**9FM0/3C: Further Mechanics 01 Mark scheme**

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| **Question** | **Scheme** | | **Marks** | **AOs** |
| **1(a)** | Driving force  (N) | | B1 | 3.1b |
| No resultant force | | M1 | 3.4 |
| is a solution\* | | A1\* | 2.2a |
| so no more real roots,  is the only solution. | | A1 | 2.4 |
|  | | **(4)** |  |
| **(b)** | Equation of motion: | | M1 | 3.4 |
|  | | A1 | 1.1b |
|  | | A1 | 1.1b |
|  | | M1 | 1.1b |
| m s-2 (0.947) | | A1 | 1.1b |
|  | | **(5)** |  |
| **(9 marks)** | | | | |
| **Notes:** | | | | |
| 1a | B1 | Use  to find the driving force | | |
|  | M1 | Use the model to form an equation in *V* | | |
|  | A1\* | Solve equation to obtain solution  (complex roots  ) | | |
|  | A1 | CSO. Justification that is the only real solution e.g. by considering determinant of quadratic factor, completing the square or stating all 3 roots and confirming that only one root is real | | |
| SR | A candidate who verifies that is a solution can score 2/4: | | | |
|  | B1 | Use  to find the driving force | | |
|  | M1 | Complete method to show that there is no resultant force when that | | |
| 1b | M1 | Use the model to form the equation of motion of the van. All terms required. Condone sign errors and sin/cos confusion | | |
|  | A1 | Unsimplified equation with at most one error | | |
|  | A1 | Correct unsimplified equation | | |
|  | M1 | Substitute for *v* and trig and solve for *a* | | |
|  | A1 | Accept 2s.f. or 3s.f. (9.8 used) | | |

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| **Question** | **Scheme** | | **Marks** | **AOs** |
| **2** | EPE  or EPE | | B1 | 3.4 |
| Gain in GPE | | B1 | 1.1b |
| Work done against friction | | B1 | 1.1b |
| Work-Energy equation | | M1 | 3.1a |
|  | | A1 | 1.1b |
| Substitute trig and solve for : | |  |  |
|  | | A1 | 1.1b |
|  | | **[6]** |  |
| **(6 marks)** | | | | |
| **Notes:** | | | | |
| 2 | B1 | Correct unsimplified expression for EPE at *B* or at *C* | | |
|  | B1 | Correct unsimplified expression for GPE gained *B* to *C* | | |
|  | B1 | Correct unsimplified expression for WD against friction *B* to *C* | | |
|  | M1 | All terms required. Condone sign errors and sin/cos confusion. | | |
|  | A1 | Correct unsimplified equation | | |
|  | A1 | or better (*g* cancels) | | |

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| **Question** | **Scheme** | | **Marks** | **AOs** |
| **3(a)** | Impulse momentum equation | | M1 | 2.1 |
|  | | A1 | 1.1b |
| Magnitude of the impulse | | M1 | 1.1b |
| Follow their **I** | | A1ft | 1.1b |
| , | | M1 | 2.2a |
| (Ns) | | A1 | 1.1b |
|  | | **(6)** |  |
| **3(b)** | Use of scalar product: | | M1 | 3.1a |
| follow their | | A1ft | 1.1b |
|  | | A1 | 1.1b |
|  | | **(3)** |  |
| **3(b) alt** | Use trig to find 2 relevant angles:  , | | (M1) | 3.1a |
| or , | | (A1) | 1.1b |
|  | | (A1) | 1.1b |
|  | | **(3)** |  |
| **(9 marks)** | | | | |
| **Notes:** | | | | |
| 3a | M1 | Use impulse momentum to find the impulse in terms of | | |
|  | A1 | Correct unsimplified equation | | |
|  | M1 | Use Pythagoras and the given modulus | | |
|  | A1ft | Correct unsimplified expression using their **I** | | |
|  | M1 | Solve for ( or ) and find **I** | | |
|  | A1 | Correct answer | | |
| 3b | M1 | Complete strategy, using vectors or equivalent, to find relevant angle  Could be working with velocity or momentum. | | |
|  | A1ft | Single trig ratio or all relevant angles. Follow their | | |
|  | A1 | or better | | |
| **Question** | **Scheme** | | **Marks** | **AOs** |
| **4(a)** | Complete strategy to find *k* | | M1 | 3.1a |
| Resolve vertically: | | B1 | 1.1b |
| Hooke’s Law and equiibrium: | | M1 | 2.1 |
| **\*** | | A1\* | 2.2a |
|  | | **(4)** |  |
| **4(b)** | Equation of motion: | | M1 | 3.1a |
| , | | A1 | 1.1b |
|  | |  |  |
|  | | A1 | 1.1b |
|  | | **(3)** |  |
| **4(c)** | Conservation of energy: | | M1 | 3.1a |
|  | | A1 | 1.1b |
|  | | A1 | 1.1b |
|  | | **(3)** |  |
| **4(d)** | Any sensible reason in context | | B1 | 3.5b |
|  | | **(1)** |  |
| **(11 marks)** | | | | |
| **Notes:** | | | | |
| 4a | M1 | Complete strategy e.g. resolve vertically to find *T* and use Hooke’s law | | |
|  | B1 | Correct substituted equation in *T* | | |
|  | M1 | Correct use of Hooke’s law and equilibrium to find the tension in the string | | |
|  | A1\* | Draw the information together to deduce the **given result** | | |

