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

Hints online, answers free with an account:
mathswariz.uk/worksheets/a-level-mechanics-a-star-revision-6/

# A-Level Mechanics A* revision 6

92 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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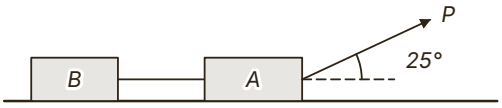
**X1** A child pulls two sledges across horizontal snow. The front sledge $A$ has mass $12$ kg and the rear sledge $B$ has mass $8$ kg. The sledges are joined by a light inextensible rope, which is horizontal. The child pulls $A$ with a light rope inclined at $25^\circ$ above the horizontal, as shown. The coefficient of friction between each sledge and the snow is $0.15$. The sledges are modelled as particles, and they move in a straight line with an acceleration of $0.4\ \mathrm{m\ s^{-2}}$.
Find the tension in the rope joining the sledges, and the tension in the child's rope. Give your answers to 3 significant figures. [9 marks]




Answer .....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**X2** A small block is projected up a line of greatest slope of a rough plane inclined at $30^\circ$ to the horizontal. It comes to instantaneous rest $1.2$ s after it is projected, and then slides back down the plane. It returns to its point of projection $2.4$ s after it came to rest. The block is modelled as a particle. [10 marks]

Find the exact value of the coefficient of friction between the block and the plane, and find the speed with which the block was projected, giving this to 3 significant figures.

Answer .....


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**X3** A car is travelling along a straight horizontal road at $20\ \text{m s}^{-1}$ when the driver starts to brake. At time $t$ seconds after braking starts, the deceleration of the car is modelled as $(2 + 1.5t)\ \text{m s}^{-2}$, until the car stops.

**(a)** Show that the car stops when $t = 4$. [4 marks]

Answer .....

**(b)** Find the distance the car travels from the moment braking starts until it stops. [3 marks]

Answer .....


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**(c)** The driver sees a hazard $60$ m ahead, and starts braking after a reaction time of $0.5$ s, during which the car moves at $20\ \text{m s}^{-1}$. Determine whether the car stops before it reaches the hazard. [2 marks]

Answer .....

**(d)** Explain why the model must not be used for $t > 4$. [2 marks]

Answer .....

**Total for X3: 11 marks**


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**X4** In this question $\mathbf{i}$ and $\mathbf{j}$ are horizontal unit vectors due east and due north. A remote-controlled boat of mass $4$ kg moves on a lake and is modelled as a particle. At time $t = 0$ it passes a fixed point $O$ with velocity $(10\mathbf{i} - 4\mathbf{j})\ \mathrm{m\ s^{-1}}$. For $t \geqslant 0$ a constant resultant force $\mathbf{F}$ N acts on the boat. Later, the boat passes through a buoy at the point $B$ with position vector $(20\mathbf{i} + 32\mathbf{j})$ m relative to $O$, and as it passes $B$ it is moving due north.
Find $\mathbf{F}$, the magnitude of $\mathbf{F}$, and the speed of the boat as it passes $B$. [11 marks]

Answer .....


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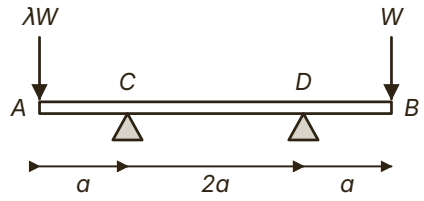
**X5** A uniform plank $AB$ has length $4a$ and weight $W$. It rests horizontally on two supports, at $C$ and at $D$, where $AC = a$ and $AD = 3a$. A load of weight $\lambda W$ is placed at $A$ and a load of weight $W$ is placed at $B$, where $\lambda > 0$, as shown in the figure. The loads are modelled as particles, and the plank stays horizontal and in equilibrium.




**(a)** Show that the reaction at $D$ has magnitude $\frac{1}{2}(4 - \lambda)W$. [4 marks]

Answer .....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**(b)** Find, in terms of $\lambda$ and $W$, the reaction at $C$. Hence find the value of $\lambda$ for which the reaction at $D$ is twice the reaction at $C$. [4 marks]

Answer .....

