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

Hints online, answers free with an account:
mathswariz.uk/worksheets/a-level-mechanics-a-star-revision-3/

A-Level Mechanics A* revision 3

85 marks

Date

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X 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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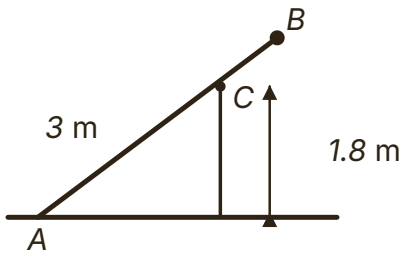
X1 A plank AB, of length $4\ \mathrm{m}$ and mass $20\ \mathrm{kg}$, is modelled as a uniform rod. It rests with its end A on rough horizontal ground and touches a smooth horizontal rail at the point C, where $AC = 3\ \mathrm{m}$. The rail is $1.8\ \mathrm{m}$ above the ground and is perpendicular to the vertical plane containing the plank. A child of mass $30\ \mathrm{kg}$, modelled as a particle, sits on the plank at B. The plank rests in equilibrium. [8 marks]

Find the least possible value of the coefficient of friction between the plank and the ground.



Answer .....

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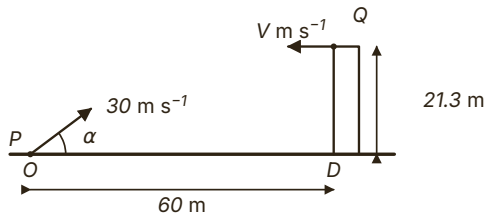
X2 A particle P is projected from a point O on horizontal ground with speed $30\ \text{m s}^{-1}$ at an angle α above the horizontal, where $\tan\alpha = \frac{3}{4}$. A vertical tower stands on the ground with its foot at the point D, where $OD = 60\ \text{m}$. The top of the tower is $21.3\ \text{m}$ above the ground. One second after P is projected, a particle Q is projected horizontally from the top of the tower, towards O, with speed $V\ \text{m s}^{-1}$. The particles move in the same vertical plane and they collide. [8 marks]

Find the value of V and the height above the ground at which the particles collide.



Answer .....

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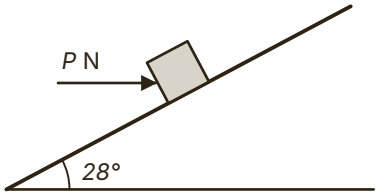
X3 A crate of mass 50 kg is on a rough ramp inclined at $28°$ to the horizontal. The coefficient of friction between the crate and the ramp is 0.25. A worker holds the crate at rest by pushing it with a horizontal force of magnitude P newtons. The force acts in the vertical plane containing a line of greatest slope of the ramp and pushes towards the ramp, as shown in the figure. The crate is modelled as a particle.



(a) Show that, if the worker lets go, the crate slides down the ramp. [2 marks]

Answer .....

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(b) Find the least value of P for which the crate stays at rest. [4 marks]
Give your answer to 3 significant figures.

Answer .....

(c) Find the greatest value of P for which the crate stays at rest. [4 marks]
Give your answer to 3 significant figures.

Answer .....

Total for X3: 10 marks

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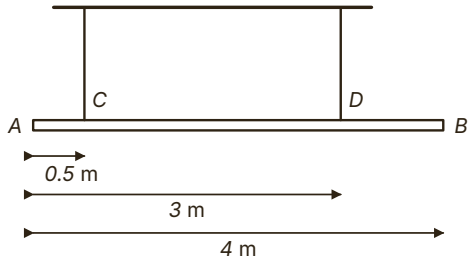
X4 A window cleaner stands on a uniform plank AB of length 4 m and mass 40 kg. The plank hangs horizontally from two vertical ropes attached to the plank at C and at D, where $AC = 0.5$ m and $AD = 3$ m, as shown in the figure. The window cleaner has mass 30 kg and is modelled as a particle. Each rope will break if the tension in it is more than 420 N. [10 marks]

Find the range of distances from A at which the window cleaner can stand without either rope breaking. Give the ends of the range to 3 significant figures.



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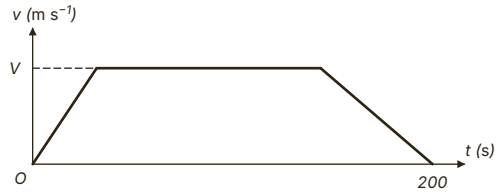
Answer .....

X5 A tram travels along a straight track between two stops, P and Q, which are 1700 m apart. The tram starts from rest at P and accelerates uniformly at $0.5\ \text{m s}^{-2}$ until its speed is $V\ \text{m s}^{-1}$. It travels at this constant speed, then decelerates uniformly at $0.25\ \text{m s}^{-2}$ until it comes to rest at Q. The journey from P to Q takes 200 s. The figure shows the speed-time graph of the journey.



(a) Show that $3V^2 - 200V + 1700 = 0$. [5 marks]

Answer .....

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(b) Hence find the value of V. [2 marks]

Answer .....

(c) Explain why the other solution of the equation in part (a) is not a possible value of V. [2 marks]

Answer .....

(d) Find the time after leaving P at which the tram has travelled 1000 m. [3 marks]

Answer .....

Total for X5: 12 marks

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X6 A particle P moves along a straight line. At time t seconds the acceleration of P is $(pt - 6)\ \mathrm{m\ s^{-2}}$, where p is a constant. When $t = 0$, P is at rest at the point O. When $t = 9$, P is at O again.

(a) Show that $p = 2$. [5 marks]

Answer .....

(b) Find the greatest distance of P from O in the interval $0 \leqslant t \leqslant 9$. [3 marks]

Answer .....

