More constant acceleration problems

122 marks

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

Date

A Do Now

Quick questions to start. They use what you need today.

A1 Needed today [3 marks]

A car accelerates uniformly from $6\ \text{m s}^{-1}$ to $20\ \text{m s}^{-1}$ in $7\ \text{s}$. Find its acceleration and the distance it travels in this time.

Answer .....

A2 Needed today [2 marks]

Solve $2t^2 - 11t + 12 = 0$.

Answer .....

A3 Common slip [2 marks]

A train moves at $54\ \text{km h}^{-1}$. It slows down uniformly and stops in $25\ \text{s}$. Find its deceleration.

Answer .....

A4 Common slip [2 marks]

A cyclist starts from rest and accelerates uniformly to $8\ \text{m s}^{-1}$ in $4\ \text{s}$, then rides at $8\ \text{m s}^{-1}$ for $6\ \text{s}$. Use a velocity–time graph to find the distance she travels.

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

Starting from $v = u + at$ and $s = \frac{1}{2}(u + v)t$, show that $v^2 = u^2 + 2as$. A particle moving in a straight line with constant acceleration passes a point A with speed $5\ \text{m s}^{-1}$ and a point B with speed $13\ \text{m s}^{-1}$, where $AB = 36\ \text{m}$. Find its acceleration.

Hint To remove t, make t the subject of $v = u + at$ and put it into the other formula. In the problem t is not given and not asked for, so use the formula with no t.

B1 [6 marks]

Starting from $v = u + at$ and $s = \frac{1}{2}(u + v)t$, show that $s = vt - \frac{1}{2}at^2$. A car moves in a straight line with constant deceleration $1.5\ \text{m s}^{-2}$. In $8\ \text{s}$ it travels $72\ \text{m}$. Find its speed at the end and at the start of the $8\ \text{s}$.

Answer .....

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EXAMPLE 2

A particle moves along a straight line with constant deceleration $2\ \text{m s}^{-2}$. At $t = 0$ it passes a point O with speed $11\ \text{m s}^{-1}$, moving towards a point A, where $OA = 24\ \text{m}$. Find the times when the particle is at A, its velocity each time, and the time when it returns to O.

Hint Take the direction from O to A as positive, so $a = -2$. You know u, a and s and want t: use $s = ut + \frac{1}{2}at^2$. This gives a quadratic, and both roots can be correct.

B2 [5 marks]

A particle moves along a straight line with constant deceleration $3\ \text{m s}^{-2}$. At $t = 0$ it passes a point O with speed $16\ \text{m s}^{-1}$, moving towards a point A, where $OA = 40\ \text{m}$. Find the times when it is at A, the length of time for which it is beyond A, and the time when it returns to O.

Answer .....

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EXAMPLE 3

A particle P moves on the x-axis with constant acceleration $-3\ \text{m s}^{-2}$. At $t = 0$ it passes through the origin O moving in the positive x-direction with speed $12\ \text{m s}^{-1}$. Find the position of P at $t = 10$, its velocity then, and the total distance it travels in the $10\ \text{s}$.

Hint $s = ut + \frac{1}{2}at^2$ gives the displacement, not the distance. Find when P stops ($v = 0$): before then it moves forward, after then it comes back.

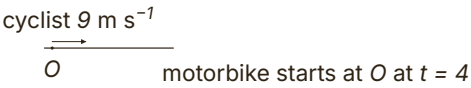
B3 A particle moves on the x-axis with constant acceleration $-2.5\ \text{m s}^{-2}$. At $t = 0$ it passes through O moving in the positive x-direction with speed $15\ \text{m s}^{-1}$. Find its position at $t = 14$, its velocity then, and the total distance it travels in the $14\ \text{s}$. [5 marks]

Answer .....

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EXAMPLE 4

A cyclist rides along a straight road at a constant $9\ \mathrm{m\ s^{-1}}$. At $t = 0$ she passes a point O. At $t = 4$ a motorbike starts from rest at O and accelerates at $2\ \mathrm{m\ s^{-2}}$ along the road in the same direction. Find the time when the motorbike draws level with the cyclist and the distance from O at which this happens.



Hint Write both displacements from O in terms of t, the time since the cyclist passed O. The motorbike has been moving for $t - 4$ seconds. They are level when the displacements are equal. The motorbike has not started for $t < 4$.

B4 A cyclist rides along a straight road at a constant $6\ \mathrm{m\ s^{-1}}$. At $t = 0$ he passes a point O. At $t = 3$ a motorbike starts from rest at O and accelerates at $3\ \mathrm{m\ s^{-2}}$ in the same direction. Find the time when the motorbike draws level with the cyclist, the distance from O, and the speed of the motorbike then. [5 marks]

Answer .....

