Hints online, answers free with an account:
mathswariz.uk/worksheets/a-level-mechanics-year-1-chapter-11-a-star/

Variable acceleration: A* questions

86 marks

Date

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X A* exam questions

A to A*

Extended Edexcel-style questions. Show every step. The hints are at the end of the sheet. Use one at a time.

X1 A particle P moves in a straight line. At time t seconds, $t \geq 0$, its displacement from a fixed point O on the line is s metres, where $s = t^3 - 9t^2 + ct$ and c is a constant with $0 < c < 27$. The distance between the two points at which P is instantaneously at rest is $62.5\ \text{m}$. Find the value of c. Find, in exact form, the length of time for which P is on the negative side of O. [9 marks]

Answer .....

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X2 Two particles P and Q leave a point O at the same time and move along the same straight line. At time t seconds their displacements from O are x_P metres and x_Q metres, where $x_P = t^3 - 10t^2 + 38t$ and $x_Q = 20t - t^2$, $0 \leq t \leq 6$.

(a) Show that Q moves with constant acceleration, and that P never comes to rest. [3 marks]

Answer .....

(b) Find the times, other than $t = 0$, at which P and Q are level. [3 marks]

Answer .....

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(c) Find the greatest distance between P and Q for $0 \leq t \leq 6$, giving your answer in the form $a\sqrt{3}$. [4 marks]

Answer .....

(d) Find the interval of time in which P is moving more slowly than Q. [3 marks]

Answer .....

Total for X2: 13 marks

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X3 A car starts from rest at a point A on a straight road. For $0 \leq t \leq 10$ its acceleration is $k(10 - t)\ \mathrm{m\ s^{-2}}$, where k is a constant. In these 10 seconds the car travels $200\ \mathrm{m}$. After $t = 10$ the car moves with constant speed. Find the value of k, and the time at which the car is $500\ \mathrm{m}$ from A. [9 marks]

Answer .....

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X4 A particle moves in a straight line. At time t seconds its displacement from its starting point O is s metres, where $s = pt^3 + qt^2 + rt$ and p, q and r are constants. The initial velocity is u and the velocity at time T is v.

(a) Show that the average velocity $\dfrac{s(T)}{T}$ over the interval $0 \leq t \leq T$ is equal to $\dfrac{u+v}{2}$ for every $T > 0$ if and only if $p = 0$. [5 marks]

Answer .....

(b) A particle has $s = t^3 + 2t$. Lin uses $s = \frac{1}{2}(u+v)t$ to find its displacement when $t = 2$. Find the error in Lin's answer, and show that it agrees with your answer to (a). [3 marks]

Answer .....

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(c) Explain how your answer to (a) relates to the condition under which the constant acceleration formulae may be used. [2 marks]

Total for X4: 10 marks

X5 A particle P starts from rest at O and moves along a straight line. At time t seconds its velocity is $v \text{ m s}^{-1}$, where $v = t^2 + 2t$ for $0 \leq t \leq k$ and $v = 32 - 2t$ for $k \leq t \leq 20$. The velocity of P is continuous at $t = k$.

(a) Find the value of k. [3 marks]

Answer .....

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(b) Find the greatest speed of P for $0 \leq t \leq 20$, and explain why it does not occur at a time when the acceleration of P is zero. [3 marks]

(c) Find the total distance travelled by P for $0 \leq t \leq 20$. [5 marks]

Answer .....

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(d) Find the distance of P from O when $t = 20$. [2 marks]

Answer .....

Total for X5: 13 marks

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X6 A particle P moves on the x-axis. At time t seconds, $t \geq 0$, its displacement from O is x metres, where $x = 2t^3 - 15t^2 + 36t$. Find the greatest distance of P from O for $0 \leq t \leq 5$. The greatest value of x for $0 \leq t \leq T$ occurs when $t = 2$. Find the set of possible values of T. [9 marks]

Answer .....

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X7 A cyclist moves along a straight road. At time t seconds, $0 \leq t \leq 8$, the acceleration of the cyclist is modelled as $(4t - 16)\ \mathrm{m\ s^{-2}}$, and her velocity is $30\ \mathrm{m\ s^{-1}}$ when $t = 0$.

(a) Find the times for which the speed of the cyclist is greater than $6\ \mathrm{m\ s^{-1}}$. [4 marks]

Answer .....

(b) Find the distance travelled by the cyclist between $t = 2$ and $t = 6$. [4 marks]

Answer .....

