The constant acceleration formulae

123 marks

Hints online, answers free with an account: mathswariz.uk/worksheets/a-level-mechanics-constant-acceleration-formulae/

Date

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A Do Now

Quick questions to start.

A1 Last lesson [2 marks]

A cyclist starts from rest, speeds up uniformly to $10\ \text{m s}^{-1}$ in 4 s, then rides at $10\ \text{m s}^{-1}$ for 6 s. Use a velocity–time graph to find the distance she travels in the 10 s.

Answer .....

A2 Needed today [2 marks]

Write $90\ \text{km h}^{-1}$ in metres per second, and 2.5 minutes in seconds.

Answer .....

A3 Common slip [2 marks]

A car slows down uniformly from $20\ \text{m s}^{-1}$ to $8\ \text{m s}^{-1}$ in 4 s. Taking the direction of motion as positive, find its acceleration.

Answer .....

A4 Needed today [3 marks]

Make t the subject of $v = u + at$. Make u the subject of $s = \frac{1}{2}(u + v)t$.

Answer .....

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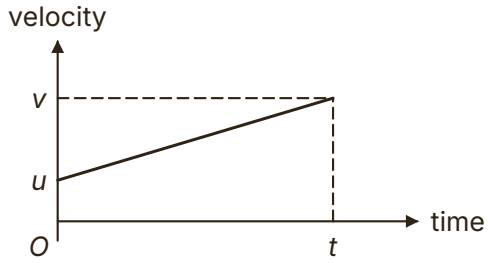
B Example, then your turn

A-Level

Your teacher works through each example with you. Then try the one beside it.

EXAMPLE 1

A particle moves in a straight line with constant acceleration $a\ \text{m s}^{-2}$. Its velocity is $u\ \text{m s}^{-1}$ at time 0 and $v\ \text{m s}^{-1}$ at time t seconds. Use the velocity–time graph to show that $v = u + at$ and that the displacement is $s = \frac{1}{2}(u + v)t$.



Hint The acceleration is the gradient of the line. The displacement is the area under it, which is a trapezium.

B1 A particle moves in a straight line with constant acceleration. Its speed increases from $U\ \text{m s}^{-1}$ to $3U\ \text{m s}^{-1}$ in T seconds. Sketch a velocity–time graph and use it to show that its acceleration is $\frac{2U}{T}\ \text{m s}^{-2}$ and the distance it travels is $2UT$ m. [4 marks]

Answer .....

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EXAMPLE 2

A cyclist moving along a straight road speeds up uniformly from $3\ \text{m s}^{-1}$ to $8.5\ \text{m s}^{-1}$ in 20 s. Find the distance she travels in this time and her acceleration.

Hint Write down s, u, v, a and t, mark the one you want, and choose the formula without the letter you do not know and do not want.

B2 A runner speeds up uniformly from $2.5\ \text{m s}^{-1}$ to $7\ \text{m s}^{-1}$ in 15 s. Find the distance she runs in this time and her acceleration. [4 marks]

Answer .....

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EXAMPLE 3

A car is moving at $72\ \text{km h}^{-1}$ along a straight road when the driver brakes. The car slows down uniformly and stops in a distance of 40 m. Find the time it takes to stop and its deceleration. State one assumption you have made.

Hint Change $72\ \text{km h}^{-1}$ to metres per second first. Take the direction of motion as positive, so a car that is slowing down has a negative acceleration.

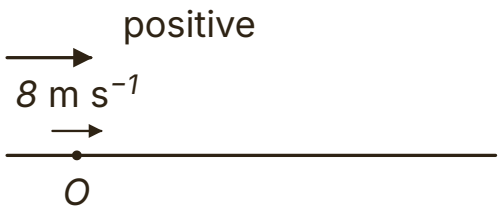
B3 A cyclist moving at $54\ \text{km h}^{-1}$ brakes and slows down uniformly, stopping in 45 m. Find the time she takes to stop and her deceleration. [5 marks]

Answer .....

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EXAMPLE 4

A particle passes a point O moving at $8\ \text{m s}^{-1}$ in the positive direction. Its acceleration is $2\ \text{m s}^{-2}$ in the negative direction. Find its velocity 6 s after passing O, the time at which it is instantaneously at rest, its displacement from O after 6 s, and the distance it travels in the 6 s.



Hint $a = -2$. The particle stops, then moves back. Distance and displacement differ, so split the 6 s at the moment it stops.

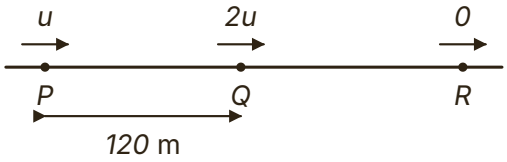
B4 A particle passes a point O moving at $10\ \text{m s}^{-1}$ in the positive direction. Its acceleration is $2.5\ \text{m s}^{-2}$ in the negative direction. Find its velocity 6 s after passing O, the time at which it is at rest, its displacement from O after 6 s, and the distance it travels in the 6 s. [6 marks]

Answer .....

