A-LEVEL FURTHER MATHS (OCR A) · FURTHER MECHANICS · CHAPTER 2: WORK, ENERGY AND POWER · A* EXAM PRACTICE

Hints online, answers free with an account:
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Work, energy and power: A* questions

78 marks

Date

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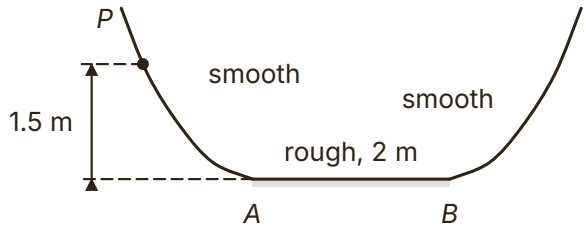
X A* exam questions

A to A*

Extended OCR-style questions. Show every step. The hints are at the end of the sheet. Use one at a time.

X1 A smooth curved track lies in a vertical plane. Its lowest part is a straight horizontal section AB of length $2\ \text{m}$, which is rough. A particle P of mass $0.6\ \text{kg}$ is released from rest on the curved part on the side of A, at a height of $1.5\ \text{m}$ above AB. The curved parts of the track are smooth. When P is on AB it is acted on by a constant frictional force of $1.05\ \text{N}$. P moves to and fro and comes to rest on AB. Find the total distance that P travels on AB, and find how far from A it comes to rest. [8 marks]



Answer distance $= \ldots\ \text{m}$; it stops $\ldots\ \text{m}$ from A

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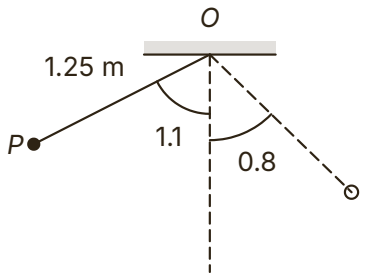
X2 A particle P of mass $0.4\ \mathrm{kg}$ is attached to one end of a light inextensible string of length $1.25\ \mathrm{m}$. The other end is attached to a fixed point O. P is held with the string taut at an angle of 1.1 radians to the downward vertical, and is released from rest. As P moves, a resistance of constant magnitude $R\ \mathrm{N}$ acts on it, opposite to its direction of motion. P first comes to instantaneous rest with the string at an angle of 0.8 radians to the downward vertical, on the other side of the vertical through O. Use an energy method to find R, and find the speed of P as it passes through the lowest point of its path. [8 marks]



Answer $R = \ldots$, speed $= \ldots\ \mathrm{m\,s^{-1}}$

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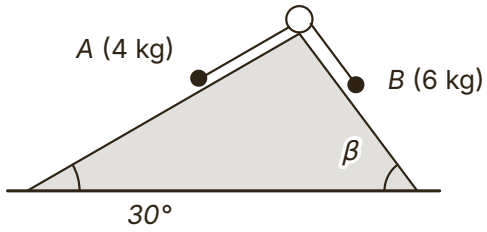
X3 A fixed wedge has two rough faces. One face is inclined at 30° to the horizontal and the other at β to the horizontal, where $\sin\beta = \frac{4}{5}$. A small smooth pulley is fixed at the top of the wedge. Particles A and B, of masses $4\ \text{kg}$ and $6\ \text{kg}$, are joined by a light inextensible string that passes over the pulley. A lies on the 30° face and B lies on the other face, each on a line of greatest slope, with the string taut. The system is released from rest and B moves down its face. While they move, a constant frictional force of $5\ \text{N}$ acts on A and a constant frictional force of $8\ \text{N}$ acts on B.

(a) Use an energy method to find the speed of the particles when each has moved $1.5\ \text{m}$. [5 marks]



Answer ... m s^{-1}

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(b) At this instant the string breaks. A continues to move up its face. Use an energy method to find how much further A moves up the face before it comes to rest. [3 marks]

Answer ... m

(c) A then slides back down the face. Find the speed of A as it passes the point from which it was released. [3 marks]

Answer ... $\mathrm{m\,s^{-1}}$

Total for X3: 11 marks

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X4 A heavy chest of mass $30\ \mathrm{kg}$ moves along a rough horizontal floor. A woman pushes the chest with a force of $150\ \mathrm{N}$ acting at 20° below the horizontal, in the direction of motion. The resistance to the motion of the chest is modelled as a constant force of $120\ \mathrm{N}$. At time $t = 0$ the chest is moving at $1\ \mathrm{m\,s^{-1}}$.

