A-LEVEL MATHS (EDEXCEL 9MA0) · MECHANICS YEAR 2 · CHAPTER 5: FORCES AND FRICTION · A* EXAM PRACTICE

Hints online, answers free with an account:
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Forces and friction: A* questions

79 marks

Date

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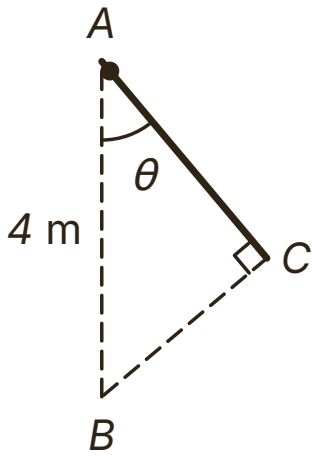
X A* exam questions

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 Points A and B are fixed in a vertical plane, with A vertically above B and $AB = 4\ \text{m}$. A straight wire joins A to a point C such that angle $ACB = 90^\circ$, and the wire makes an angle θ with AB, where $0^\circ < \theta < 90^\circ$. A small bead is threaded on the wire and released from rest at A. The bead is modelled as a particle.

(a) The wire is smooth. Show that the time the bead takes to reach C does not depend on θ, and find this time. [5 marks]



Answer .....

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(b) The wire is now rough, and the coefficient of friction between the bead and the wire is 0.25. Show that the bead moves when it is released only if $\tan\theta < 4$. [3 marks]

Answer .....

(c) For the rough wire with $\theta = 50°$, find the time the bead takes to reach C and its speed when it gets there. [4 marks]

Answer .....

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(d) For the rough wire, show that the time to reach C is T seconds, where $T^2 = \dfrac{8}{g(1 - 0.25\tan\theta)}$. Hence find the value of θ for which this time is twice the time on the smooth wire. [4 marks]

Answer .....

Total for X1: 16 marks

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X2 A straight chute is fixed with its lower end at a point B on horizontal ground and its upper end at a point A. The horizontal distance from B to the vertical line through A is $6\ \mathrm{m}$, and the chute makes an angle α with the horizontal, where the builder can choose α. A parcel is released from rest at A and slides down the chute. The coefficient of friction between the parcel and the chute is 0.5 and the parcel is modelled as a particle. Show that the time taken to reach B is least when $\tan 2\alpha = -2$. Find this value of α, the least time and the length of the chute. [10 marks]

Answer .....

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X3 A crate of mass $5\ \text{kg}$ is at rest on a rough horizontal floor. The coefficient of friction between the crate and the floor is 0.4. At time $t = 0$ a horizontal force of magnitude $2t$ N starts to act on the crate, where t is in seconds.

(a) Find the friction force acting on the crate when $t = 5$, and the time at which the crate starts to move. [3 marks]

Answer .....

(b) Show that, for $t \geq 9.8$, the speed of the crate is $\dfrac{(t - 9.8)^2}{5}\ \text{m s}^{-1}$, and find its speed when $t = 15$. [4 marks]

Answer .....

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(c) Find the distance moved by the crate in the first 15 seconds. [3 marks]

Answer .....

Total for X3: 10 marks

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X4 A small block is placed on a rough board. One end of the board is raised slowly, and the block is on the point of slipping when the board makes an angle of 25° with the horizontal. The board is then fixed at 40° to the horizontal and the block is released from rest. Show that the acceleration of the block down the board is $\dfrac{g\sin 15^\circ}{\cos 25^\circ}$, and find the time it takes to slide $2\ \mathrm{m}$. The board is then fixed at 20° to the horizontal and the block, of mass $0.5\ \mathrm{kg}$, is placed on it. Find the friction force on the block, giving a reason. [9 marks]

Answer .....

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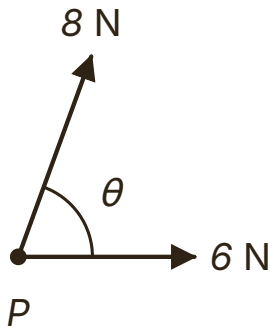
X5 A particle P of mass $2\ \text{kg}$ is at rest on a rough horizontal table. The coefficient of friction between P and the table is 0.5. Two horizontal forces, of magnitudes $6\ \text{N}$ and $8\ \text{N}$, act on P, and the angle between their directions is θ, where $0^\circ \leq \theta \leq 180^\circ$.

(a) Find the set of values of θ for which P stays at rest. [4 marks]



Answer .....

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(b) Given instead that $\theta = 60°$, find the magnitude of the acceleration of P and the angle between its direction and the direction of the $6\ \mathrm{N}$ force. [6 marks]

Answer .....

Total for X5: 10 marks

X6 A car of mass $1200\ \mathrm{kg}$ moves down a straight road inclined at $8°$ to the horizontal. With the engine off and the brakes off, the car moves at a constant speed of $20\ \mathrm{m\ s^{-1}}$. In this situation the car meets a resistance to motion, which is modelled as a constant force. The car is modelled as a particle.

(a) Find the resistance to motion. [2 marks]

Answer .....

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(b) The driver applies the brakes so that the wheels lock. The car skids and comes to rest after $50\ \mathrm{m}$. The resistance to motion is unchanged. Find the coefficient of friction between the tyres and the road. [4 marks]

Answer .....