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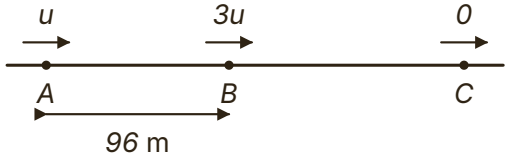
EXAMPLE 5

A particle moves in a straight line with constant acceleration from P to Q. It passes P with speed $u\ \text{m s}^{-1}$ and Q with speed $2u\ \text{m s}^{-1}$, 10 s later. $PQ = 120$ m. It then slows down uniformly from Q and comes to rest at R, 20 s after passing Q. Find u, the distance QR and the deceleration from Q to R.



Hint Treat P to Q and Q to R as two separate stages, each with its own constant acceleration. The speed at Q ends the first stage and starts the second.

B5 A particle moves in a straight line with constant acceleration from A to B. It passes A with speed $u\ \text{m s}^{-1}$ and B with speed $3u\ \text{m s}^{-1}$, 8 s later. $AB = 96$ m. From B it slows down uniformly at $1.5\ \text{m s}^{-2}$ until it comes to rest at C. Find u and the distance AC. [7 marks]



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Answer .....

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C1 A particle slows down from $18\ \text{m s}^{-1}$ to $6\ \text{m s}^{-1}$ with a constant deceleration of $1.5\ \text{m s}^{-2}$. Mia writes $6 = 18 + 1.5t$, gets $t = -8$ and says the time is 8 s. Explain why her method is wrong, then find the time and the distance travelled. [4 marks]

Answer .....

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C2 A car starts from rest and speeds up uniformly to $12\ \text{m s}^{-1}$ in 8 s. It then slows down with a constant deceleration of $2\ \text{m s}^{-2}$. Jake works out the velocity 12 s after the start as $v = 0 + 1.5 \times 12 = 18\ \text{m s}^{-1}$. Explain his mistake, then find the velocity 12 s after the start and the distance travelled in these 12 s. [5 marks]

Answer .....

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C3 A train passes a signal at $36\ \text{km h}^{-1}$. It speeds up uniformly for 2 minutes until its speed is $108\ \text{km h}^{-1}$. Leo uses $t = 2$ and gets an acceleration of 36. Find the correct acceleration, and the distance the train travels in these 2 minutes in km. [4 marks]

Answer .....

C4 A particle moves in a straight line with constant acceleration $0.5\ \text{m s}^{-2}$. It passes A with speed $u\ \text{m s}^{-1}$ and passes B, 6 s later. $AB = 48$ m. Find u and the speed of the particle at B. [5 marks]

Answer .....

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C5 A car speeds up uniformly from $4\ \text{m s}^{-1}$ to $16\ \text{m s}^{-1}$ in 6 s, then keeps a speed of $16\ \text{m s}^{-1}$ for 10 s. Sam writes $s = \frac{1}{2}(4 + 16)(16) = 160$ m for the distance in the 16 s. Explain why this is wrong and find the correct distance. [4 marks]

Answer .....

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D Exam-style questions

Edexcel exam style

D1 A particle moves along a straight line with constant acceleration $a\ \text{m s}^{-2}$. At time 0 its velocity is $u\ \text{m s}^{-1}$ and at time t seconds its velocity is $v\ \text{m s}^{-1}$.

(a) Sketch a velocity–time graph and use it to show that the displacement in time t is $s = \dfrac{1}{2}(u + v)t$. [3 marks]

Answer .....

(b) The particle passes a point P with speed $5\ \text{m s}^{-1}$ and a point Q with speed $17\ \text{m s}^{-1}$, 8 s later. Find the acceleration and the distance PQ. [4 marks]

Answer .....

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(c) The particle passes a point R, beyond Q, with speed $23\ \text{m s}^{-1}$ [2 marks]
. Find the distance QR.

Answer .....

Total for D1: 9 marks

D2

A car passes a point A at $30\ \text{m s}^{-1}$. The driver brakes and the car slows down with a constant deceleration of $2\ \text{m s}^{-2}$ until it stops. Lily works out how far the car travels in the 20 s after passing A. She writes $v = 30 - 2 \times 20 = -10$ and $s = \frac{1}{2}(30 + (-10)) \times 20 = 200$ m.

Lily's answer is wrong.

(a) Find the time the car takes to stop. [2 marks]

Answer .....

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(b) Find the distance the car travels in the 20 s after passing A. [3 marks]

Answer .....

