3.5 Further Mechanics: Momentum, Impulse and Collisions Depth: 10-minute Pack

EDEXCEL 9FM0 · Calculator allowed · about 10 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

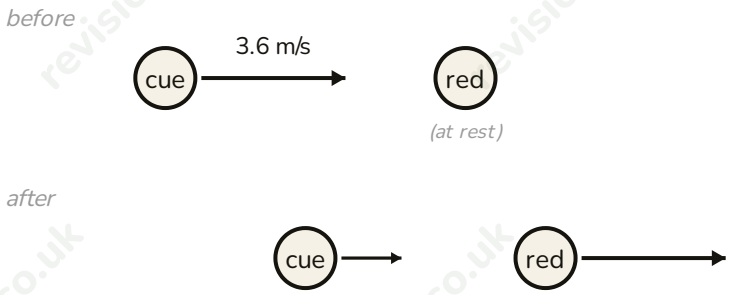
Key results: momentum, impulse and Newton's law of restitution

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Unless a question states otherwise, take g = 9.8 m/s^2, model each object as a particle, and take all strings as light and inextensible, all pulleys and surfaces as smooth, and all spheres as smooth (so there is no friction, and no tangential impulse, at any point of contact). The impulse-momentum principle states that the impulse J exerted on a particle of mass m equals its change in momentum, J = m*(v - u); when a force F varies with time t, the impulse delivered over an interval is the integral of F with respect to t over that interval. Provided no external horizontal force acts on a system of colliding or jerked particles, total momentum is conserved: m1*u1 + m2*u2 = m1*v1 + m2*v2, with velocities signed along the line of centres (or along the string). Newton's experimental law of restitution states that the speed of separation is e times the speed of approach, v2 - v1 = -e*(u2 - u1), where 0 <= e <= 1 is the coefficient of restitution between the two surfaces; e = 1 gives a perfectly elastic collision (no kinetic energy lost) and e = 0 gives a perfectly inelastic collision (the particles coalesce, or move off together immediately after a string jerks taut). The loss in kinetic energy due to a direct collision is m1*m2*(1-e^2)*(u1-u2)^2 / (2*(m1+m2)). When a sphere strikes a fixed smooth surface obliquely, the component of its velocity parallel to the surface is unchanged by the impact, while the component perpendicular to the surface obeys Newton's law of restitution.

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1 In snooker, a cue ball of mass 0.17 kg travelling at 3.6 m/s strikes a stationary red ball of the same mass directly. The coefficient of restitution between the balls is 0.9.



(a) Find the velocities of both balls immediately after the collision. **(4)**

(b) Calculate the percentage of the cue ball's original kinetic energy that is lost due to the collision, giving your answer to 3 significant figures. **(3)**

(Total for Question 1 is 7 marks)

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Mark scheme · 3.5 Further Mechanics: Momentum, Impulse and Collisions Depth: 10-minute Pack

Question 1

(a) momentum equation: $0.17(3.6) + 0.17(0) = 0.17*v1 + 0.17*v2$, simplifying (dividing by 0.17) to $v1+v2=3.6$	**M1**
(a) restitution equation: $v2-v1 = -0.9(0-3.6)$, simplifying to $v2-v1=3.24$	**M1**
(a) cue ball velocity $v1 = 0.18$ m/s, cao	**A1**
(a) red ball velocity $v2 = 3.42$ m/s, cao	**A1**

(a) Answer: Cue ball: 0.18 m/s; red ball: 3.42 m/s

(b) KE before $= 0.5(0.17)(3.6^2)$; KE after $= 0.5(0.17)(0.18^2+3.42^2)$, using their velocities from part (a) (ft)	**M1**
(b) loss = 1.1016 - 0.996948 = 0.105 J (awrt 3 s.f.)	**A1**
(b) percentage lost = 9.50% (awrt 3 s.f.), cao	**A1**

(b) Answer: 9.50% (3 s.f.)

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