**(c)** Explain why the model is valid only for $\lambda \leq 4$, and state what would happen to the plank if $\lambda > 4$. [2 marks]

Answer .....

**(d)** State how you have used the modelling assumption that the plank is uniform. [1 mark]

Answer .....

**Total for X5: 11 marks**


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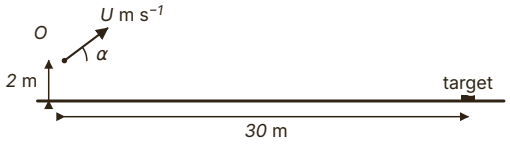
**X6** A ball is thrown from a point $O$, $2\ \text{m}$ above horizontal ground, with speed $U\ \text{m s}^{-1}$ at an angle $\alpha$ above the horizontal, where $\tan\alpha = \frac{3}{4}$. It lands on a small target on the ground, $30\ \text{m}$ horizontally from $O$. The ball is modelled as a particle moving freely under gravity.




**(a)** Show that $U = \dfrac{15\sqrt{5}}{2}$. [5 marks]

Answer .....

**(b)** Find the exact time taken for the ball to reach the target. [2 marks]

Answer .....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**(c)** Find the greatest height of the ball above the ground. [3 marks]

Answer .....

**(d)** In a refined model, air resistance is included. State, with a reason, whether the speed of projection needed to land on the target would be greater than or less than $U$. [2 marks]

Answer .....

**(e)** State one other way in which the model could be refined. [1 mark]

Answer .....

**Total for X6: 13 marks**


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**X7** A model for the stopping distance of a car on a straight horizontal road assumes that, after the driver sees a hazard, the car travels at constant speed for a reaction time of $r$ seconds. The car then decelerates uniformly at $a\ \mathrm{m\ s^{-2}}$ until it stops.
In a test, a car travelling at $15\ \mathrm{m\ s^{-1}}$ stops in a distance of $34.5$ m, and a car travelling at $30\ \mathrm{m\ s^{-1}}$ stops in a distance of $114$ m.

**(a)** Show that $r = 0.8$ and $a = 5$. [5 marks]

Answer .....


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**(b)** Using the model, find the greatest speed at which the car can be travelling if it is to stop within $50$ m of the point where the driver sees a hazard. Give your answer to 3 significant figures. [4 marks]

Answer .....

**(c)** A car is travelling at $30\ \text{m}\ \text{s}^{-1}$ when the driver sees a fallen tree $90$ m ahead. Using the model, find the speed of the car when it reaches the tree. Give your answer to 3 significant figures. [3 marks]

Answer .....


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

Answer .....

**Total for X7: 13 marks**

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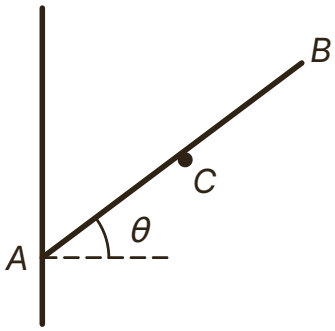
**X8** A non-uniform rod $AB$, of length $3\ \text{m}$ and mass $8\ \text{kg}$, has its centre of mass at $G$. The end $A$ is freely hinged to a fixed vertical wall. The rod rests in equilibrium on a small smooth peg at $C$, where $AC = 1.6\ \text{m}$. The rod is in a vertical plane perpendicular to the wall and makes an angle $\theta$ above the horizontal, where $\tan\theta = \frac{3}{4}$.




**(a)** Explain why the force exerted by the peg on the rod is perpendicular to the rod. [1 mark]

Answer .....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**(b)** Given that the force exerted on the rod by the hinge is horizontal, show that $AG = 2.5\ \text{m}$. [5 marks]

Answer .....

**(c)** Find, in terms of $g$, the magnitude of the force exerted on the rod by the hinge, and state its direction. [3 marks]

Answer .....