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(c) Determine whether P is speeding up or slowing down when $t = 4$. Give a reason for your answer. [2 marks]

Answer .....

(d) Find the speed of P as it passes through O when $t = 9$. [2 marks]

Answer .....

Total for X6: 12 marks

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X7 In this question $\mathbf{i}$ and $\mathbf{j}$ are horizontal unit vectors due east and due north. Two particles P and Q move on a smooth horizontal surface. Particle P has mass 0.6 kg. At time $t = 0$ it is at rest at a fixed point O, and for $t \geqslant 0$ the only horizontal force on it is a constant force $(1.2\mathbf{i} + 1.8\mathbf{j})$ N. At time $t = 0$, Q is at the point with position vector $(28\mathbf{i} + 4\mathbf{j})$ m, and Q moves with constant speed $\sqrt{34}\ \mathrm{m\ s^{-1}}$ in the direction of the vector $(-3\mathbf{i} + 5\mathbf{j})$.

(a) Find, in terms of t, the position vectors of P and Q at time t seconds. [4 marks]

Answer .....

(b) Show that P and Q collide, and find the position vector of the point where they collide. [4 marks]

Answer .....

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(c) Explain why P is never due north of Q. [2 marks]

Answer .....

(d) Find the exact speed of P at the instant of the collision. [2 marks]

Answer .....

Total for X7: 12 marks

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X8 A car of mass 1200 kg tows a trailer of mass 800 kg up a straight road inclined at an angle θ to the horizontal, where $\sin\theta = \frac{1}{14}$. The tow bar is light, rigid and parallel to the road. The resistances to motion are modelled as constant forces of magnitude 300 N on the car and 200 N on the trailer, each acting in the direction opposite to the motion. The car's engine produces a constant driving force, and the car and trailer accelerate up the road at $0.5\ \mathrm{m\ s^{-2}}$.

(a) Find the driving force. [3 marks]

Answer .....

(b) Find the tension in the tow bar. [3 marks]

Answer .....

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(c) When the speed is $9.5\ \mathrm{m\ s^{-1}}$ the tow bar breaks. Find the distance that the trailer then moves up the road before it comes to rest. [3 marks]

Answer .....

(d) The trailer then moves back down the road. Explain why its acceleration is not $0.95\ \mathrm{m\ s^{-2}}$, and find its speed as it passes the point where the tow bar broke. Give your answer to 3 significant figures. [4 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 The rail is smooth, so its force on the plank is perpendicular to the plank, not vertical. Find the angle of the plank from the height of the rail and AC.

Hint 2 Take moments about A to find the reaction at the rail. Then resolve horizontally and vertically, using the components of that reaction.

Hint 3 Use $F \leq \mu R$. The value of μ you find may be greater than 1; that is possible.

X2

Hint 1 Let t be the time after P is projected. Q has only been moving for $t - 1$ seconds, and it starts with no vertical velocity.

Hint 2 At the collision both particles are at the same height: write the height of each in terms of t and set them equal. The t^2 terms cancel.

Hint 3 They are also at the same horizontal position, so the horizontal distances they have moved towards each other add to $60\ \text{m}$. This gives V.

X3

Hint 1 Resolve perpendicular to the ramp. The horizontal force has a component $P\sin 28^\circ$ into the ramp, so R is not $50g\cos 28^\circ$ any more.

Hint 2 For the least P the crate is about to slide down, so friction acts up the ramp. For the greatest P it is about to slide up, so friction acts down the ramp.

Hint 3 In each case put $F = 0.25R$ into the equation along the ramp and collect the terms in P on one side.

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X4

Hint 1 Let the window cleaner be x m from A. Take moments about D to find the tension at C in terms of x, then resolve vertically for the tension at D.

Hint 2 Each rope gives one condition: $T_C \leq 420$ and $T_D \leq 420$. The second is the same as $T_C \geq 686 - 420$.

Hint 3 Solve the two inequalities for x. One gives the least distance from A and the other the greatest. Check both tensions stay positive in that range.

X5

Hint 1 Write the time for each of the three stages in terms of V. The three times add to 200.

Hint 2 The distance is the area under the graph. The shape is a trapezium whose top side is the time at constant speed.

Hint 3 For (c), put the other root into the time spent speeding up and slowing down, and compare it with 200 s.

X6

Hint 1 Integrate twice. Use the conditions at $t = 0$ for the two constants before you use the condition at $t = 9$.

Hint 2 For (b), P moves away from O until it is at rest, then comes back. Find when $v = 0$.

Hint 3 For (c), a positive acceleration does not mean speeding up. Compare the sign of v with the sign of a.

X7

Hint 1 P starts from rest at O, so $\mathbf{r}_P = \frac{1}{2}\mathbf{a}t^2$. For Q, find the length of $(-3\mathbf{i} + 5\mathbf{j})$: it is $\sqrt{34}$, so this vector is already the velocity.

Hint 2 They collide only if the $\mathbf{i}$ components AND the $\mathbf{j}$ components are equal at the same time. Solve with the $\mathbf{i}$ components, then test the $\mathbf{j}$ components.

Hint 3 For (c), "due north of" needs the $\mathbf{i}$ components to be equal. When does that happen? For (d), $\mathbf{v}_P = \mathbf{a}t$ and give the speed as a surd.

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X8

Hint 1 For the driving force treat the car and trailer as one body of mass 2000 kg: the tow bar force is internal and does not appear.

Hint 2 For the tension take the trailer on its own. After the tow bar breaks the trailer has only its weight component and the resistance acting along the road.

Hint 3 The resistance opposes the motion. When the trailer starts to roll back, the resistance changes direction, so you need a new acceleration.

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