EDEXCEL A-LEVEL MATHEMATICS (9MA0) · PAPER 3 MECHANICS · A-LEVEL MECHANICS A* REVISION · SHEET 2 OF 6

Hints online, answers free with an account:
mathswariz.uk/worksheets/a-level-mechanics-a-star-revision-2/

A-Level Mechanics A* revision 2

89 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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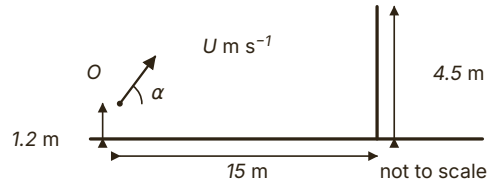
X1 A girl throws a ball from a point O, $1.2\ \text{m}$ above horizontal ground, towards a vertical wall of height $4.5\ \text{m}$. The foot of the wall is $15\ \text{m}$ horizontally from O. The ball is thrown with speed $U\ \text{m s}^{-1}$ at an angle α above the horizontal, where $\tan\alpha = \frac{4}{3}$, in a vertical plane perpendicular to the wall. The ball is modelled as a particle moving freely under gravity, and the wall is modelled as having no thickness. [9 marks]

Find the least value of U for which the ball passes over the wall. For this value of U, find how far beyond the wall the ball first hits the ground. Give your answers to 3 significant figures.



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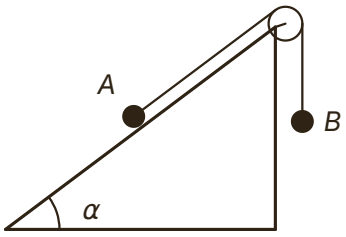
Answer .....

X2 A particle A of mass $2m$ lies on a rough plane inclined at an angle α to the horizontal, where $\tan\alpha = \frac{3}{4}$. It is attached to a light inextensible string which passes over a small smooth pulley fixed at the top of the plane. The other end of the string is attached to a particle B of mass $3m$, which hangs freely. The part of the string between A and the pulley is parallel to a line of greatest slope of the plane. The coefficient of friction between A and the plane is $\frac{1}{4}$. The system is released from rest with the string taut, and B moves downwards.



(a) Find, in terms of m and g, the tension in the string. [5 marks]

Answer .....

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(b) Find the magnitude of the force exerted on the pulley by the string, giving your answer in terms of m and g to 3 significant figures, and the angle that this force makes with the vertical. [4 marks]

Answer .....

(c) In a refined model the pulley is rough. State how this would affect the working in part (a). [1 mark]

Answer .....

Total for X2: 10 marks

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X3 A ball is thrown vertically upwards from a point A which is h metres above horizontal ground. The ball is above the level of A for exactly 3 s, and it hits the ground 4.5 s after it was thrown. [10 marks]

The ball is modelled as a particle moving freely under gravity. Find the value of h and the total distance travelled by the ball from the moment it is thrown until it hits the ground. Give your answers to 3 significant figures.

Answer .....

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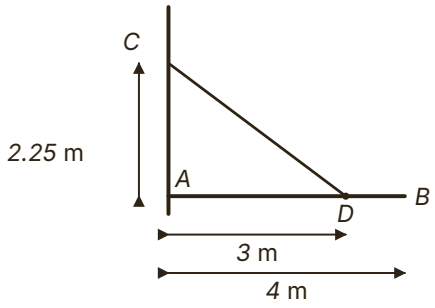
X4 A loading platform is modelled as a uniform rod AB of length $4\ \text{m}$ and mass $150\ \text{kg}$. The end A is freely hinged to a vertical wall. The platform is held horizontal by a light inextensible chain. One end of the chain is fixed to the platform at the point D, where $AD = 3\ \text{m}$, and the other end is fixed to the wall at the point C, vertically above A, where $AC = 2.25\ \text{m}$. A crate of mass $300\ \text{kg}$ is placed on the platform at a point P on AB. The platform and the chain lie in a vertical plane perpendicular to the wall. The chain breaks if the tension in it exceeds $6000\ \text{N}$. [11 marks]

Modelling the crate as a particle, find the greatest possible distance AP. For the crate at this point, find the magnitude of the force exerted on the platform by the hinge, and the angle this force makes with the horizontal, stating its direction. Give your answers to 3 significant figures.