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**(d)** A bird of mass $0.5\ \text{kg}$ lands on the rod at $B$ and the rod stays in equilibrium. By taking moments about $A$, explain why the force exerted by the hinge now has a vertical component. Find this vertical component and state its direction. [5 marks]

Answer .....

**Total for X8: 14 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** Take sledge $B$ on its own: only the rope joining the sledges and the friction act on it horizontally. That gives the first tension.

**Hint 2** For sledge $A$ the child's rope pulls partly upwards, so resolve vertically: $R_A = 12g - P\sin 25°$, not $12g$.

**Hint 3** Write the horizontal equation of motion for $A$: $P\cos 25°$ forwards, and the joining rope and the friction $0.15R_A$ backwards. Collect the terms in $P$.

**X2**

**Hint 1** Find the acceleration on the way up and on the way down separately. Friction changes direction when the block turns round.

**Hint 2** The block travels the same distance up as down. On the way down it starts from rest. On the way up it ends at rest, so you can use $s = \frac{1}{2}at^2$ there as well.

**Hint 3** Equating the distances gives $1.44a_1 = 5.76a_2$, so $a_1 = 4a_2$. Write both in terms of $\mu$ and solve. Then $u = a_1 \times 1.2$.

**X3**

**Hint 1** The deceleration changes with time, so suvat cannot be used. Integrate, using the speed when braking starts.

**Hint 2** Setting $v = 0$ gives a quadratic in $t$. Keep the root that makes sense for a time after braking starts.

**Hint 3** For (c), the car travels at constant speed for $0.5$ s before the braking distance from (b) begins.


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**X4**

**Hint 1** Call the acceleration $p\mathbf{i} + q\mathbf{j}$ and the time at $B$ $T$. Write the velocity and the position at time $t$ in terms of $p$ and $q$.

**Hint 2** Moving due north at $B$ means the $\mathbf{i}$ component of the velocity is zero there. That gives $pT$. Put it into the $\mathbf{i}$ component of the position at $B$.

**Hint 3** The $\mathbf{i}$ components give $T$ and $p$; the $\mathbf{j}$ component of the position gives $q$. Then $\mathbf{F} = m\mathbf{a}$, and check the boat really is moving north at $B$.

**X5**

**Hint 1** Take moments about $C$: the load at $A$ and the reaction at $D$ turn the plank one way; the plank's weight and the load at $B$ turn it the other way.

**Hint 2** For (b), resolve vertically for $R_C$, then set $R_D = 2R_C$ and solve for $\lambda$.

**Hint 3** For (c), ask what sign $R_D$ must have. A support can push the plank up but it cannot hold it down.

**X6**

**Hint 1** Resolve $U$. Use the horizontal motion to write the time to reach the target in terms of $U$.

**Hint 2** The target is $2\ \mathrm{m}$ below $O$, so the vertical displacement is $-2$. Substitute your time and solve for $U^2$ exactly, keeping fractions or decimals exact.

**Hint 3** For the greatest height use $v^2 = u^2 - 2gs$ vertically with $v = 0$, then add the height of $O$ above the ground.

**X7**

**Hint 1** During the reaction time the car moves at constant speed. While braking, $v^2 = u^2 + 2as$ gives the braking distance.

**Hint 2** Write the stopping distance for each test. You get two equations in $r$ and $\dfrac{1}{a}$; eliminate one of them.

**Hint 3** For (c), the car brakes over only $90 - 24$ metres. Use $v^2 = u^2 - 2as$ over that distance.


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**X8**

**Hint 1** A smooth contact can only push along the normal to the surface it touches.

**Hint 2** If the hinge force is horizontal, resolving vertically gives the reaction at $C$ at once. Then take moments about $A$ with the perpendicular distance $AG\cos\theta$.

**Hint 3** For (d), the bird's weight acts at $3\cos\theta$ from $A$ horizontally. Find the new reaction at $C$ by moments, then resolve vertically to see what the hinge must supply.


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