(a) Find the work done by the pushing force in the first $5\ \mathrm{s}$. [4 marks]

Answer ... J

(b) Find the average power of the pushing force over the first $5\ \mathrm{s}$, and its power at the instant $t = 5$. [3 marks]

Answer average $=$ ... W , at $t = 5$: ... W

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(c) At $t = 5$ the woman stops pushing. The resistance is still modelled as $120\ \text{N}$. Use an energy method to find how much further the chest moves. [2 marks]

Answer ... m

(d) The resistance is mostly friction between the chest and the floor. Explain whether your answer to part (c) is likely to be too large or too small. [2 marks]

Total for X4: 11 marks

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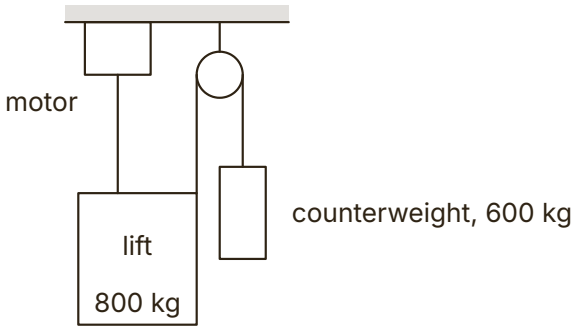
X5 A lift of mass $800\ \mathrm{kg}$ is joined to a counterweight of mass $600\ \mathrm{kg}$ by a cable that passes over a smooth fixed pulley at the top of the lift shaft. A motor at the top of the shaft pulls the lift upwards with a second cable. As the lift rises, the counterweight moves down. A resistance of $300\ \mathrm{N}$ acts on the lift. Ignore any resistance on the counterweight. Both cables are light and inextensible.

(a) The lift rises at a constant speed of $2\ \mathrm{m\,s^{-1}}$. Find the power of the motor. [3 marks]



Answer ... W

(b) On another trip the lift starts from rest and accelerates uniformly, reaching $2\ \mathrm{m\,s^{-1}}$ after rising $4\ \mathrm{m}$. Use an energy method to find the work done by the motor during this stage. [4 marks]

Answer ... J

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(c) Find the greatest power of the motor during this stage. Show that the average power of the motor during this stage is half of this greatest power. [3 marks]

(d) At the instant the lift reaches $2\ \mathrm{m\,s^{-1}}$ it stops accelerating and moves at a constant speed. Explain why the power of the motor falls at this instant, although the speed does not change. [2 marks]

Total for X5: 12 marks

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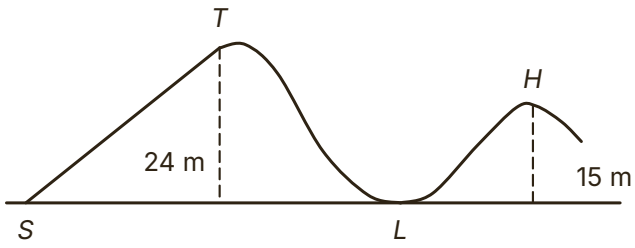
X6 A roller-coaster car and its riders have a total mass of $500\ \mathrm{kg}$. A chain pulls the car from ground level at S up a straight track of length $48\ \mathrm{m}$ to the top T, which is $24\ \mathrm{m}$ above the ground. The car then runs freely along the track. From T the track goes down to the lowest point L, at ground level, and then up to the top H of a second hill, $15\ \mathrm{m}$ above the ground. The length of track from T to L is $70\ \mathrm{m}$ and from L to H is $40\ \mathrm{m}$. A resistance of $150\ \mathrm{N}$ acts on the car along the track throughout. Model the car as a particle. The figure is not to scale.

(a) The chain pulls the car from S to T at a constant speed of $1.5\ \mathrm{m\,s^{-1}}$, parallel to the track. Find the power used to pull the car. [3 marks]



Answer ... W

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(b) The car leaves T with speed $1.5\ \mathrm{m\,s^{-1}}$. Find the speed of the car at L. [4 marks]

Answer ... $\mathrm{m\,s^{-1}}$

(c) Find the speed of the car at H. [3 marks]

Answer ... $\mathrm{m\,s^{-1}}$

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(d) A designer claims that the car would still reach H if the resistance on the track from T to H were three times as large. The car still leaves T with speed $1.5\ \mathrm{m\,s^{-1}}$. Determine whether the claim is correct. [3 marks]

Total for X6: 13 marks

X7 A car of mass $1200\ \mathrm{kg}$ has a maximum power of $36\ \mathrm{kW}$. The resistance to its motion is modelled as $(a + bv)\ \mathrm{N}$, where $v\ \mathrm{m\,s^{-1}}$ is its speed and a and b are constants. With the engine working at its maximum power, the greatest speed of the car on a horizontal road is $40\ \mathrm{m\,s^{-1}}$, and its greatest speed up a straight road inclined at α to the horizontal, where $\sin\alpha = \frac{1}{24}$, is $30\ \mathrm{m\,s^{-1}}$.

