A-LEVEL FURTHER MATHS (OCR A) · FURTHER MECHANICS · CHAPTER 3: IMPULSE AND MOMENTUM · A* EXAM PRACTICE

Hints online, answers free with an account:
mathswariz.uk/worksheets/ocr-further-maths-mechanics-chapter-3-a-star/

Impulse and momentum: A* questions

76 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 ball of mass $0.2\ \mathrm{kg}$ is released from rest at a height of $2.5\ \mathrm{m}$ above a horizontal floor. It bounces and rises to a greatest height of $1.6\ \mathrm{m}$. The ball is in contact with the floor for $0.04\ \mathrm{s}$. Model the ball as a particle and ignore air resistance. Take $g = 9.8\ \mathrm{m\,s^{-2}}$. Find the coefficient of restitution between the ball and the floor, the magnitude and direction of the change in momentum of the ball, and the magnitude of the average force that the floor exerts on the ball during the contact. [8 marks]

Answer $e = \ldots$, change $= \ldots\ \mathrm{N\,s}$, force $= \ldots\ \mathrm{N}$

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X2 Three smooth spheres A, B and C, of equal radius, have masses m, km and k^2m, where k is a positive constant. They lie at rest in a straight line on a smooth horizontal surface, with B between A and C. A is projected towards B with speed u. The coefficient of restitution between A and B, and between B and C, is e. After A collides with B, A is at rest. Find e in terms of k, and state the set of possible values of k. Show that B is at rest after it collides with C, and determine whether there are any further collisions. Find, in terms of k, the fraction of the original kinetic energy of A that is lost in the collisions. [9 marks]

Answer $e = \ldots$, $k \ldots$, fraction lost $= \ldots$

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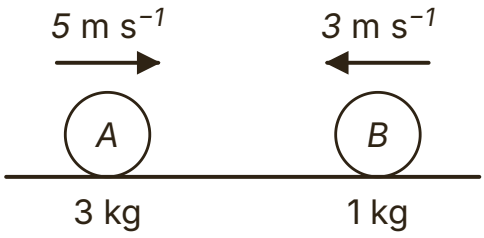
X3 Smooth spheres A and B, of equal radius, have masses $3\ \text{kg}$ and $1\ \text{kg}$. They move towards each other along a straight line on a smooth horizontal surface, A at $5\ \text{m s}^{-1}$ and B at $3\ \text{m s}^{-1}$. After they collide, B has speed $6\ \text{m s}^{-1}$.

(a) Find the coefficient of restitution between A and B. You must consider both possible directions of motion of B after the collision, and explain why one of them is impossible. [6 marks]



Answer $e = \ldots$

(b) Find the kinetic energy lost in the collision, as a percentage of the total kinetic energy before the collision. [2 marks]

Answer $\ldots\%$

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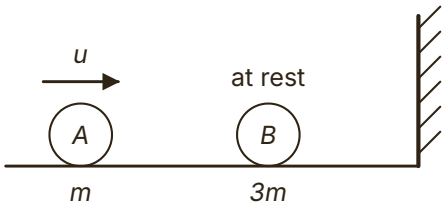
(c) Find the magnitude and direction of the impulse on A in the collision. Hence write down the impulse on B. [2 marks]

Answer ... $\mathrm{N\,s}$

Total for X3: 10 marks

X4 A smooth sphere A, of mass m, moves with speed u on a smooth horizontal surface towards a smooth sphere B, of equal radius and mass $3m$, which is at rest. B is between A and a smooth vertical wall that is perpendicular to the line of centres. The coefficient of restitution between A and B is e, and between B and the wall is also e, where $0 < e \leqslant 1$.

(a) Show that, after A and B collide, B moves towards the wall with speed $\frac{1}{4}u(1+e)$, and that the velocity of A is $\frac{1}{4}u(1-3e)$ towards the wall. [3 marks]



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(b) Show that A and B collide again if $0 < e < 1$, and that they do not collide again if $e = 1$. [5 marks]

(c) Given that $e = \frac{1}{2}$, find, in terms of m and u, the total kinetic energy lost before A and B collide for the second time. [3 marks]

Answer ...

Total for X4: 11 marks

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X5 Particles P and Q, of masses $2\ \text{kg}$ and $3\ \text{kg}$, lie on a rough horizontal floor. Q is at rest. P is projected directly towards Q with speed $7\ \text{m s}^{-1}$ from a point $4\ \text{m}$ from Q. While P moves, the floor exerts a constant resistance of $6\ \text{N}$ on it. While Q moves, the floor exerts a constant resistance of $9\ \text{N}$ on it. The particles collide, and after the collision Q moves $1.5\ \text{m}$ before it comes to rest. The resistances have no impulse during the collision.

(a) Use an energy method to show that the speed of P just before the collision is $5\ \text{m s}^{-1}$. [2 marks]

(b) Find the speed of Q just after the collision. [2 marks]

Answer ... m s^{-1}

(c) Find the coefficient of restitution between P and Q. [3 marks]

Answer $e = \ldots$

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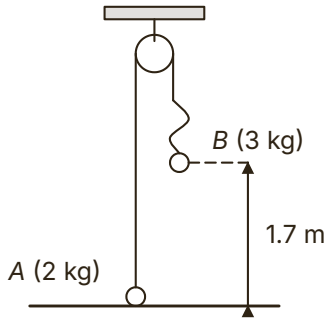
(d) Show that P and Q do not collide again, and find the distance between them when they are both at rest. [4 marks]

Answer ... m

Total for X5: 11 marks

X6 Particles A and B, of masses $2\ \mathrm{kg}$ and $3\ \mathrm{kg}$, are attached to the ends of a light inextensible string which passes over a small smooth fixed pulley. A rests on a horizontal floor directly below the pulley. B is held at rest $1.7\ \mathrm{m}$ above the floor, and the string is slack. B is released and falls vertically. The string becomes taut when B has fallen $0.9\ \mathrm{m}$, and A is jerked off the floor. The parts of the string that are not in contact with the pulley are vertical, and A does not reach the pulley. When B reaches the floor it does not rebound. Take $g = 9.8\ \mathrm{m\,s^{-2}}$.