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Answer .....

X5 In this question $\mathbf{i}$ and $\mathbf{j}$ are horizontal unit vectors due east and due north. A particle P of mass 0.5 kg moves on a smooth horizontal surface. At time t seconds, $t \geqslant 0$, the only horizontal force acting on P is $\mathbf{F} = \big((3t-2)\mathbf{i} - 1.5\mathbf{j}\big)$ N. When $t = 0$, P is at the point with position vector $(4\mathbf{i} + \mathbf{j})$ m relative to a fixed point O, and P is moving with velocity $(2\mathbf{i} + 9\mathbf{j})\ \mathrm{m\ s^{-1}}$.

(a) Find the velocity of P at time t seconds. [3 marks]

Answer .....

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(b) Show that P is never at rest. [3 marks]

Answer .....

(c) Find the speed of P at the instant when it is moving due east. [2 marks]

Answer .....

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(d) Find the distance of P from O at the instant when it is moving due east. Give your answer to 3 significant figures. [4 marks]

Answer .....

Total for X5: 12 marks

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X6 A car of mass 1200 kg is moving at $18\ \mathrm{m\ s^{-1}}$ down a straight road inclined at 4° to the horizontal. The driver brakes so hard that the wheels lock, and the car slides in a straight line down the road. The coefficient of friction between the tyres and the road is μ. The car is modelled as a particle and air resistance is ignored.

(a) Given that $\mu = 0.6$, find the distance the car slides before it stops. Give your answer to 3 significant figures. [5 marks]

Answer .....

(b) On a wet day the car must stop within 40 m from the same speed. Find the least value of μ that allows this. Give your answer to 3 significant figures. [3 marks]

Answer .....

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(c) Find the value of μ below which the car cannot be brought to rest by braking on this road, and explain why it cannot be brought to rest. [3 marks]

Answer .....

(d) State one limitation of the model. [1 mark]

Answer .....

Total for X6: 12 marks

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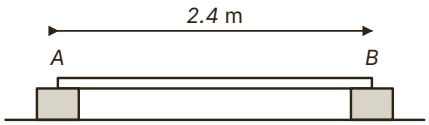
X7 A non-uniform plank AB has length 2.4 m. It rests horizontally with the end A on one set of weighing scales and the end B on another. Each set of scales shows a reading in kilograms: a reading of x kg means that the scales push up on the plank with a force of xg newtons. With nothing on the plank, the scales at A read 7.2 kg and the scales at B read 4.8 kg.



(a) Find the mass of the plank and the distance from A of its centre of mass. [4 marks]

Answer .....

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(b) A child stands on the plank at the point P. The scales at A now read 25.2 kg and the scales at B read 18.8 kg. The child is modelled as a particle. Find the mass of the child and the distance AP. [4 marks]

Answer .....

(c) Explain why the readings in kilograms can be used in the equations without first multiplying each of them by g. [2 marks]

Answer .....

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(d) The child walks to B and stands there. Find the reading on each set of scales. [2 marks]

Answer .....

Total for X7: 12 marks

X8 A particle P moves along a straight line. At time t seconds, $0 \leqslant t \leqslant 6$, the velocity of P is v m s^{-1}, where

$$v = t^3 - 9t^2 + 15t$$

When $t = 0$, P is at the point O.

(a) Find the values of t at which P is instantaneously at rest. Give any value that is not exact to 3 significant figures. [3 marks]

Answer .....

