EDEXCEL A-LEVEL MATHEMATICS (9MA0) · PAPER 3 MECHANICS · A-LEVEL MECHANICS A* REVISION · SHEET 5 OF 6

Hints online, answers free with an account:
mathswariz.uk/worksheets/a-level-mechanics-a-star-revision-5/

A-Level Mechanics A* revision 5

90 marks

Date

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Exam questions

Edexcel 9MA0 Paper 3 Mechanics style, later parts of long questions. Take g = 9.8 m s^{-2} and give answers to 2 or 3 significant figures. Show all your working: an answer with no method may score no marks. The hints are at the end of the sheet. Use one at a time.

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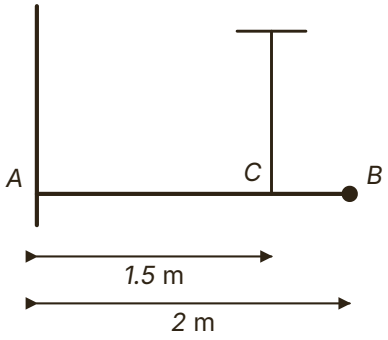
X1 A uniform rod AB has length 2 m and mass 8 kg. The end A is freely hinged to a fixed vertical wall. The rod is held in a horizontal position by a light vertical string attached to the rod at C, where $AC = 1.5$ m, and to a fixed point vertically above C. A particle of mass 10 kg is attached to the rod at B, as shown in the figure. [9 marks]

Find the tension in the string, and the magnitude and direction of the force exerted by the hinge on the rod. The particle is then moved along the rod to the point P, and the force exerted by the hinge on the rod becomes zero. Find the distance AP. Give your answers to 3 significant figures.



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Answer .....

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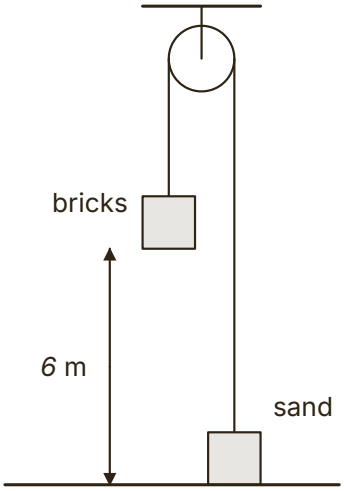
X2 At a building site a light inextensible rope passes over a small smooth pulley fixed high above the ground. One end is attached to a bucket of bricks of total mass M kg, which is held at rest 6 m above the ground. The other end is attached to a bucket of sand of mass 20 kg, which rests on the ground with the rope taut and vertical. The bucket of bricks is released. [9 marks]

The builder wants the bucket of sand to rise, and wants the bucket of bricks to be moving at no more than $4\ \mathrm{m\ s^{-1}}$ when it reaches the ground. The buckets are modelled as particles and air resistance is ignored.

Find the range of possible values of M. Give the upper limit to 3 significant figures.



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Answer .....

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X3 A box rests on a rough ramp inclined at 20° to the horizontal. A worker finds that the least force, acting up a line of greatest slope of the ramp, that stops the box sliding down the ramp has magnitude 30 N. The least force, acting up a line of greatest slope, that makes the box start to move up the ramp has magnitude 90 N. The box is modelled as a particle. [9 marks]

Find the mass of the box and the coefficient of friction between the box and the ramp. The worker then lets go of the box. Find the acceleration of the box. Give your answers to 3 significant figures.

Answer .....

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X4 A ball is struck from a point O on horizontal ground. Immediately after it is struck, the ball is moving with a horizontal velocity of $15\ \mathrm{m\ s^{-1}}$ and a vertical velocity of $20\ \mathrm{m\ s^{-1}}$ upwards. The ball is modelled as a particle moving freely under gravity.

(a) Find the length of time for which the ball is at least $15\ \mathrm{m}$ above the ground. Give your answer to 3 significant figures. [3 marks]

Answer .....

(b) Find the two times at which the direction of motion of the ball is at 45° to the horizontal, and show that both of these times are before the ball lands. [4 marks]

Answer .....

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(c) Show that the ball is at the same height at these two times, explaining why, and find this height. [3 marks]

Answer .....

