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| **Question** | **Scheme** | **Marks** | **AOs** |
| **1(a)** | For trailer: Equation of motion | M1 | 3.4 |
|  | A1 | 1.1b |
| For system or lorry: Equation of motion | M1 | 3.4 |
| or | A1 | 1.1b |
| Power = 900  20 | M1 | 3.3 |
| *P* = 18 | A1 | 1.1b |
|  | **(6)** |  |
| **(b)** | Inextensibility of tow bar => acceleration of trailer = acceleration of car | B1 | 2.4 |
|  | **(1)** |  |
| **(7 marks)** | | | |
| **Notes:** | | | |
| **(a)**  **M1:** Use the model to form equation of motion.  **A1:** Correct equation  **M1:** Use the model to form another equation of motion  **A1:** Correct equation  **M1:** Use of*P* =*Fv*  **A1:** Correct answer | | | |
| **(b)**  **B1:** Clear explanation | | | |

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| **Question** | **Scheme** | **Marks** | **AOs** |
| **2** | Conservation of momentum | M1 | 3.1b |
|  | A1 | 1.1b |
| Newton’s Impact Law | M1 | 3.4 |
|  | A1 | 1.1b |
| Solve for  :complete strategy (set up 2 equations and solve) to find | M1 | 3.1b |
|  | A1 | 1.1b |
|  | M1 | 1.1b |
| *Q* reverses its direction \* | A1\* | 2.1 |
| **(8 marks)** | | | |
| **Notes:** | | | |
| **M1:** All terms needed but condone sign errors  **A1:** A correct unsimplified equation  **M1:** Use NIL as a model for the motion with *e* on the correct side of the equation  **A1**: A correct equation in any form  **M1**: Solve for *vQ*  **A1**: A correct expression in *vQ* and *e* only  **M1:** Appropriate statement and inequality **(M0** for converse**)**  **A1\***: Correct conclusion, fully justified (given answer) | | | |

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| **Question** | **Scheme** | **Marks** | **AOs** |
| **3** | Use work-energy principle to solve the problem | M1 | 3.4 |
|  |  | A1 | 1.1b |
|  |  | A1 | 1.1b |
|  |  | A1 | 1.1b |
|  |  | **(4)** |  |
| **(4 marks)** | | | |
| **Notes:** | | | |
| **M1:** All terms needed (M0 if anything other than work-energy used)  **A1**: All correct, condone one error  **A1**: All correct  **A1**: 2SF or 3SF following use of *g* = 9.8 | | | |
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| **Question** | **Scheme** | **Marks** | **AOs** |
| **4(a)** | Conservation of momentum | M1 | 3.1a |
|  | A1 | 1.1b |
| Newton’s Impact Law | M1 | 3.4 |
|  | A1 | 1.1b |
| Overall strategy for solving for either velocity | M1 | 3.1a |
|  | A1 | 1.1b |
|  | A1 | 1.1b |
| oe | M1 | 3.1a |
|  | A1 | 1.1b |
|  | A1 | 1.1b |
|  | **(10)** |  |
| **(b)** | Particles move with same speed in same direction as *A* oe | B1 | 2.2a |
| speed = | B1 | 2.2a |
|  | **(2)** |  |
| **(12 marks)** | | | |
| **Notes:** | | | |
| **(a)**  **M1:** Correct strategy with use of CLM, with all terms but condone sign errors  **A1:** Correct equation  **M1:** Correct use of NIL model with *e* on correct side of equation  **A1:** Correct equation  **M1:** Solving for either velocity  **A1:** Correct expressions for *vA*  **A1:** Correct expressions for *vB*  **M1:** Using a correct strategy to set up an energy equation  **A1:** Correct equation  **A1:** cao | | | |
| **(b)**  **B1:** Clear explanation  **B1:** Correct speed | | | |

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| **Question** | **Scheme** | **Marks** | **AOs** |
| **5(a)** | Use of Impulse-momentum principle | M1 | 3.1b |
|  | A1 | 1.1b |
|  | M1 | 1.1b |
|  | A1 | 1.1b |
|  | **(4)** |  |
| **(b)** | KE Loss = Initial KE Final KE | M1 | 3.4 |
| = | A1 | 1.1b |
| = 1 (J) | A1 | 1.1b |
|  | **(3)** |  |
| **(c)** | Resolve velocities along the normal (impulse) | M1 | 3.1b |
| Separation speed = | A1 | 1.1b |
| Approach speed = | A1 | 1.1b |
| Use of Newton’s Impact Law along normal: | M1 | 3.4 |
| *e* = | A1 | 1.1b |
|  | **(5)** |  |
| **(d)** | Find vector along the wall and resolve | M1 | 3.1a |
| ;  Hence momentum conserved ‘along the wall’ \* | A1\* | 2.4 |
|  | **(2)** |  |
| **(e)** | Wall is modelled as being smooth | B1 | 3.5b |
|  | **(1)** |  |
| **(15 marks)** | | | |

