A-LEVEL MATHS (EDEXCEL 9MA0) · MECHANICS YEAR 1 · CHAPTER 10: FORCES AND MOTION · A* EXAM PRACTICE

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

101 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 In this question $\mathbf{i}$ and $\mathbf{j}$ are horizontal unit vectors due east and due north. A particle P of mass $0.5\ \text{kg}$ is at rest at the origin O on a smooth horizontal surface. At time $t = 0$ a constant force $(2\mathbf{i} + \mathbf{j})$ N starts to act on P. At $t = 4\ \text{s}$ this force is removed and a different constant force $\mathbf{G}$ N acts on P instead. At $t = 6\ \text{s}$, P is moving parallel to $\mathbf{i}$ with speed $20\ \text{m s}^{-1}$. Find the two possible forces $\mathbf{G}$. For each, find the distance of P from O at $t = 6\ \text{s}$. [10 marks]

Answer $\mathbf{G} = \ldots$ or $\ldots$; distances $\ldots$

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X2 In this question $\mathbf{i}$ and $\mathbf{j}$ are horizontal unit vectors due east and due north. A particle P of mass $4\ \text{kg}$ moves on a smooth horizontal surface under the action of a single constant force $(2\mathbf{i} - 4\mathbf{j})$ N. At time $t = 0$, P is at the point with position vector $(-20\mathbf{i} + 4\mathbf{j})\ \text{m}$ and has velocity $(4\mathbf{i} + 3\mathbf{j})\ \text{m s}^{-1}$.

(a) Find the time at which P is moving parallel to the vector $\mathbf{i} - \mathbf{j}$, and the speed of P at that time. [4 marks]

Answer .....

(b) Show that there is exactly one time $t \geqslant 0$ at which P is due north of O, and find the distance of P from O at that time. [5 marks]

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(c) P has speed $5\ \text{m s}^{-1}$ at $t = 0$. Find the other time at which P has speed $5\ \text{m s}^{-1}$. [3 marks]

Answer .....

(d) Find the bearing of P from O at $t = 10\ \text{s}$. [3 marks]

Answer .....

Total for X2: 15 marks

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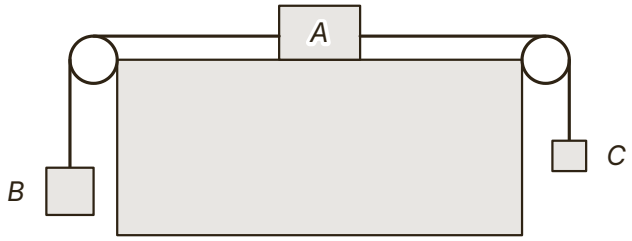
X3 A rough horizontal table has a small smooth pulley fixed at each of two opposite edges. Particle A, of mass $5\ \text{kg}$, lies on the table between the pulleys. Two light inextensible strings are attached to A. One passes over one pulley to particle B, of mass $3\ \text{kg}$. The other passes over the other pulley to particle C, of mass $1\ \text{kg}$. B and C hang freely, and both strings are horizontal on the table and in line with A. When A moves, the resistance to its motion is a constant force of $7\ \text{N}$. The system is released from rest with both strings taut. After $2\ \text{s}$ the string joining A to B breaks. A does not reach either pulley and C does not reach its pulley. Find the total distance that A moves before it first comes to instantaneous rest. [10 marks]



Answer Total distance $= \ldots$

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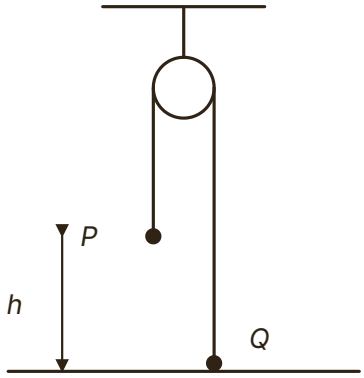
X4 Two particles P and Q, of masses km and m, where $k > 1$, are attached to the ends of a light inextensible string which passes over a small smooth fixed pulley. The particles hang with the string taut, P at a height h above the ground and Q on the ground. The system is released from rest. P does not rebound when it hits the ground, and Q does not reach the pulley.

(a) Show that, while the string is taut, the acceleration of P is $\dfrac{(k-1)g}{k+1}$. [3 marks]



(b) Show that the greatest height of Q above the ground is $\dfrac{2kh}{k+1}$. [4 marks]

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(c) Given that the greatest height of Q above the ground is $1.6h$, find the value of k, and find, in terms of m and g, the magnitude of the force exerted on the pulley by the string while P is falling. [4 marks]

Answer .....