Total for X4: 10 marks

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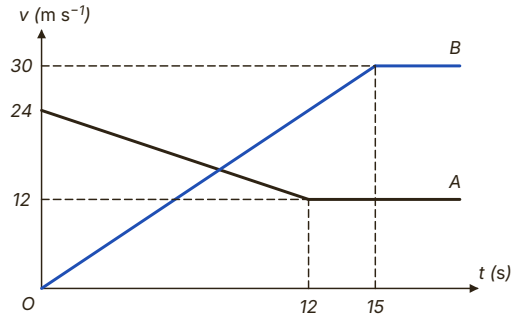
X5 Two cars, A and B, move along a straight road in the same direction. At time $t = 0$ both cars are at the point O.
Car A passes O at $24\ \text{m s}^{-1}$ and decelerates uniformly at $1\ \text{m s}^{-2}$ until $t = 12$. After this it moves at a constant speed of $12\ \text{m s}^{-1}$.
Car B starts from rest at O and accelerates uniformly at $2\ \text{m s}^{-2}$ until $t = 15$. After this it moves at a constant speed of $30\ \text{m s}^{-1}$.
The figure shows the velocity-time graphs of the two cars.



(a) Explain why the distance between the cars is greatest at the time at which they have the same speed. [2 marks]

Answer .....

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(b) Find the greatest distance between the cars before B overtakes A. [3 marks]

Answer .....

(c) Find the time at which B overtakes A, and the distance from O at which this happens. [7 marks]

Answer .....

Total for X5: 12 marks

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X6 In this question $\mathbf{i}$ and $\mathbf{j}$ are horizontal unit vectors due east and due north. A drone of mass 1.2 kg flies in a horizontal plane. It is modelled as a particle. At time t seconds, $0 \leqslant t \leqslant 8$, its velocity is

$$\mathbf{v} = \left((t^2 - 6t + 5)\mathbf{i} + (8 - 2t)\mathbf{j}\right) \text{ m s}^{-1}$$

When $t = 0$ the drone is at the point with position vector $(3\mathbf{i} - 4\mathbf{j})$ m relative to a fixed point O.

(a) Find the value of t at which the drone is moving due north. Give a reason for rejecting any other value. [3 marks]

Answer .....

(b) Find the magnitude of the resultant force on the drone at this instant. Give your answer to 3 significant figures. [3 marks]

Answer .....

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(c) Find the position vector of the drone when $t = 6$. [3 marks]

Answer .....

(d) Find the distance of the drone from its starting point when $t = 6$, and the bearing of the drone from its starting point. Give your answers to 3 significant figures. [4 marks]

Answer .....

Total for X6: 13 marks

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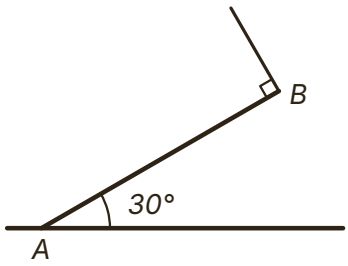
X7 A uniform rod AB, of length $2a$ and weight W, rests with its end A on rough horizontal ground. The rod is held at 30° to the horizontal by a light string attached at B. The string is perpendicular to the rod and lies in the vertical plane containing the rod. The coefficient of friction between the rod and the ground is μ.



(a) Show that the tension in the string is $\frac{\sqrt{3}}{4}W$. [3 marks]

Answer .....

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(b) Show that $\mu \geq \frac{\sqrt{3}}{5}$, stating the direction of the friction force at A with a reason. [6 marks]

Answer .....

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(c) A particle of weight kW is now attached to the rod at B. The string is adjusted so that it is still perpendicular to the rod and the rod is still at 30° to the horizontal. Given that $\mu = \frac{\sqrt{3}}{3}$ and that the rod is now about to slip, find the value of k. [5 marks]

Answer .....

Total for X7: 14 marks

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X8 A radio-controlled car moves along a straight horizontal track. It leaves the point O at time $t = 0$. Its velocity at time t seconds is modelled as

$$v = 0.15t(8 - t) \text{ m s}^{-1}, \qquad 0 \leqslant t \leqslant 12$$

(a) Find the greatest distance of the car from O. [4 marks]

Answer .....