(a) Find the values of a and b. [5 marks]

Answer $a = \ldots$, $b = \ldots$

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(b) Find the acceleration of the car on the horizontal road at an instant when its speed is $20\ \mathrm{m\,s^{-1}}$ and the engine is working at its maximum power. [3 marks]

Answer ... $\mathrm{m\,s^{-2}}$

(c) The car goes down the same hill with the engine working at $20\ \mathrm{kW}$. Find its greatest speed. You must explain why you reject one solution of your equation. [4 marks]

Answer ... $\mathrm{m\,s^{-1}}$

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(d) The model is used to predict the greatest speed of the car when it freewheels down the hill with the engine switched off. When this is tested, the car's greatest speed is $25\ \mathrm{m\,s^{-1}}$. Comment on the model in the light of this result. [3 marks]

Total for X7: 15 marks

F How did it go?

Colour one circle on each line.

	Not yet	Nearly	Yes
I can write one energy equation for a whole motion, with every KE, PE and work term, including resistance along a curved path.	○	○	○
I can use the work-energy principle for connected particles and for a body whose resistance changes direction.	○	○	○
I can tell average power from instantaneous power and use P = Fv with the right force, on a level road or a slope.	○	○	○
I can find the constants in a resistance model, reject an impossible root with a reason and judge a model against data.	○	○	○

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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 curved parts are smooth, so energy is lost only while P is on AB.
	Hint 2	Write one energy equation from the moment of release to the moment P stops. The work done against friction is the force multiplied by the total distance moved on AB.
	Hint 3	Divide the total distance by 2. Count the complete crossings and note which end P is at after them.
X2	**Hint 1**	Draw the two positions of the string. Find the height of P above the lowest point in each position.
	Hint 2	The resistance acts along the path, which is an arc of a circle. The distance moved along an arc is $r\theta$, with θ in radians.
	Hint 3	From release to the first stop, P starts and ends at rest. The PE lost equals the work done against the resistance over the whole arc.
X3	**Hint 1**	Draw the wedge. Both particles move the same distance along their faces, but they change height by different amounts.
	Hint 2	The height change is the distance along the face multiplied by the sine of the angle of the face. Friction does work equal to force times distance along the face.
	Hint 3	After the string breaks, treat A on its own. Friction always opposes the direction A is moving in, so it acts down the face on the way up and up the face on the way down.
X4	**Hint 1**	Only the horizontal component of the push does work, because the chest moves horizontally.
	Hint 2	The chest is speeding up, so you cannot find the distance from the speed alone. Find the acceleration, then use suvat with the initial speed of $1\ \mathrm{m\,s^{-1}}$.
	Hint 3	Average power is total work divided by time. Power at an instant is force times speed at that instant. For part (d), think about how hard the chest is pressed against the floor.

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X5

Hint 1 At constant speed every body is in equilibrium. Start with the counterweight to find the tension in its cable.

Hint 2 In the energy method, count the KE of both moving bodies. One body rises and one falls, so take the difference of the two PE changes.

Hint 3 The motor's force is constant while the acceleration is constant. Power is force times speed, and the speed rises steadily from 0 to $2\ \mathrm{m\,s^{-1}}$.

X6

Hint 1 On the lift hill the car moves at constant speed, so the pulling force balances the resistance and the component of the weight along the track.

Hint 2 The car is already moving at T, so include its kinetic energy there. The resistance does work along the whole length of track, not along the height.

Hint 3 For part (d), compare the energy the car has at T, measured from the level of H, with the work the larger resistance would take from T to H.

X7

Hint 1 At the greatest speed the acceleration is zero. The driving force is the power divided by the speed, with the power in watts.

Hint 2 Write one equation for the horizontal road and one for the hill, then solve them together. Going down the hill, the weight component acts with the driving force.

Hint 3 Multiply every term of the downhill equation by v, including the constant terms. For part (d), find the model's freewheeling speed and compare it with the measured one.

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