(d) Find, in terms of h and g, the time for which the string is slack. [2 marks]

Answer .....

Total for X4: 13 marks

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X5 In this question $\mathbf{i}$ and $\mathbf{j}$ are horizontal unit vectors due east and due north. A particle P of mass $0.5\ \text{kg}$ is at rest on a smooth horizontal surface. At $t = 0$ two horizontal forces start to act on P: $\mathbf{F}_1$, of magnitude $8\ \text{N}$, acting due north, and $\mathbf{F}_2$, of magnitude $5\ \text{N}$, acting on a bearing between $000°$ and $180°$. The resultant of $\mathbf{F}_1$ and $\mathbf{F}_2$ has magnitude $7\ \text{N}$.

(a) Show that the angle between the directions of $\mathbf{F}_1$ and $\mathbf{F}_2$ is $120°$. [3 marks]

(b) Write $\mathbf{F}_2$ in the form $(p\mathbf{i} + q\mathbf{j})$ N, and find the bearing on which P moves. [4 marks]

Answer .....

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(c) Find the distance P moves in the first $2\ \text{s}$. [2 marks]

Answer .....

(d) At $t = 2\ \text{s}$, $\mathbf{F}_2$ is removed and a force $\mathbf{G}$, acting due west, is applied instead. $\mathbf{F}_1$ still acts. At $t = 4\ \text{s}$, P is moving due north. Find the magnitude of $\mathbf{G}$ and the speed of P at $t = 4\ \text{s}$. [6 marks]

Total for X5: 15 marks

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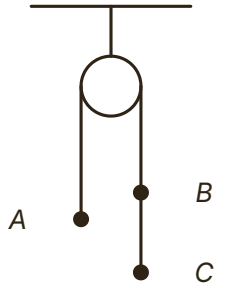
X6 Particle A, of mass $3\ \text{kg}$, and particle B, of mass $2\ \text{kg}$, are attached to the ends of a light inextensible string that passes over a small smooth fixed pulley. A second light inextensible string joins B to particle C, of mass $2\ \text{kg}$, which hangs directly below B. The system is released from rest with both strings taut and the hanging parts of the strings vertical. A does not reach the pulley and B does not reach the ground.

(a) Find the acceleration of the system and the tension in each string. [6 marks]



(b) Find the magnitude of the force exerted on the pulley by the string. [2 marks]

Answer .....

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(c) After 1.5 s the string joining B and C is cut. Find the total distance that B moves downwards. [5 marks]

(d) Find the time from release until B is first back at its starting level. [3 marks]

Total for X6: 16 marks

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X7 In this question $\mathbf{i}$ and $\mathbf{j}$ are horizontal unit vectors due east and due north. A boat of mass $300\ \text{kg}$ is modelled as a particle. It starts from rest at a fixed point O. The engine gives a constant force $(p\mathbf{i} + q\mathbf{j})$ N and the water gives a resistance of constant magnitude $50\sqrt{5}$ N, acting in the direction opposite to the motion of the boat. The boat moves in a straight line and reaches the point with position vector $(50\mathbf{i} + 25\mathbf{j})$ m after 10 s. Find the values of p and q, and the bearing on which the boat moves. [9 marks]

Answer $p = \ldots$, $q = \ldots$, bearing $\ldots$

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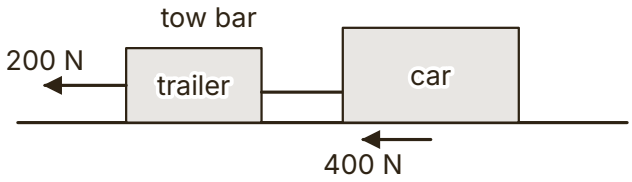
X8 A car of mass $1200\ \text{kg}$ tows a trailer of mass $800\ \text{kg}$ along a straight horizontal road using a light rigid tow bar. The resistances to motion are modelled as constant forces of magnitude $400\ \text{N}$ on the car and $200\ \text{N}$ on the trailer. The tow bar breaks if the force in it, whether a tension or a thrust, is more than $1000\ \text{N}$.

(a) Find the greatest possible driving force of the engine. [4 marks]



Answer .....