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(b) Ali says, "$\frac{dv}{dt} = 0$ when $t = 1$, and $v = 7$ there, so the greatest speed of P is $7\ \mathrm{m\ s^{-1}}$." Explain why Ali is wrong, and find the greatest speed of P. [5 marks]

Answer .....

(c) Find the total distance travelled by P in the interval $0 \leqslant t \leqslant 6$. Give your answer to 3 significant figures. [5 marks]

Answer .....

Total for X8: 13 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 Resolve U into components. Find the time at which the ball has travelled $15\ \text{m}$ horizontally, in terms of U.

Hint 2 The ball starts $1.2\ \text{m}$ above the ground, so it must rise $4.5 - 1.2 = 3.3\ \text{m}$ by the time it reaches the wall. Write this as an inequality in U.

Hint 3 For the landing point, the ground is $1.2\ \text{m}$ below O: solve $-1.2 = (0.8U)t - 4.9t^2$ with your value of U, then find the horizontal distance and subtract 15.

X2

Hint 1 Resolve perpendicular to the plane for R, then $F = \mu R$. A moves up the plane, so the friction and $2mg\sin\alpha$ both act down the plane.

Hint 2 Write one equation for A and one for B with the same T and a. Find a first, then T from the equation for B.

Hint 3 The pulley feels T along each part of the string, towards A and towards B. Add these two vectors: the angle between them is $90^\circ - \alpha$.

X3

Hint 1 The motion above A is symmetric. How long does the ball take to reach its highest point?

Hint 2 Use $v = 0$ at the highest point to find the speed of projection. Then find the displacement after 4.5 s with up as positive.

Hint 3 A negative displacement means below A. The total distance is up to the top, back down to A, and then down to the ground.

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X4

Hint 1 Find the angle between the chain and the platform from the right-angled triangle ACD.

Hint 2 Take moments about A. The chain is attached at D, so the perpendicular distance from A to the chain is $3\sin\beta$, not $4\sin\beta$. The chain does not break while $T \leq 6000$.

Hint 3 With $T = 6000$, resolve horizontally and vertically for the two components of the hinge force, then combine them with Pythagoras and find the angle with $\tan$.

X5

Hint 1 Divide the force by the mass to get the acceleration, then integrate. The constant of integration is the velocity when $t = 0$, not zero.

Hint 2 At rest means BOTH components of the velocity are zero. Look at the $\mathbf{i}$ component on its own: can a quadratic with a negative discriminant be zero?

Hint 3 Moving due east means the $\mathbf{j}$ component is zero and the $\mathbf{i}$ component is positive. Integrate again for the position, adding the starting position $4\mathbf{i} + \mathbf{j}$.

X6

Hint 1 Friction acts up the road because the car slides down it. The weight component $1200g\sin 4^\circ$ acts down the road, against the friction.

Hint 2 For (b), find the deceleration needed to stop in 40 m first, then set it equal to $\mu g\cos 4^\circ - g\sin 4^\circ$.

Hint 3 For (c), the car can only slow down if the friction can be larger than the weight component down the road. Compare $\mu mg\cos 4^\circ$ with $mg\sin 4^\circ$.

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X7

Hint 1 Resolving vertically gives the total mass. Then take moments about A: only the reading at B and the weight of the plank have moments about A.

Hint 2 For (b), the child adds weight and a new moment. Take moments about A again with three downward weights and the push at B.

Hint 3 For (d), take moments about B. The child is at B, so the child's weight has no moment about B, and the reading at A is the same as with nothing on the plank.

X8

Hint 1 Take out the common factor of t. Check every root against the interval $0 \leqslant t \leqslant 6$.

Hint 2 $\dfrac{dv}{dt} = 0$ gives the greatest and least values of v. The greatest speed could come from the least value of v, or from an end of the interval.

Hint 3 For (c), the particle turns round at $t = 2.21$. Find its position there and at $t = 6$, and add the two distances.

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