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| **Q** | **Scheme** | **Marks** | **AO** | **Pearson Progression Step and Progress Descriptor** |
| **1a** | Uses conservation of momentum to form equation  or | **M1** | 3.1b | 3rd  Understand the concept of elasticity and the coefficient of restitution |
| Uses *e* =1 with Newton’s law of restitution to form equation:  or | **M1** | 1.1a |
| Solves simultaneously to find  and | **A1** | 1.1b |
|  | **(3)** |  |  |
| **1b** | Forms equation in terms of e using Newton’s law of restitution:  or | **M1** | 3.4 | 4th  Use Newton's experimental law of restitution for direct impacts of elastic spheres |
| Uses new equation and conservation of momentum equation to find that:  and | **M1** | 3.4 |
| Deduces from question that | **M1** | 1.2 |
| Forms  solves to find | **A1** | 1.1b |
|  | **(4)** |  |  |
| **1c** | Shows clearly that because  then  thus  for any permissible value of | **B1** | 2.1 | 3rd  Understand the range of values that the coefficient of restitution can take |
| Thus, by considering  critical value of  defines range of values for motion in opposite directions as | **B1** | 2.1 |
|  | **(2)** |  |  |
| (9 marks) | | | | |
| **Notes** | | | | |

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| Q | Scheme | Marks | AOs | Pearson Progression Step and Progress Descriptor |
| **2a** | Speed of ball as it hits the horizontal plane using suvat:  or | **M1** | 3.3 | 5th  Solve problems of balls bouncing off horizontal elastic planes |
| Uses Newton’s law of restitution to deduce speed of ball at instant after first collision: | **A1** | 1.1b |
| Uses suvat to find maximum height after first collision, : | **M1** | 1.1a |
| Rearranges to show | **A1** | 1.1b |
|  | **(4)** |  |  |
| **2b** | Deduces that part **a** answer is part of an inductive sequence: | **M1** | 2.2a | 6th  Solve problems involving successive collisions including collisions with walls |
| Thus, derives formula in terms of  and | **A1** | 2.2a |
|  | **(2)** |  |  |
| **2c** | Interprets question to form equation: | **M1** | 3.1b | 6th  Solve problems involving successive collisions including collisions with walls |
| Solves: | **A1** | 1.1b |
| States that the collisions are highly elastic, i.e.  close to 1. | **B1** | 3.2a |
|  | **(3)** |  |  |
| (9 marks) | | | | |
| **Notes** | | | | |

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| Q | Scheme | Marks | AOs | Pearson Progression Step and Progress Descriptor |
| **3a** | States velocity of 2kg sphere after first impact with wall | **M1** | 1.2 | 5th  Calculate the change in kinetic energy as a result of a collision |
| Uses KE formula to form an equation for energy lost: | **A1** | 1.1a |
|  | **(2)** |  |  |
| **3b** | Uses conservation of momentum to form an equation eg. | **M1** | 3.3 | 5th  Calculate the change in kinetic energy as a result of a collision |
| Forms an equation using Newton’s law of restitution eg. | **M1** | 3.4 |
| Solves for expressions for  and :  oe and  oe | **A1** | 1.1b |
| Uses correct KE loss equation: | **M1** | 1.1a |
| Expands: | **M1** | 1.1a |
| Thus  \* (must show intermediate step) | **A1** | 1.1b |
|  | **(6)** |  |  |
| **3c** | Forms equation using *their* | **M1** | 3.1b | 5th  Calculate the change in kinetic energy as a result of a collision |
| Forms quartic: | **M1** | 1.1a |
| Forms quadratic  and square roots positive solution, or otherwise, to find: | **A1** | 1.1b |
|  | **(3)** |  |  |
| (11 marks) | | | | |
| **Notes:** | | | | |

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| Q | Scheme | Marks | AOs | Pearson Progression Step and Progress Descriptor |
| **4a** | Forms two equations using conservation of momnetum and Newton’s law of restitution for example:  and | **M1** | 3.4 | 6th  Solve problems involving successive collisions including collisions with walls |
| Thus, velocity of *B* after collision with *A*, | **A1** | 1.1b |
| Uses  above as initial velocity with Newton’s law of restitution to form one equation for the collision between *B* and *C*, using  for the velocity of *B* after this collision for example: | **M1** | 3.4 |
| Forms second equation using conservation of momentum eg. | **M1** | 3.4 |
| Solves simultaneously to show:   **(Please see notes section also for this mark)** | **M1** | 1.1b |
| Uses substitution to derive:  AG | **A1** | 1.1b |
|  | **(6)** |  |  |
| **4b** | Deduces that for *A* and *B* to collide again whilst travelling in the same direction as *C* then | **M1** | 2.2a | 5th  Solve problems involving successive collisions of pairs of spheres in one dimension |
| Thus: | **M1** | 1.1a |
| Rearranges to form quadratic inequality: | **M1** | 1.1a |
| Solves quadratic inequality:  or | **A1** | 1.1b |
| States possible range for *e*: | **A1** | 2.2a |
|  | **(5)** |  |  |
| (11 marks) | | | | |
| **Notes**  If the student derives  correctly in 4a without finding  award M1A1 for correct  expression but must the working must be very clear. | | | | |

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| Q | Scheme | Marks | AOs | Pearson Progression Step and Progress Descriptor |
| **5a** | Resolves to find forces in direction of motion:  Force due to friction  and Force down slope due to gravity | **M1** | 3.3 | 7th  Solve problems involving collisions in unfamiliar contexts |
| Energy lost in journey down slope = Work done against friction:  Frictional force  distance = | **A1** | 3.4 |
| Equates energy or, using suvat, deduces the speed before the collision with buffer, | **M1** | 3.4 |
| Thus, deduces the speed after collision: | **M1** | 1.1b |
| Uses KE formula with  and  to find energy lost in the collision with buffer: | **M1** | 3.4 |
| Simplifies to show: | **M1** | 1.1b |
| So total energy lost from work done against friction and collision:    So  AG | **A1** | 1.1b |
|  | **(7)** |  |  |

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| **5b** | Interprets question to form equation: | **M1** | 3.1b | 7th  Solve problems involving collisions in unfamiliar contexts |
| Rearranges to form quartic: | **M1** | 1.1a |
| Uses discriminant:  to state:  Maximum possible value of  to 3dp. | **A1** | 2.2a |
|  | **(3)** |  |  |
| (10 marks) | | | | |
| **Notes** | | | | |