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EXAMPLE 5

A particle moves in a straight line with constant acceleration. It travels $14\ \text{m}$ in the 4th second of its motion and $20\ \text{m}$ in the 6th second. Find its initial speed and its acceleration.

Hint The 4th second runs from $t = 3$ to $t = 4$. The distance in it is $s(4) - s(3)$, where $s(t) = ut + \frac{1}{2}at^2$.

B5 A particle moves in a straight line with constant acceleration. It travels $11\ \text{m}$ in the 3rd second of its motion and $21\ \text{m}$ in the 8th second. Find its initial speed, its acceleration, and the distance it travels in the first $10\ \text{s}$. [5 marks]

Answer .....

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C1 A cyclist starts from rest and accelerates uniformly at $1.5\ \text{m s}^{-2}$ for $8\ \text{s}$. She then decelerates uniformly at $0.5\ \text{m s}^{-2}$. Ali finds her distance from the start after $12\ \text{s}$ like this: "$s = 0 \times 12 + \frac{1}{2} \times 1.5 \times 12^2 = 108$ m". Explain Ali's mistake and find the correct distance. [5 marks]

Answer .....

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C2 Car A moves along a straight road at a constant $16\ \mathrm{m\ s^{-1}}$. At the instant it passes a point O, car B starts from rest at O and accelerates at $2\ \mathrm{m\ s^{-2}}$ in the same direction. Sam says: "B catches A when their speeds are equal, at $t = 8$." Explain why Sam is wrong. Find the time when B catches A, and the greatest distance between the cars before then. [5 marks]

Answer .....

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C3 A particle moves with constant acceleration along a straight line through A, M and C, where M is the midpoint of AC. Its speed is $4\ \text{m s}^{-1}$ at A and $16\ \text{m s}^{-1}$ at C. Leo says its speed at M is $\dfrac{4+16}{2} = 10\ \text{m s}^{-1}$. Find the speed at M, and explain what $10\ \text{m s}^{-1}$ is. [5 marks]

Answer .....

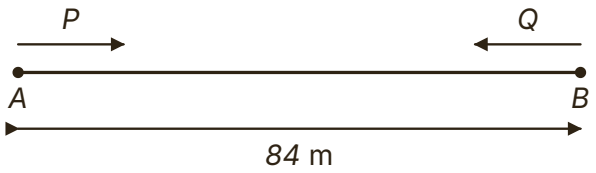
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C4 A particle moves on the x-axis with constant acceleration $-2\ \mathrm{m\ s^{-2}}$. At $t = 0$ it passes through O moving in the positive x-direction with speed $6\ \mathrm{m\ s^{-1}}$. The point B is on the axis at $x = -16$. Jo writes "$v^2 = 6^2 + 2(-2)(16) = -28$, which is impossible, so the particle never reaches B". Explain her mistake. Find the velocity of the particle and the time when it reaches B. [5 marks]

Answer .....

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C5 Two points A and B are $84\ \text{m}$ apart on a straight track. At $t = 0$ particle P starts from rest at A and moves towards B with acceleration $2\ \text{m s}^{-2}$. At the same instant particle Q passes B moving towards A with speed $5\ \text{m s}^{-1}$ and acceleration $1\ \text{m s}^{-2}$. Find when and where the particles meet, and the speed of each then. [5 marks]

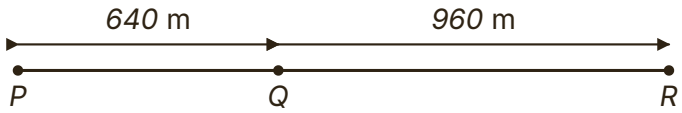


Answer .....

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D1 A train moves along a straight track through three points P, Q and R, in that order. It passes P with speed $u\ \text{m s}^{-1}$ and accelerates uniformly at $0.4\ \text{m s}^{-2}$ to Q, where $PQ = 640\ \text{m}$ and its speed is $3u\ \text{m s}^{-1}$. From Q it decelerates uniformly and comes to rest at R, where $QR = 960\ \text{m}$.

(a) Show that $u = 8$. [3 marks]



Answer .....

(b) Find the time taken to travel from P to R. [3 marks]

Answer .....

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(c) Find the distance of the train from P when $t = 60$, where t seconds is the time since it passed P. [3 marks]

Answer .....

(d) Find the value of t when the train is $1000\ \text{m}$ from P. [3 marks]

Answer .....