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| **Notes:** |
| **(a)**  **M1:** Difference of momenta and dimensionally correct  **A1:** Correct unsimplified expression  **M1:** Must be a sum of squares and dimensionally correct  **A1:** Correct answer |
| **(b)**  **M1:** Using the model: must be a difference and dimensionally correct  **A1:** Correct unsimplified expression  **A1:** cao |
| **(c)**  **M1:** Clear attempt to resolve but condone sin/cos confusion  **A1:** Allow +/-  **A1:** Allow +/-  **M1:** Use of Newton’s Impact Law to model impact  **A1:** cao |
| **(d)**  **M1:** Clear attempt to resolve but condone sin/cos confusion  **A1\*:** Correct justification of given answer |
| **(e)**  **B1:** Correct answer |

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| **Question** | **Scheme** | **Marks** | **AOs** |
| **6(a)** | Using work-energy principle to solve the problem | M1 | 3.1a |
| *R* = *mg* and *use* of  *F* =*R* | M1 | 3.4 |
|  | A1 | 1.1b |
| A1 | 1.1b |
| Finding the *total* distance moved | M1 | 1.1b |
|  | A1 | 1.1b |
|  | **(6)** |  |
| **(b)** | Thrust = = | B1 | 1.2 |
| Overall strategy to solve problem by comparing thrust with max friction () | M1 | 3.1a |
| *P* comes to instantaneous rest and then immediately slides back since | A1\* | 2.4 |
|  | **(3)** |  |
| **(c)** | Using work-energy principle to solve the problem | M1 | 3.1a |
| Use of EPE formula | M1 | 1.2 |
|  | A1ft | 1.1b |
| A1ft | 1.1b |
| ; comes to rest at unstretched length position | A1 | 2.4 |
|  | **(5)** |  |
| **(d)** | No tension/thrust in spring => no friction | B1 | 2.4 |
| *P* comes to permanent rest at unstretched length position | B1 | 2.4 |
|  | **(2)** |  |
| **(16 marks)** | | | |

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| **Notes:** |
| **(a)**  **M1:** Must include all terms  **M1:** Use of *R*  **A1:** Condone 1 error  **A1:** All correct  **M1:** Complete method to find the *total* distance moved  **A1:** cao |
| **(b)**  **B1:** Use of Hookes’ law to obtain force in spring  **M1:** Compare max friction with thrust  **A1\*:**  Correct justification of given answer |
| **(c)**  **M1:** Must include all terms  **M1:** Use of EPE at least once  **A1ft:** Condone 1 error, follow through on their answer from (a)  **A1ft:** All correct, follow through on their answer from (a)  **A1:** Correct *y* value and statement |
| **(d)**  **B1:** Clear explanation  **B1:** Clear explanation |

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| **Question** | **Scheme** | **Marks** | **AOs** |
| **7(a)**  **(b)** | At *D*, use CLM along wall | M1 | 3.1a |
|  | A1 | 1.1b |
| At *D*, use NIL along normal | M1 | 3.4 |
|  | A1 | 1.1b |
| Overall strategy to obtain connection between angles: | M1 | 3.1a |
| Use this result at *E*  (second impact on *AB*) | M1 | 3.4 |
|  | A1 | 1.1b |
| A1 | 1.1b |
| Expand and sub for | M1 | 1.1b |
|  | A1\* | 2.1 |
|  | **(10)** |  |
| 0 < | M1 | 2.1 |
|  | A1 | 1.1b |
| i.e. angle between walls must be at least 30o \* | A1\* | 2.2a |
|  | **(3)** |  |
| **(13 marks)** | | | |
| **Notes:** | | | |
| **(a) M1:** Condone sin/cos confusion  **A1:** Correct unsimplified  **M1:** Correct use of NIL with *e* on correct side of equation but condone sin/cos confusion  **A1:** Correct equation  **M1:** Correct strategy to set up two equations to obtain connection between angles  **M1:** Correct use of NIL with *e* on correct side  **A1:** Condone 1 error  **A1:** All correct  **M1:** For producing equation in tan and *e* only  **A1\*:** Correct justification of given answer | | | |
| **(b) M1:** Use of 0 < *e*  1 to give inequality  **A1:** Correct inequality  **A1\*:** Correct justification of given answer | | | |