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(c) Using your answer to (a) or (b), give one criticism of the model and suggest a refinement. [2 marks]

Total for X7: 10 marks

X8 A lift of mass $500\ \text{kg}$ carries a box of mass $40\ \text{kg}$ on its floor. The lift is raised from rest by a vertical cable. At time t seconds, $0 \leq t \leq 5$, the upward velocity of the lift is $v\ \text{m s}^{-1}$, where $v = kt(5 - t)$ and k is a positive constant. The cable breaks if the tension in it exceeds $6000\ \text{N}$. The lift is modelled as a particle and air resistance is ignored.

(a) Show that the tension in the cable is greatest when $t = 0$, and find this greatest tension in terms of k. [4 marks]

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(b) Hence find the greatest possible height through which the lift can rise in the 5 seconds without the cable breaking. [4 marks]

Answer .....

(c) In the case $k = 0.24$, find the magnitude of the force exerted by the floor of the lift on the box when $t = 4$. [3 marks]

Answer .....

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(d) Give one criticism of the model for v at the start of the motion. [2 marks]

Total for X8: 13 marks

F How did it go?

Colour one circle on each line.

	Not yet	Nearly	Yes
I can find an unknown constant in a model from a distance, a continuity condition or a total distance travelled.	○	○	○
I can solve problems with two particles, or two stages, by differentiating and integrating.	○	○	○
I can prove when the constant acceleration formulae hold for a polynomial model.	○	○	○
I can combine calculus with Newton's second law and criticise a model.	○	○	○

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Hints

Use one hint at a time. Cover the ones below it with a sheet of paper.

X1	**Hint 1**	Complete the square on v. The two rest times are equally spaced either side of $t = 3$.
	Hint 2	Write the rest times as $3 \pm h$. The distance between the rest points is the size of $\int v \, \mathrm{d}t$ between them; substitute $w = t - 3$.
	Hint 3	With c found, $s = t \times (\text{a quadratic})$. P is on the negative side while the quadratic is negative: the time is the difference of its roots. Leave it as a surd.
X2	**Hint 1**	For (a), a quadratic with a negative discriminant has the same sign everywhere.
	Hint 2	"Level" means equal displacements. The distance between them is the size of $x_P - x_Q$: find its stationary points and check the ends.
	Hint 3	Check the signs of v_P and v_Q first: if both are positive, "more slowly" means $v_P < v_Q$, a quadratic inequality.
X3	**Hint 1**	The acceleration depends on t, so the constant acceleration formulae cannot be used in the first stage. Integrate twice; the car starts from rest at A.
	Hint 2	"Travels $200\ \mathrm{m}$ in these 10 seconds" gives an equation for k. Check that v does not change sign for $0 \leq t \leq 10$.
	Hint 3	After $t = 10$ the speed is constant at $v(10)$. Use distance $=$ speed $\times$ time for the rest of the $500\ \mathrm{m}$.
X4	**Hint 1**	Average velocity is displacement divided by time. Write u and v by differentiating s and substituting $t = 0$ and $t = T$.
	Hint 2	Subtract the two expressions and simplify. "For every T" means the difference must be identically zero.
	Hint 3	Differentiate s twice. What must be true of p for the acceleration not to depend on t?

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X5	**Hint 1**	"Continuous" means the two expressions give the same velocity at $t = k$. Reject a value of k outside $0 \leq t \leq 20$.
	Hint 2	Differentiate each expression to find the sign of the acceleration in each stage. Where does v stop increasing? Check the end $t = 20$ too.
	Hint 3	In the second stage v changes sign. Integrate up to the time it is zero and then beyond it, and add the sizes for the distance.
X6	**Hint 1**	Find the stationary points of x and compare with the value at the end $t = 5$.
	Hint 2	The greatest value on $0 \leq t \leq T$ stays at $t = 2$ until x climbs back up to $x(2)$ after $t = 3$.
	Hint 3	Solve $x = 28$. You already know $t = 2$ is a solution, and the curve touches $x = 28$ there, so $(t - 2)^2$ is a factor.
X7	**Hint 1**	Speed is the size of v: solve $v > 6$ AND $v < -6$.
	Hint 2	Between $t = 2$ and $t = 6$ the velocity is zero twice. Find the position at each of these times.
	Hint 3	Look at the sign of v between $t = 3$ and $t = 5$. What does it say the cyclist does?
X8	**Hint 1**	Differentiate v. A force that gives the greatest upward acceleration is the greatest tension; apply $F = ma$ to the lift and box together.
	Hint 2	The tension must not exceed 6000: this gives an inequality for k. The height is the integral of v from 0 to 5, which is a multiple of k.
	Hint 3	For the force on the box, apply $F = ma$ to the box on its own; the acceleration is negative when $t = 4$.

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