(c) On a horizontal road, with the same coefficient of friction and the same resistance to motion, the car skids with locked wheels from $20\ \mathrm{m\ s^{-1}}$. Find the distance it travels before it stops. [3 marks]

Answer .....

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(d) In fact the resistance comes mainly from the air, and it decreases as the car slows down. State how this affects your answer to part (c), giving a reason. [2 marks]

Total for X6: 11 marks

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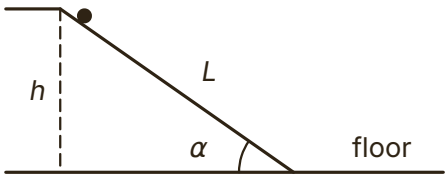
X7 A straight ramp of length L metres is inclined at an angle α to the horizontal, and its foot joins a horizontal floor. A parcel is released from rest at the top of the ramp. The coefficient of friction between the parcel and both the ramp and the floor is μ. The parcel is modelled as a particle, and its speed does not change as it passes from the ramp onto the floor.

(a) Show that the parcel moves down the ramp only if $\tan\alpha > \mu$, and that it then travels a distance $\dfrac{L(\sin\alpha - \mu\cos\alpha)}{\mu}$ along the floor before coming to rest. [5 marks]



Answer .....

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(b) The top of the ramp is h metres above the floor. Show that the parcel comes to rest at a horizontal distance $\dfrac{h}{\mu}$ metres from the point vertically below the top of the ramp. [3 marks]

Answer .....

(c) Two ramps start at the same point, $3\ \text{m}$ above the floor, and go down in the same direction. One is inclined at $30°$ and the other at $50°$, and the coefficient of friction is 0.4 for both. Find the distance each parcel travels along the floor, and show that the two parcels stop at the same point. [3 marks]

Answer .....

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(d) In practice the parcel loses some speed as it moves from the ramp onto the floor. State, with a reason, how this changes where the parcels stop, and which ramp is likely to be affected more. [2 marks]

Total for X7: 13 marks

F How did it go?

Colour one circle on each line.

	Not yet	Nearly	Yes
I can find the time to slide down a smooth or rough wire and the angles for which a bead moves.	○	○	○
I can decide when friction is limiting, including when a force changes with time or acts in two dimensions.	○	○	○
I can find μ from the angle at which a body starts to slip or from a stopping distance with a resistance to motion.	○	○	○
I can prove a general result for a body that slides down a ramp and along a floor.	○	○	○

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Hints

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

X1

Hint 1 Triangle ACB has a right angle at C, so $AC = AB\cos\theta$. On the smooth wire the acceleration along it is $g\cos\theta$.

Hint 2 The wire pushes on the bead at right angles to the wire, so $R = mg\sin\theta$. Friction acts along the wire, up it.

Hint 3 Use $s = \frac{1}{2}at^2$ with $s = 4\cos\theta$, then divide both sides by $\cos\theta$. Twice the time means four times t^2.

X2

Hint 1 Find the acceleration down the chute in terms of α, and the length of the chute from the horizontal distance $6\ \text{m}$.

Hint 2 Use $s = \frac{1}{2}at^2$ to write t^2 as a fraction. The time is least when the denominator $\cos\alpha(\sin\alpha - 0.5\cos\alpha)$ is greatest.

Hint 3 Write the denominator with $\sin 2\alpha$ and $\cos 2\alpha$, then differentiate, or write it in the form $R\sin(2\alpha - \beta)$ plus a constant.

X3

Hint 1 Friction only reaches μR when the crate moves or is about to move. Before that it equals the applied force.

Hint 2 Once the crate moves, write $F = ma$ with $a = \dfrac{dv}{dt}$ and integrate with respect to t. The crate starts from rest at the time you found in part (a).

Hint 3 The distance is the integral of v, but only from the time the crate starts to move.

X4

Hint 1 On the point of slipping at angle λ, the weight component down the board equals μR. This gives $\mu = \tan\lambda$.

Hint 2 Put $\mu = \dfrac{\sin 25^\circ}{\cos 25^\circ}$ into the equation of motion at 40° and write the bracket over the common denominator $\cos 25^\circ$.

Hint 3 At 20° the block is below its slipping angle, so friction is not limiting. It is only as large as it needs to be.

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X5

Hint 1 Friction on a horizontal surface can act in any horizontal direction, and its greatest size is μR. The particle stays at rest if the resultant of the two applied forces is no bigger than this.

Hint 2 The resultant of two forces with an angle θ between them has magnitude X where $X^2 = 6^2 + 8^2 + 2(6)(8)\cos\theta$.

Hint 3 When P moves from rest, it moves along the resultant and friction acts directly against it.

X6

Hint 1 Constant speed means zero resultant: with only the resistance and the weight component along the road, they must balance.

Hint 2 When the brakes lock, friction μR with $R = 1200g\cos 8^\circ$ also acts up the road. The weight component and the resistance still cancel each other.

Hint 3 On the level there is no weight component along the road, so both friction and the resistance slow the car.

X7

Hint 1 On the ramp $R = mg\cos\alpha$. Find the speed at the foot with $v^2 = 2aL$. On the floor the deceleration is μg.

Hint 2 The foot of the ramp is $L\cos\alpha$ horizontally from the point below the top. Add the distance along the floor and use $h = L\sin\alpha$.

Hint 3 For each ramp $L = \dfrac{3}{\sin\alpha}$. By part (b), each parcel stops $\dfrac{3}{0.4}$ m horizontally from the point below the top.

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