Total for D1: 12 marks

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D2

A particle moves on the x-axis with constant acceleration $-3.5\ \text{m s}^{-2}$. At $t = 0$ it passes through O moving in the positive x-direction with speed $14\ \text{m s}^{-1}$. Rui finds the distance travelled by the particle in the first 6 s: "$s = ut + \frac{1}{2}at^2 = 14 \times 6 - \frac{1}{2} \times 3.5 \times 36 = 21$, so the distance is 21 m."

Rui is wrong.

(a) Explain Rui's mistake. [2 marks]

(b) Find the distance travelled in the first 6 s. [4 marks]

Answer .....

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(c) Find all the times when the particle is $21\ \text{m}$ from O. [3 marks]

Answer .....

Total for D2: 9 marks

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D3 A particle P moves along a straight line with constant deceleration $a\ \mathrm{m\ s^{-2}}$. At time $t = 0$ it passes a point O with speed $10\ \mathrm{m\ s^{-1}}$, moving towards a point A, where $OA = 21\ \mathrm{m}$. P passes A, comes to instantaneous rest, and passes A again $4\ \mathrm{s}$ after it first passed A. Find the value of a and the greatest distance of P from O. [8 marks]

Answer .....

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D4 A car moves along a straight horizontal road at $u\ \mathrm{m\ s^{-1}}$ when the driver sees an obstacle $60\ \mathrm{m}$ ahead. In a model, the car keeps moving at $u\ \mathrm{m\ s^{-1}}$ for $0.7\ \mathrm{s}$, the driver's reaction time, and then decelerates uniformly at $6\ \mathrm{m\ s^{-2}}$ until it stops.

(a) Given that $u = 20$, show that the car stops before it reaches the obstacle, and find how far from the obstacle it stops. [3 marks]

Answer .....

(b) Show that the car stops before it reaches the obstacle when $u^2 + 8.4u - 720 < 0$. [3 marks]

Answer .....

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(c) Hence find the greatest speed at which the car can be moving if it is to stop before the obstacle. Give your answer in $\mathrm{km\ h^{-1}}$. [3 marks]

Answer .....

(d) On another day the car is moving at $25\ \mathrm{m\ s^{-1}}$ when the driver sees the obstacle $60\ \mathrm{m}$ ahead. Find the speed of the car when it hits the obstacle. [3 marks]

Answer .....

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(e) State one limitation of the model, and say how it would change your answer to part (c). [2 marks]

Total for D4: 14 marks

D5 A particle moves along a straight line with constant acceleration a m s^{-2}. Its initial speed is u m s^{-1}.

(a) Starting from $v = u + at$ and $s = \frac{1}{2}(u + v)t$, show that $s = ut + \frac{1}{2}at^2$. [3 marks]

Answer .....

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(b) Hence show that the distance travelled in the nth second is $u + \frac{1}{2}(2n - 1)a$. [3 marks]

Answer .....

(c) The distances travelled in the 3rd second and the 7th second are in the ratio $1 : 2$. The particle travels $18\ \text{m}$ in the 5th second. Find u and a. [4 marks]

Answer .....

Total for D5: 10 marks

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E Extension

Stretch

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

E1 [9 marks]

Car A moves along a straight road with constant acceleration $1\ \mathrm{m\ s^{-2}}$. At $t = 0$ it passes a point O with speed $10\ \mathrm{m\ s^{-1}}$. Car B passes O, in the same direction, $4\ \mathrm{s}$ later, with speed $30\ \mathrm{m\ s^{-1}}$ and a constant deceleration of $1\ \mathrm{m\ s^{-2}}$. Show that B draws level with A twice. Find the two times, the distance from O of each meeting point, and the greatest distance by which B is ahead of A.

Answer .....

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Extension hints

Cover these with paper. Uncover one at a time.

E1

Hint 1 Measure all times from when A passes O. B has been moving past O for $t - 4$ seconds.

Hint 2 Write $s_B - s_A$ as a quadratic in t. Level means it is zero. Check each root is a time when both formulae hold: B stops at $t = 34$.

Hint 3 The lead $s_B - s_A$ is greatest when its derivative is zero, which is when the two cars have the same speed. Or complete the square.

How did it go?

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

I can derive the constant acceleration formulae from v = u + at and s = ½(u + v)t.	○ ○ ○
I can solve a quadratic in t and say what each root means, rejecting a root that cannot happen.	○ ○ ○
I can tell displacement from distance travelled when a particle changes direction.	○ ○ ○
I can set up equations for two particles that meet, or for motion in two stages.	○ ○ ○

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