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| Q | Scheme | Marks | AOs | Pearson Progression Step and Progress Descriptor |
| **1** | By resolving and using the rule that the velocity of the ball after the collision **parallel to the slope** is unchanged,  | **M1** | 3.3 | 6thUse Newton's experimental law of restitution in the direction of the impulse |
| By resolving and using NEL formula finds an expression for the velocity of the ball after the collision **perpendicular to the slope**: | **M1** | 3.3 |
| Uses KE formula and components to attempt to form an expression for the KE of the ball immediately **after** the collision with *their* velocity components: | **M1** | 3.4 |
| Expression for KE of ball after collision fully correct as above. | **A1** | 1.1b |
| Interprets given ratio to form equation:  | **M1** | 1.1a |
| Solves:  | **A1** | 1.1b |
| (6 marks) |
| **Notes** |

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| Q | Scheme | Marks | AOs | Pearson Progression Step and Progress Descriptor |
| **2ai** | Correctly applies Impulse formula to find Impulse vector, **I**:  | **M1****A1** | 1.1a | 5thUnderstand that impulse acts perpendicular to the surface through the sphere's centre |
| Thus magnitude of Impulse  | **A1** | 1.1b |
|  | **(3)** |  |  |
| **2aii** | States the unit vector for the Impulse as  | **B1** | 1.1b | 5thUnderstand that impulse acts perpendicular to the surface through the sphere's centre |
|  | **(1)** |  |  |
| **2b** | Chooses to use **u**.**v** to find the components of velocities perpendicular to the wall. PI  | **M1** | 3.1b | 5thUnderstand that impulse acts perpendicular to the surface through the sphere's centre |
| Finds the component of the velocity of the sphere perpendicular to the wall **before the collision**: | **M1** | 1.1b |
| Likewise finds the component of the velocity of the sphere perpendicular to the wall **after the collision**:  | **M1** | 1.1b |
| Using the NEL formula:  | **M1** | 1.1a |
| Thus  | **A1** | 1.1b |
|  | **(5)** |  |  |
| (9 marks) |

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| Q | Scheme | Marks | AOs | Pearson Progression Step and Progress Descriptor |
| **3a** | [Note: Diagram or otherwise defines *v* and *w*perpendicular components may be omitted]**Parallel to the line of centres** forms equation using COL momentum formula using deduced values for cos *α* and cos *β*. | **M1****A1** | 3.4 | 7thRelate two dimensional impacts to problems involving two spheres of equal radius |
| **Similarly** forms equation using NEL formula:  | **M1****A1** | 3.4 |
| Thus solves the two simultaneous equations to find *v* and *w*. and  oe (allow 3 decimal places or better) | **A2** | 1.1b |
| Uses both components and total KE formula to calculate total KE lost, **Or** considers energy change in parallel components only | **M1** | 3.4 |
| Equates to given value  and solves:   | **A1** | 3.2a |
|  | **(8)** |  |  |

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| **3b** | Impulse acts parallel to the line of the centres (may be implied) | **M1** | 3.1b | 5thUnderstand that impulse acts perpendicular to the surface through the sphere's centre |
| Thus for *Q* on *P*: Impulse   | **M1** | 1.1a |
| Thus magnitude of Impulse of *Q* on *P* = 0.892 Ns  | **A1** | 1.1b |
|  | **(3)** |  |  |
| (11 marks) |
| **Notes** |

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| Q | Scheme | Marks | AOs | Pearson Progression Step and Progress Descriptor |
| **4a** | Derives (or simply states) relationship between angles before (60) and after  colliding with Wall *A*:  | **M1** | 1.1a | 6thCalculate the angle of deflection in an oblique impact with a surface |
| Deduces for sphere to hit wall *B*:  | **M1** | 2.2a |
| Thus:  | **A1\*** | 1.1b |
|  | **(3)** |  |  |
| **4b** | Uses  with  to find:  | **M1** | 1.1b | 6thCalculate the angle of deflection in an oblique impact with a surface |
| Thus deduces sphere meets wall *B* at an angle:  | **M1** | 1.1a |
| Hence:  (5.1 or better) | **A1** | 1.1b |
|  | **(3)** |  |  |

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| **4c** | Uses parallel and perpendicular directions, and NEL formula, to find, for speed of sphere, *v*, after colliding with wall *A*:  and  | **M1** | 3.3 | 8thSolve a wide range of problems involving successive oblique impacts with smooth surfaces |
| Thus uses Pythagoras to find:  | **M1** | 1.1b |
| Similarly establishes parallel and perpendicular relationships for before and after the sphere collides with wall *B*, where the sphere leaves with speed *w*, at an angle , such that: and/or  | **M1** | 3.3 |
| Uses Pythagoras or  value from part **4bi** to find *w* or :  | **M1** | 1.1b |
| Uses correct formula to find KE lost over both collisions, *L*: | **M1** | 1.1a |
| Thus Overall KE lost,  joules (accept 0.77 or better) | **A1** | 1.1b |
|  | **(6)** |  |  |
| (12 marks) |
| Notes |

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| Q | Scheme | Marks | AOs | Pearson Progression Step and Progress Descriptor |
| **5** | Uses COL momentum formula along the line of centres using *X* and *Y* as the speeds of *M* and *N* in that same direction after the collision respectively: | **M1****A1** | 3.3 | 8thSolve a wide range of problems involving oblique impacts between two spheres |
| Uses NEL formulaalong line of centres | **M1A1** | 3.4 |
| Solves these two equations simultaneously, and correctly for *X*:  | **A1** | 1.1b |
| Uses NEL result relating to angle  made by *N* relative to the wall after the collision with it:  | **M1** | 3.4 |
| After the collision with *N*, the perpendicular component of the velocity of *M* is unchanged:  | **M1** | 1.1a |
| The acute angle, , from the line of centres made by *M* after the collision, by trigonometry is thus:  | **M1** | 2.1 |

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|  | Deduces from parallel line geometry if the paths are to be parallel after the collisions then:  | **M1** | 2.2a |  |
| Thus:  | **M1** | 2.1 |
| Now substitutes  to give: | **M1** | 1.1b |
| Hence:  | **A1\*** | 2.2a |
| (12 marks) |
| Notes |