(c) Explain Lily's mistake. [2 marks]

(d) Find the speed of the car 10 s after passing A, and its distance from A at that moment. [2 marks]

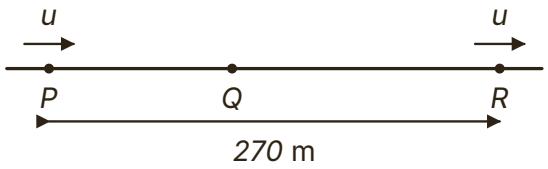
Answer .....

Total for D2: 9 marks

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D3 A cyclist rides along a straight road. She passes a point P with speed $u\ \mathrm{m\ s^{-1}}$ and accelerates uniformly at $0.5\ \mathrm{m\ s^{-2}}$ for 12 s, until she reaches a point Q. From Q she slows down uniformly, and 18 s after passing Q she passes a point R, again with speed $u\ \mathrm{m\ s^{-1}}$. The distance PR is 270 m.

(a) Show that $u = 6$. [4 marks]



Answer .....

(b) Find the distance QR and the deceleration from Q to R. [3 marks]

Answer .....

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(c) Find her distance from P 20 s after she passes P. [3 marks]

Answer .....

Total for D3: 10 marks

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D4 A particle moves along a straight line with constant acceleration. It passes a point A with velocity $4\ \text{m s}^{-1}$ and passes a point B, 10 s later. $AB = 90$ m. Find the distance of the particle from A at the moment its speed is $25\ \text{m s}^{-1}$. [7 marks]

Answer .....

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D5 A train is modelled as a particle moving along a straight track. It passes a signal S at $54\ \text{km h}^{-1}$ and speeds up uniformly for 1.5 minutes until it reaches $90\ \text{km h}^{-1}$ at a point T. It keeps this speed for 2 km, then slows down uniformly and stops at a station X, 50 s after it starts to slow down.

(a) Find the acceleration of the train between S and T. [2 marks]

Answer .....

(b) Find the distance ST. [2 marks]

Answer .....

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(c) Find the time the train takes to travel from S to X. [3 marks]

Answer .....

(d) Find the distance SX in kilometres. [2 marks]

Answer .....

(e) State one limitation of modelling the train as a particle with constant acceleration in each stage. [2 marks]

Total for D5: 11 marks

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D6 A car is moving along a straight road with speed $u\ \mathrm{m\ s^{-1}}$ when the driver brakes. The car slows down with a constant deceleration of $2\ \mathrm{m\ s^{-2}}$. In the time it takes for its speed to fall to $\frac{u}{2}\ \mathrm{m\ s^{-1}}$, the car travels 75 m.

(a) Show that the time taken for the speed to fall to $\frac{u}{2}\ \mathrm{m\ s^{-1}}$ is $\frac{u}{4}$ s. [2 marks]

Answer .....

(b) Hence show that $u = 20$. [3 marks]

Answer .....

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(c) The car keeps the same deceleration until it stops. Find the total time from when the driver brakes until the car stops, and the total distance it travels in this time. [3 marks]

Answer .....

(d) The car loses the first half of its speed in the same time as the second half. Explain why it travels much further while losing the first half. [2 marks]

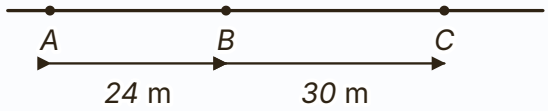
Total for D6: 10 marks

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No route is given. The hints are at the end of the sheet. Use one at a time.

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E1 Three points A, B and C lie in that order on a straight line, with $AB = 24$ m and $BC = 30$ m. A particle moves along the line with constant acceleration. It passes A, then takes 2 s to travel from A to B and 3 s to travel from B to C. Find the acceleration of the particle and its speed at A. Show that it is still moving towards C when it passes C, and find how far beyond C it comes to rest. [10 marks]



Answer .....

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Extension hints

Cover these with paper. Uncover one at a time.

E1

Hint 1 Call the velocity at A u and the acceleration a. Write the velocities at B and at C in terms of u and a.

Hint 2 Use $s = \frac{1}{2}(u + v)t$ for A to B and again for B to C. That gives two equations in u and a.

Hint 3 The acceleration comes out negative. The particle is at rest when $v = 0$; use the velocity at C as the starting velocity for the last stage.

How did it go?

Colour one circle on each line: not yet, nearly, yes.

I can derive v = u + at and s = (u + v)t/2 from a velocity–time graph.	○ ○ ○
I can list s, u, v, a and t, choose a formula and give answers with units to 3 significant figures.	○ ○ ○
I can state a positive direction and use a negative acceleration for a particle that is slowing down.	○ ○ ○
I can split a journey into stages and use the final velocity of one stage as the initial velocity of the next.	○ ○ ○

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