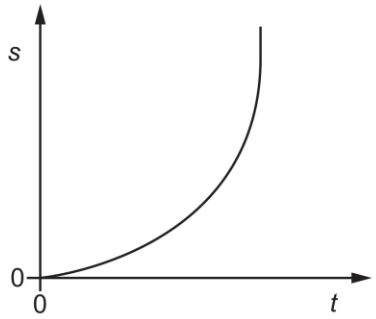
**A**



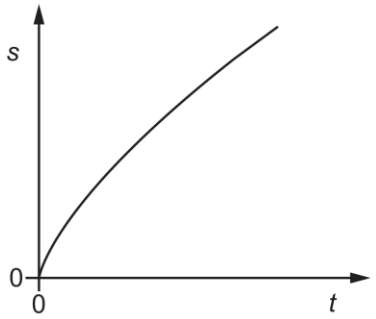

**B**



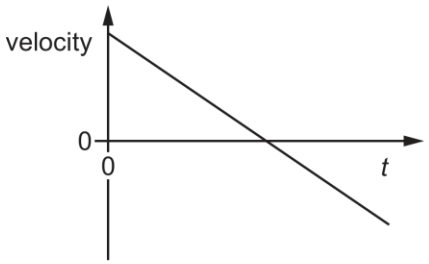

**C**




**D**

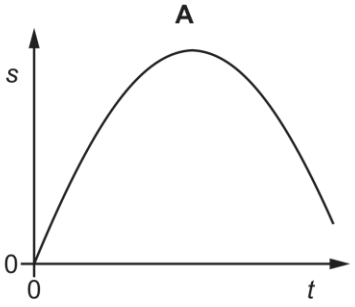


**49** The velocity of an object changes with time *t* as shown.

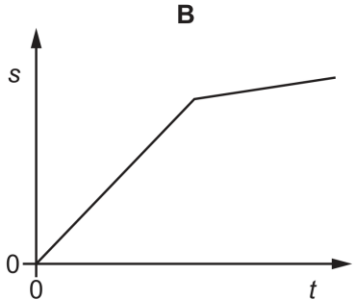



Which graph best shows the variation with time *t* of the displacement *s* of the object?

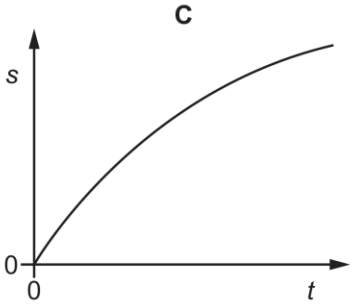
**A**



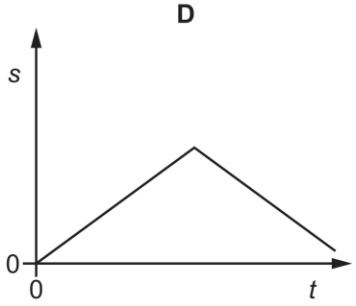

**B**



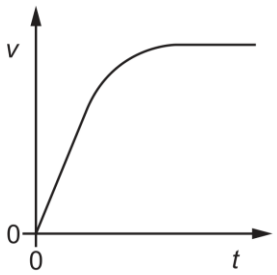

**C**




**D**

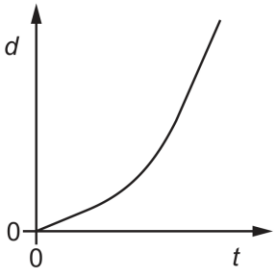


**50** A sky-diver falls vertically from a helicopter and reaches constant (terminal) velocity. The graph shows the variation with time $t$ of the speed $v$ of the sky-diver.

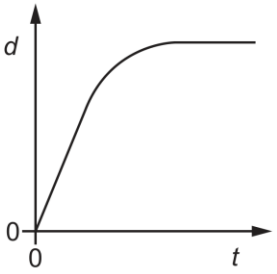



Which graph shows the variation with time $t$ of the distance $d$ fallen by the sky-diver?

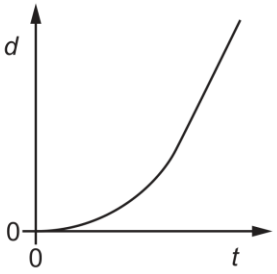
**A**



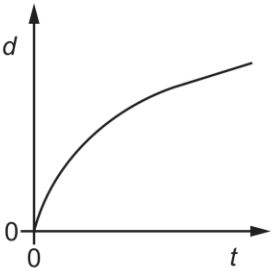

**B**




**C**




**D**




**51** A sprinter runs a 100 m race. The sprinter has a constant acceleration from rest of 2.5 m s$^{-2}$ until reaching a speed of 10 m s$^{-1}$. The speed then remains constant until the end of the race.

Which time does it take the sprinter to run the race?

**A** 8.9 s **B** 10 s **C** 12 s **D** 14 s