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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 |