EDEXCEL A-LEVEL MATHEMATICS (9MA0) · PAPER 3 MECHANICS · A-LEVEL MECHANICS A* REVISION · SHEET 4 OF 6

Hints online, answers free with an account:
mathswariz.uk/worksheets/a-level-mechanics-a-star-revision-4/

A-Level Mechanics A* revision 4

88 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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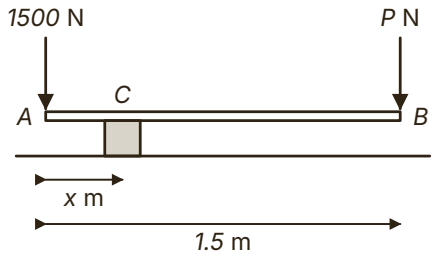
X1 A worker uses a crowbar to lift one edge of a heavy stone. The crowbar is modelled as a uniform rod AB of length 1.5 m and mass 6 kg. It is held horizontal, resting on a small brick at the point C between A and B. The end A is under the stone. When the stone is about to lift, it exerts a vertical downward force of 1500 N on the crowbar at A. The worker pushes vertically downwards at B with a force of P N, and P can be at most 400, as shown in the figure. [8 marks]

Find the greatest possible distance AC for which the worker can lift the stone, and the magnitude of the force exerted by the brick on the crowbar in this case. Give your answers to 3 significant figures.



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Answer .....

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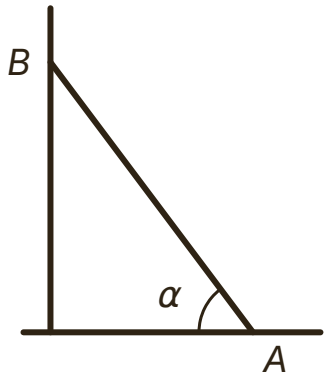
X2 A ladder AB, of length $2a$ and weight W, is modelled as a non-uniform rod with its centre of mass at G. The ladder rests with its end A on rough horizontal ground and its end B against a rough vertical wall, in a vertical plane perpendicular to the wall. The ladder makes an angle α with the ground, where $\tan\alpha = \frac{4}{3}$. The coefficient of friction between the ladder and the ground is $\frac{1}{2}$, and the coefficient of friction between the ladder and the wall is $\frac{1}{3}$. The ladder is about to slip. [8 marks]

Find the distance AG in terms of a.



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Answer .....

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X3 A lorry moves along a straight road that rises at 6° to the horizontal. A crate rests on the flat floor of the lorry, which is parallel to the road. The coefficient of friction between the crate and the floor is 0.35. The lorry starts from rest and accelerates uniformly up the road until its speed is $20\ \mathrm{m\ s^{-1}}$. Later, while still moving up the road at $20\ \mathrm{m\ s^{-1}}$, it brakes uniformly to rest. The crate must not slide on the floor of the lorry at any time. The crate is modelled as a particle. [11 marks]

Find the least time the lorry can take to reach $20\ \mathrm{m\ s^{-1}}$ from rest, and the least distance in which it can stop from $20\ \mathrm{m\ s^{-1}}$. Give your answers to 3 significant figures.

Answer .....

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X4 In this question $\mathbf{i}$ and $\mathbf{j}$ are horizontal unit vectors due east and due north. A hovercraft of mass 400 kg moves on the surface of a lake. It is modelled as a particle. The engine produces a constant force $(250\mathbf{i} + 400\mathbf{j})$ N and the wind produces a constant force $(-50\mathbf{i} + q\mathbf{j})$ N, where q is a constant. No other horizontal forces act. The resultant of these two forces is parallel to the vector $(2\mathbf{i} + 3\mathbf{j})$.

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

Answer .....

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(b) At time $t = 0$ the hovercraft is at a point O and moving with velocity $(2\mathbf{i} - \mathbf{j})\ \mathrm{m\ s^{-1}}$. Find the value of t at which the hovercraft is north-east of O, and its distance from O at that time. Give the distance to 3 significant figures. [5 marks]

Answer .....

(c) Find the speed of the hovercraft at this time. [2 marks]

Answer .....

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

Answer .....

Total for X4: 11 marks

X5 A particle is projected from a point O on horizontal ground with speed $35\ \mathrm{m\ s^{-1}}$ at an angle α above the horizontal. At time t seconds after projection the particle is at the point (x, y), where x metres is the horizontal distance from O and y metres is the height above the ground.

(a) Show that $y = x\tan\alpha - \dfrac{x^2(1+\tan^2\alpha)}{250}$. [4 marks]

Answer .....

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(b) The particle passes through the point $(100, 20)$. Find the two possible values of α. [5 marks]

Answer .....

(c) The particle is to reach the point $(100, 20)$ as soon as possible. State which value of α should be used, explaining your choice, and find how much sooner the particle arrives than with the other value. Give your answer to 2 significant figures. [3 marks]

Answer .....

Total for X5: 12 marks

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X6 A lift of mass 600 kg carries a box of mass 40 kg on its floor. The lift is raised by a vertical cable. The lift starts from rest and moves upwards in three stages:
- it accelerates uniformly for 4 s, with a tension in the cable of 6720 N;
- it moves at constant speed;
- it decelerates uniformly to rest. During this stage the box exerts a force of 378 N on the floor of the lift.

The lift rises 44.8 m altogether. The lift and the box are modelled as particles and air resistance is ignored.

(a) Find the acceleration of the lift during the first stage. [2 marks]

Answer .....

(b) Find the force exerted by the box on the floor of the lift during the first stage. [3 marks]

Answer .....

