3.1 Further Mechanics: Momentum, Impulse and Collisions: 1-hour Pack

AQA 7367 · Calculator allowed · about 60 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 A small ball of mass 0.2 kg hits a smooth fixed vertical wall at right angles with speed 9 m/s. The coefficient of restitution between the ball and the wall is 1/2.

(a) Find the speed of the ball immediately after it rebounds from the wall. **(2)**

(b) Find the magnitude of the impulse exerted by the wall on the ball. **(2)**

(c) Find the kinetic energy lost at the impact. **(2)**

(d) The ball bounces between the wall and a second smooth wall opposite so that each bounce reduces the speed by the same factor. Find the least number of impacts after which the speed is below 1 m/s. **(4)**

(Total for Question 1 is 10 marks)

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2 A small ball of mass 0.2 kg hits a smooth fixed vertical wall at right angles with speed 20 m/s. The coefficient of restitution between the ball and the wall is 1/3.

(a) Find the speed of the ball immediately after it rebounds from the wall. **(2)**

(b) Find the magnitude of the impulse exerted by the wall on the ball. **(2)**

(c) Find the kinetic energy lost at the impact. **(2)**

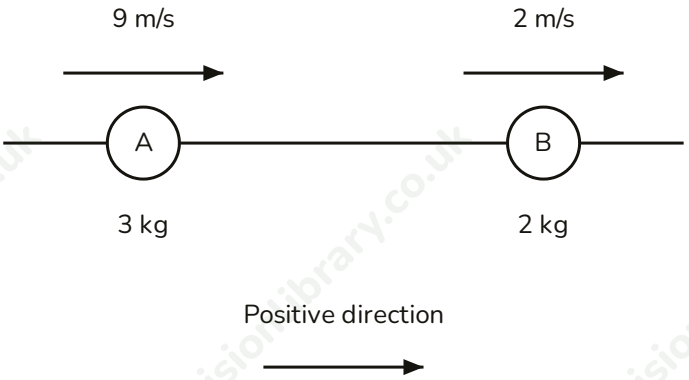
(d) The ball bounces between the wall and a second smooth wall opposite so that each bounce reduces the speed by the same factor. Find the least number of impacts after which the speed is below 2 m/s. **(4)**

(Total for Question 2 is 10 marks)

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3 Two smooth spheres A and B, of masses 3 kg and 2 kg, are moving in the same straight line on a smooth horizontal table. A has velocity 9 m/s and B has velocity 2 m/s, both measured in the same direction along the line. The spheres collide directly, and the coefficient of restitution between them is 1/4.

Diagram NOT accurately drawn



(a) Find the velocities of A and B immediately after the collision. **(4)**

(b) Find the magnitude of the impulse exerted by A on B in the collision. **(2)**

(c) Find the total kinetic energy lost in the collision. **(3)**

(Total for Question 3 is 9 marks)

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4 A particle P of mass 3 kg is moving with speed 7 m/s along a smooth horizontal straight line. It collides directly with a particle Q of mass 7 kg, which is moving along the same line with velocity 4 m/s (a negative value means moving in the opposite direction to P). After the collision P and Q coalesce.

(a) Find the common velocity of the combined particle after the collision. **(3)**

(b) Find the magnitude of the impulse exerted by Q on P. **(2)**

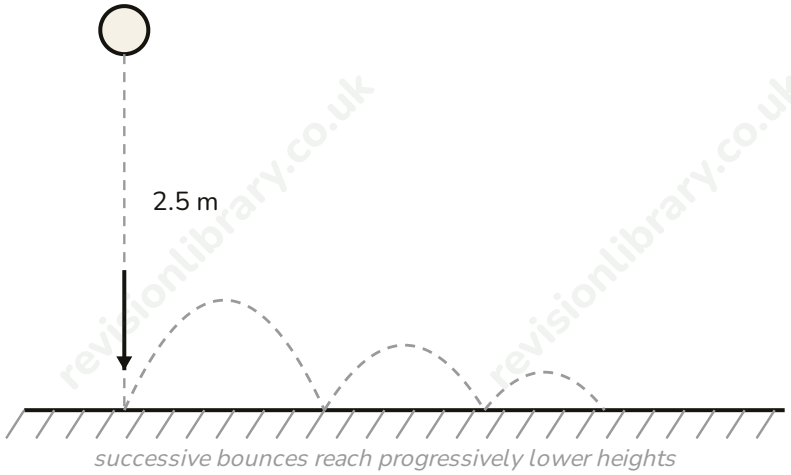
(c) Find the kinetic energy lost in the collision. **(3)**

(d) The contact between P and Q lasts 0.25 s. Find the magnitude of the average force between them, to 3 significant figures. **(2)**

(Total for Question 4 is 10 marks)

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5 A ball is dropped from rest from a height of 2.5 m onto smooth, horizontal ground. The coefficient of restitution between the ball and the ground is $e = 0.6$. Air resistance may be ignored, and $g = 9.8$ m/s^2 throughout this question.