(b) Show that the car is back at O when $t = 12$. [2 marks]

Answer .....

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(c) Find the speed of the car when it reaches O. Use your answer to give one reason why the model is not realistic at the end of the motion. [3 marks]

Answer .....

(d) Find the length of time for which the car is more than 10 m from O. Give your answer to 3 significant figures. [5 marks]

Answer .....

Total for X8: 14 marks

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F How did it go?

Colour one circle on each line.

	Not yet	Nearly	Yes
I can draw a full force diagram and resolve, take moments or write F = ma for the right body, with every distance perpendicular.	○	○	○
I can find my own route through a mechanics question that has no parts, and give answers to 2 or 3 significant figures.	○	○	○
I can use calculus and vectors for motion that is not constant acceleration, with the constant of integration from the start.	○	○	○
I can explain a result and criticise a model: friction direction, limiting equilibrium, one limitation of the 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 Every force except the hinge force is vertical, so the hinge force is vertical too, but it may act up or down. Take moments about A to find T without it.

Hint 2 Resolve vertically. If your value of the hinge force comes out negative, it acts in the opposite direction to the one you assumed.

Hint 3 For the second part, the hinge force is zero, so the tension equals the total weight. Put that into a moments equation about A with the particle at P.

X2

Hint 1 Write $F = ma$ for each bucket, with the same tension and the same size of acceleration. Find a in terms of M.

Hint 2 The bricks fall 6 m from rest, so $v^2 = 12a$. Turn $v \leqslant 4$ into an inequality for a.

Hint 3 Substitute your a and solve for M (the denominator $M + 20$ is positive). Then add the condition for the sand to rise at all.

X3

Hint 1 Write two equations along the ramp. In the first the box is about to slide down, so friction acts up. In the second it is about to move up, so friction acts down.

Hint 2 The friction is limiting in both and $R = mg\cos 20^\circ$ in both, so it is the same unknown F each time. Add the equations to find m, subtract to find F.

Hint 3 When the worker lets go, compare $mg\sin 20^\circ$ with the greatest friction. If the box moves, friction is limiting and acts up the ramp.

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X4	**Hint 1**	Write the height at time t and solve the equation height $= 15$. The time above $15\ \text{m}$ is the gap between the two roots.
	Hint 2	At 45° to the horizontal the vertical and horizontal speeds are equal. The vertical velocity is $+15$ on the way up and -15 on the way down.
	Hint 3	Find the time of the greatest height. How far is each of your two times from it?
X5	**Hint 1**	Compare the two speeds before and after the time at which they are equal. Which car is pulling away in each case?
	Hint 2	At the time of equal speeds both cars are still changing speed, so use the first stage for each.
	Hint 3	Before you set the displacements equal, check which stage each car is in. Compare their positions when $t = 15$.
X6	**Hint 1**	Due north: the $\mathbf{i}$ component of $\mathbf{v}$ is zero AND the $\mathbf{j}$ component is positive. Check each root.
	Hint 2	Differentiate $\mathbf{v}$ for the acceleration, then $\mathbf{F} = m\mathbf{a}$. For the position, integrate $\mathbf{v}$ and add the position at $t = 0$.
	Hint 3	The distance from the START is the length of $\mathbf{r}(6) - \mathbf{r}(0)$, not of $\mathbf{r}(6)$. Measure the bearing clockwise from north.
X7	**Hint 1**	Take moments about A. The string is perpendicular to the rod, so its perpendicular distance from A is the whole length $2a$.
	Hint 2	The tension has a horizontal component $T\sin 30^\circ$ and a vertical component $T\cos 30^\circ$. The rod is in equilibrium, so use $F \leq \mu R$; do not assume it is about to slip.
	Hint 3	With the particle at B, find T again by moments about A, then find F and R in terms of k, and set $F = \mu R$.

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X8

Hint 1 Integrate v to get the position, using $x = 0$ when $t = 0$. The car is furthest away when $v = 0$.

Hint 2 For (d), set the position equal to 10 and clear the decimals to get a cubic.

Hint 3 Try $t = 10$ in the cubic. Of the other two roots, keep only the one in the interval $0 \leqslant t \leqslant 12$.

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