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(c) Find the tension in the cable during the third stage. [4 marks]

Answer .....

(d) Find the total time for which the lift is moving. [3 marks]

Answer .....

Total for X6: 12 marks

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X7 A particle P moves along a straight line with constant acceleration. At time $t = 0$, P passes through the point A, moving with speed $12\ \text{m s}^{-1}$. When $t = 5$, P is 20 m from A, on the same side of A as it was moving towards at $t = 0$.

(a) Find the magnitude of the acceleration of P and state its direction. [2 marks]

Answer .....

(b) Show that the total distance travelled by P in the first 5 s is 25 m. [4 marks]

Answer .....

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(c) Find all the values of t at which P is 14 m from A. Give your answers to 3 significant figures. [5 marks]

Answer .....

(d) A student says, "The average speed of P over the first 5 s is $4\ \mathrm{m\ s^{-1}}$." Explain why the student is wrong. [2 marks]

Answer .....

Total for X7: 13 marks

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X8 A particle P starts from rest at the point O at time $t = 0$ and moves along a straight line. At time t seconds:
for $0 \leqslant t \leqslant 4$, the acceleration of P is $(6 - 1.5t)\ \mathrm{m\ s^{-2}}$;
for $t > 4$, the velocity of P is $\dfrac{k}{t^2}\ \mathrm{m\ s^{-1}}$, where k is a constant.
The velocity of P does not change suddenly at $t = 4$.

(a) Find the velocity of P when $t = 4$, and hence show that $k = 192$. [4 marks]

Answer .....

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(b) Show that, for $t \geqslant 4$, the distance of P from O is $\left(80 - \frac{192}{t}\right)$ m. [5 marks]

Answer .....

(c) Find the time at which P is 70 m from O. [2 marks]

Answer .....

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(d) Explain why, according to the model, P never reaches a point 80 m from O. [2 marks]

Answer .....

Total for X8: 13 marks

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 Mark the forces on the crowbar: 1500 N down at A, its weight down at the midpoint, P down at B, and the brick's force up at C. Let $AC = x$.

Hint 2 Take moments about C so that the brick's force does not appear. The stone is on one side of C; the weight and the worker's push are on the other.

Hint 3 Write P in terms of x and decide whether a larger x needs a larger or smaller push. Then put $P = 400$ and resolve vertically for the brick's force.

X2

Hint 1 The ladder is about to slip, so friction is limiting at both ends. B is about to slide down the wall, so the friction at B acts upwards.

Hint 2 Resolve horizontally and vertically, with friction $\frac{1}{2}R$ at A and $\frac{1}{3}S$ at B, to find R and S in terms of W.

Hint 3 Take moments about A. Both the reaction and the friction at B have moments about A; use $\sin\alpha = \frac{4}{5}$ and $\cos\alpha = \frac{3}{5}$, and let $AG = d$.

X3

Hint 1 The crate moves with the lorry, so it has the same acceleration. Draw the forces on the crate alone: weight, R and friction. Which of these can make it speed up up the hill?

Hint 2 When the lorry accelerates, friction acts up the road. When the lorry brakes hard, the crate tends to keep moving up the road, so friction acts down the road. Use $F \le 0.35R$ in each case.

Hint 3 The greatest acceleration is $g(0.35\cos 6^\circ - \sin 6^\circ)$ and the greatest deceleration is $g(0.35\cos 6^\circ + \sin 6^\circ)$. Then use $v = u + at$ and $v^2 = u^2 + 2as$.

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X4

Hint 1 Add the two forces. Parallel to $2\mathbf{i} + 3\mathbf{j}$ means the $\mathbf{i}$ component divided by the $\mathbf{j}$ component is $\frac{2}{3}$.

Hint 2 Find the position vector, not the velocity. North-east of O means the $\mathbf{i}$ and $\mathbf{j}$ components of the POSITION are equal and both positive.

Hint 3 The equation gives $t = 0$ as well: that is the start. Use the other root, then $\mathbf{v} = \mathbf{u} + \mathbf{a}t$ for the speed.

X5

Hint 1 Write x and y in terms of t, then make t the subject of the x equation and substitute into the y equation.

Hint 2 $\dfrac{1}{\cos^2\alpha} = \sec^2\alpha = 1 + \tan^2\alpha$. Substituting the point gives a quadratic in $\tan\alpha$.

Hint 3 For (c), only the horizontal motion decides when the particle reaches $x = 100$. Compare $\dfrac{100}{35\cos\alpha}$ for the two angles.

X6

Hint 1 For the cable, take the lift and the box together. For the force between the box and the floor, take the box on its own.

Hint 2 In the third stage the box presses on the floor with less than its weight, so the acceleration is downwards. Find it from the box first.

Hint 3 Find the top speed from stage 1. Stages 1 and 3 are uniform, so their distances are areas of triangles on a speed-time graph; the rest is at constant speed.

X7

Hint 1 Use $s = ut + \frac{1}{2}at^2$ with the initial direction as positive. The sign of a tells you its direction.

Hint 2 Find when P comes to rest. The distance before that and the distance after it are added, not subtracted.

Hint 3 "14 m from A" can mean a displacement of 14 or of -14. Solve both and keep only the times that are not negative.

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X8

Hint 1 Integrate the first acceleration, using $v = 0$ when $t = 0$. The two formulas for v must agree at $t = 4$.

Hint 2 For the second stage the constant of integration comes from the position at $t = 4$, not from $t = 0$.

Hint 3 For (d), look at the sign of $\dfrac{192}{t}$ and what happens to it as t grows.

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