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(b) The engine is switched off and a braking force of B N acts on the car only. Show that the force in the tow bar is a thrust of magnitude $(0.4B + 40)$ N, and hence find the greatest possible value of B. [5 marks]

(c) Find the shortest distance in which the car and trailer can stop, with the engine off, from a speed of $20\ \mathrm{m\ s^{-1}}$. [2 marks]

Answer .....

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(d) Explain why, with the engine off and no braking force, the force in the tow bar is still a thrust. [2 marks]

Total for X8: 13 marks

F How did it go?

Colour one circle on each line.

	Not yet	Nearly	Yes
I can use F = ma with vectors when the force changes, and use conditions on the velocity or position to find unknowns.	○	○	○
I can use a triangle of forces and bearings to write forces in i, j form.	○	○	○
I can solve problems with three connected particles, including a string that breaks or is cut.	○	○	○
I can use a limit on the force in a tow bar to find the greatest driving or braking force.	○	○	○

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Hints

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

X1

Hint 1 Find the velocity and the position at $t = 4$ from the first force.

Hint 2 After $t = 4$ the acceleration is $2\mathbf{G}$. Write the velocity at $t = 6$ in terms of the components of $\mathbf{G}$. Parallel to $\mathbf{i}$ means the $\mathbf{j}$ component is zero.

Hint 3 Moving parallel to $\mathbf{i}$ with speed 20: the $\mathbf{i}$ component could be 20 or -20. That gives two answers.

X2

Hint 1 Write $\mathbf{v}$ and $\mathbf{r}$ in terms of t, using $\mathbf{v} = \mathbf{u} + \mathbf{a}t$ and $\mathbf{r} = \mathbf{r}_0 + \mathbf{u}t + \frac{1}{2}\mathbf{a}t^2$.

Hint 2 Parallel to $\mathbf{i} - \mathbf{j}$: the two components are equal in size and opposite in sign. Due north of O: the $\mathbf{i}$ component of $\mathbf{r}$ is zero and the $\mathbf{j}$ component is positive.

Hint 3 The speed squared is a quadratic in t, and $t = 0$ is one root.

X3

Hint 1 While both strings are taut, write one equation for each of A, B and C. A moves towards B's pulley.

Hint 2 After the break, only C's string and the resistance act along A's line of motion, and both act against the motion. A and C move together while that string is taut.

Hint 3 Find the deceleration, then the extra distance from $v^2 = u^2 + 2as$. Add it to the distance moved in the first 2 s.

X4

Hint 1 Write an equation of motion for each particle and add them to remove T.

Hint 2 When P lands, Q is at height h moving upwards at speed v. After that only gravity acts on Q.

Hint 3 The string is taut again when Q comes back down to height h. Use $0 = vt - \frac{1}{2}gt^2$.

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X5

Hint 1 Draw the triangle of forces. The angle opposite the $7\ \mathrm{N}$ side is 180° minus the angle between the forces.

Hint 2 A force of magnitude F on a bearing β is $F(\sin\beta\,\mathbf{i} + \cos\beta\,\mathbf{j})$ when $\mathbf{j}$ is north.

Hint 3 At $t = 2$, P already has a velocity with an east component. After the change, set the east component of the velocity at $t = 4$ equal to zero.

X6

Hint 1 Take the particles one at a time. B has its weight, the tension above it and the tension below it.

Hint 2 After the cut, A ($3\ \mathrm{kg}$) is heavier than B ($2\ \mathrm{kg}$), so B slows down, stops and then moves back up.

Hint 3 There are three stages: the first $1.5\ \mathrm{s}$; slowing to rest; speeding up from rest through the $2.7\ \mathrm{m}$.

X7

Hint 1 It starts from rest and moves in a straight line to $(50\mathbf{i} + 25\mathbf{j})$. In which direction does it move?

Hint 2 Use $\mathbf{r} = \mathbf{u}t + \frac{1}{2}\mathbf{a}t^2$ to find $\mathbf{a}$, then the resultant force $m\mathbf{a}$.

Hint 3 Write the resistance as a vector: $50\sqrt{5}$ times a unit vector opposite to $2\mathbf{i} + \mathbf{j}$. The engine force is the resultant minus the resistance.

X8

Hint 1 The tow bar limits the force on the trailer, so start with the trailer's equation when the tension is $1000\ \mathrm{N}$.

Hint 2 When braking, find the deceleration from the whole system first, then use the trailer's equation to find the force in the tow bar.

Hint 3 Compare the resistance per kilogram on the car and on the trailer. Which would slow down faster on its own?

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