(a) Find the speed of the ball immediately before it first strikes the ground. **(2)**

(b) Find the height to which the ball rebounds after the first bounce. **(3)**

(c) Show that the height reached after the nth bounce is $h_n = 2.5\ e^{2n}$, and hence find the height reached after the third bounce, giving your answer to 3 significant figures. **(4)**

(Total for Question 5 is 9 marks)

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Mark scheme · 3.1 Further Mechanics: Momentum, Impulse and Collisions: 1-hour Pack

Question 1

(a) uses the restitution law: speed after = e x speed before **M1**

(a) 1/2 x 9 = 4.500 m/s **A1**

(a) Answer: 4.500 m/s

(b) impulse = change in momentum, with the velocity reversing **M1**

(b) 0.2(9 + 4.500) = 2.70 N s **A1**

(b) Answer: 2.70 N s

(c) KE before - KE after **M1**

(c) $(1/2)(0.2)(9^2)(1 - 1/4) = 6.075 = 6.08$ J **A1**

(c) Answer: 6.08 J

(d) forms $9 \times (1/2)^n < 1$ **M1**

(d) takes logarithms (or tests values of n) **M1**

(d) n > 3.170 **A1**

(d) n = 4 **A1**

(d) Answer: 4

Question 2

(a) uses the restitution law: speed after = e x speed before **M1**

(a) 1/3 x 20 = 6.667 m/s **A1**

(a) Answer: 6.667 m/s

(b) impulse = change in momentum, with the velocity reversing **M1**

(b) 0.2(20 + 6.667) = 5.33 N s **A1**

(b) Answer: 5.33 N s

(c) KE before - KE after **M1**

(c) $(1/2)(0.2)(20^2)(1 - 1/9) = 35.6$ J **A1**

(c) Answer: 35.6 J

(d) forms $20 \times (1/3)^n < 2$ **M1**

(d) takes logarithms (or tests values of n) **M1**

(d) n > 2.096 **A1**

(d) n = 3 **A1**

(d) Answer: 3

Question 3

(a) conservation of momentum: m1 u1 + m2 u2 = m1 v1 + m2 v2 **M1**

(a) Newton's experimental law: v2 - v1 = e(u1 - u2) **M1**

(a) v1 = 11/2 m/s **A1**

(a) v2 = 29/4 m/s **A1**

(a) Answer: $v_A = 11/2$ m/s, $v_B = 29/4$ m/s

(b) impulse = change in momentum of B **M1**

(b) 2(29/4 - (2)) = 21/2 N s **A1**

(b) Answer: 21/2 N s

(c) KE before - KE after **M1**

(c) before 251/2 J, after 1567/16 J **A1**

(c) loss = 441/16 J **A1**

(c) Answer: 441/16 J

Question 4

(a) conservation of momentum: m1 u1 + m2 u2 = (m1 + m2) v **M1**

(a) 21 + (28) = 10v **A1**

(a) v = 49/10 m/s **A1**

(a) Answer: 49/10 m/s

(b) change of momentum of P **M1**

(b) 3(49/10 - 7) = -63/10 N s **A1**

(b) Answer: 63/10 N s

(c) KE before - KE after **M1**

(c) 259/2 - 2401/20 **A1**

(c) 189/20 J **A1**

(c) Answer: 189/20 J

(d) force = impulse/time **M1**

(d) 25.2 N **A1**

(d) Answer: 25.2 N

Question 5

(a) uses $v^2 = u^2 + 2gh$ with u = 0, h = 2.5, g = 9.8 **M1**

(a) v = 7 m/s, cao (exact) **A1**

(a) Answer: 7 m/s

(b) speed just after first bounce = e x 7 = 0.6 x 7 = 4.2 m/s (ft from part (a)) **M1**

(b) uses $0 = (4.2)^2 - 2gh$ to find the rebound height **M1**

(b) h = 0.9 m, cao **A1**

(b) Answer: 0.9 m

(c) recognises that since rebound speed = e x (impact speed) and height is proportional to $(\text{speed})^2$, each successive rebound height is e^2 times the previous one **M1**

(c) correctly derives $h_n = 2.5\, e^{2n}$ (cso), noting $h_1 = 2.5\, e^2 = 0.9$ agrees with part (b) **A1**

(c) substitutes n = 3: $h_3 = 2.5 \times (0.6)^6$ **M1**

(c) $h_3 = 0.117$ m (awrt 3 s.f.), cao **A1**

(c) Answer: $h_n = 2.5\, e^{2n}$; h_3 = awrt 0.117 m

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