(a) Find the speed of the particles just after the string becomes taut. [4 marks]



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

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(b) Find the kinetic energy lost when the string becomes taut. [2 marks]

Answer ... J

(c) Find the greatest height of A above the floor in the motion that follows. [5 marks]

Answer ... m

(d) Explain why the string is slack while A rises after B has reached the floor. [2 marks]

Total for X6: 13 marks

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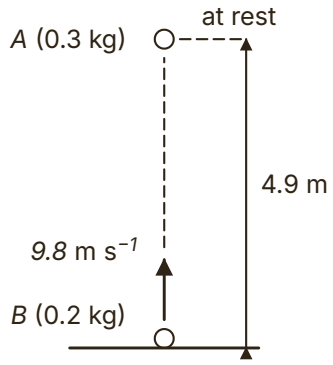
X7 A ball A, of mass $0.3\ \text{kg}$, is released from rest at a point $4.9\ \text{m}$ above horizontal ground. At the same instant, a ball B, of mass $0.2\ \text{kg}$, is projected vertically upwards with speed $9.8\ \text{m s}^{-1}$ from the point on the ground directly below A. The balls move in the same vertical line and collide. The coefficient of restitution between them is e. Model the balls as particles, ignore air resistance, and take $g = 9.8\ \text{m s}^{-2}$.

(a) Show that the balls collide $0.5\ \text{s}$ after they start to move, at a height of $3.675\ \text{m}$ above the ground. Find the velocity of each ball just before the collision. [3 marks]



Answer A : ... , B : ...

(b) Taking upwards as positive, find, in terms of e, the velocity of each ball just after the collision. [4 marks]

Answer $v_A = \ldots$, $v_B = \ldots$

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(c) Show that B moves downwards just after the collision for every possible value of e. Find the set of values of e for which A moves upwards just after the collision. [2 marks]

Answer ...

(d) Given that $e = \frac{1}{2}$, find the greatest height above the ground that A reaches after the collision. [3 marks]

Answer ... m

(e) In part (b) the total momentum of the balls was taken as unchanged in the collision, although both balls have weight. Explain why this is a reasonable model. [2 marks]

Total for X7: 14 marks

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F How did it go?

Colour one circle on each line.

	Not yet	Nearly	Yes
I can use the impulse-momentum principle with signs, including a force that acts for a short time with the weight.	○	○	○
I can combine momentum and restitution with algebra, reject impossible cases and find ranges of e or of a mass ratio.	○	○	○
I can decide whether two spheres collide again by comparing velocities, and write a conclusion.	○	○	○
I can link collisions and jerked strings with work-energy, suvat and connected particles.	○	○	○

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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 speed just before the ball hits the floor and the speed just after it leaves the floor.
	Hint 2	The ball reverses direction, so with upwards positive one velocity is negative. The change in momentum is $mv - mu$ with signs.
	Hint 3	Over the 0.04 s two forces act on the ball: the floor and the weight. Their resultant gives the change in momentum.
X2	**Hint 1**	Write a momentum equation and a restitution equation for the first collision, using the fact that A is at rest afterwards.
	Hint 2	The coefficient of restitution must satisfy $0 \leqslant e \leqslant 1$. For the second collision, B moves at the speed you found from the first.
	Hint 3	In the second collision, substitute C's velocity from the restitution equation into the momentum equation. Only C has kinetic energy at the end.
X3	**Hint 1**	A speed has no direction. After the collision B could move either way, so try $v_B = 6$ and $v_B = -6$ in the momentum equation.
	Hint 2	For each case, compare the velocities of A and B afterwards. Can A be moving forwards faster than B when B is in front of it?
	Hint 3	For the energy, add the kinetic energies of both spheres. For the impulse, use $mv - mu$ for A with signs, then Newton's third law.
X4	**Hint 1**	Take the direction towards the wall as positive and write a momentum equation and a restitution equation.
	Hint 2	After the wall, B's velocity is reversed and multiplied by e. Another collision happens when the velocity of A (towards the wall) is greater than the velocity of B.
	Hint 3	Your inequality should become a perfect square. Look at what happens when it equals zero.

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X5

Hint 1 Use the work-energy principle: the kinetic energy at the start, minus the work done against the resistance, is the kinetic energy at the end.

Hint 2 Q's kinetic energy just after the collision is all used up against its resistance over $1.5\ \mathrm{m}$. Then use momentum and restitution.

Hint 3 Compare the decelerations of P and Q after the collision. Which one is in front, and which one is faster?

X6

Hint 1 Find B's speed after falling $0.9\ \mathrm{m}$ freely. When the string becomes taut, both particles then move with the same speed.

Hint 2 The string gives A and B impulses of the same size. Write an impulse-momentum equation for each particle separately, each in its own direction of motion.

Hint 3 After the jerk, use the equations of motion until B hits the floor. Then A moves freely upwards.

X7

Hint 1 Write the height of each ball at time t using $s = ut + \frac{1}{2}at^2$, and set them equal.

Hint 2 Just before the collision the balls move in opposite directions, so with upwards positive A's velocity is negative. Then use momentum and restitution together.

Hint 3 In restitution, the separation is the upper ball's velocity minus the lower ball's. For part (c), a ball moves upwards when its velocity is positive. For part (e), think about the size of an impulse Ft when t is very short.

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