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| 4b | M1 | Use the model to form the equation of motion of *P*. Need all terms. Dimensionally correct. Condone sign errors and sin/cos confusion. |
| A1 | Correct substituted unsimplified. |
| A1 | 25 or 25.0 m s-2 if 9.8 used. |
| 4c | M1 | Use the model to write down the equation for conservation of energy: EPE lost = GPE gained + KE gained |
| A1 | Any unsimplified equivalent |
| A1 | Accept any equivalent simplified form or |
| 4d | B1 | e.g. The pebble has dimensions, so the instant of crossing *AB* is not well-  defined  Some of the string could be taken up attaching the pebble  Accuracy of the measurement of the speed |

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| **Question** | **Scheme** | | **Marks** | **AOs** |
| **5** |  | |  |  |
| After first impact: parallel to *AB*  2**i** | | B1 | 2.1 |
| Use of impact law perpendicular to *AB* | | M1 | 3.4 |
|  | | A1 | 1.1b |
| Strategy to find final velocity | | M1 | 3.1b |
| Second impact: parallel to *BC* | | M1 | 3.1b |
| follow their **v** | | A1ft | 1.1b |
| Component of velocity | | A1 | 1.1b |
| Vector perpendicular to the wall | | B1 | 3.1b |
| Use of impact law: | | M1 | 3.4 |
| Follow their velocity and their perpendicular vector | | A1ft | 1.1b |
| Component of velocity | | A1 | 1.1b |
| (sum of their components) | |  |  |
| (m s-1) **\*** | | A1\* | 2.2a |
|  | | **(12)** |  |
| **5 alt** | ***For the last 9 marks*** | |  |  |
| Strategy to find final velocity | | M1 |  |
| Perpendicular to  is | | B1 |  |
| Find components of the initial velocity parallel and perpendicular to : | | M1 |  |
|  | | A1 |  |
| , | | A1 |  |
| Impact law perpendicular to plane: | | M1 |  |
| Follow their perpendicular component | | A1ft |  |
| Parallel component: Follow their parallel component | | A1ft |  |
| Final velocity  \* | | A1\* |  |
|  |  | |  |  |
| **(12 marks)** | | | | |
| **Notes:** | | | | |
| 5 | B1 | Conservation of component parallel to the first wall | | |
| M1 | Use the impact law on the model to find the component of the velocity perpendicular to *AB* after the impact | | |
| A1 | Correct value | | |
| M1 | Complete strategy to find final velocity: find components parallel and perpendicular to *BC* and add. | | |
| M1 | Scalar product of their velocity with a vector parallel to *BC* . Condone missing modulus. | | |
| A1 | Correct unsimplified (follow their ) | | |
| A1 | Correct parallel component | | |
| B1 | Any parallel vector | | |
| M1 | Correct use of the model and the impact law to find the magnitude of the perpendicular component. Condone missing modulus. | | |
| A1ft | Correct unsimplified. Follow their  and their perpendicular vector | | |
| A1 | Correct perpendicular component | | |
| A1\* | Combine the components to deduce the **given answer** | | |

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| **Question** | **Scheme** | **Marks** | **AOs** |
| **6(a)** |  |  |  |
| Two correct possibilities identified | B1 | 2.1 |
| Form and solve a pair of simultaneous equations in *k* and *e* | M1 | 3.1a |
| Use of CLM: | M1 | 3.1a |
| or | A1 | 1.1b |
| Use of impact law: | M1 | 3.1a |
| or | A1 | 1.1b |
| , | A1 | 1.1b |
|  |  |  |
| Second pair of simultaneous equations | M1 | 3.4 |
| Both equations correct | A1 | 1.1b |
|  |  |  |
| impossible since max | M1 | 1.1b |
| Convincing argument to support just one possible value for *k***\***. | A1\* | 2.2a |
|  |  |  |
| ***Alternative for last 4 marks:*** |  |  |
| Second CLM equation | M1 | 3.4 |
|  | A1 | 1.1b |
| both particles gain KE, which is impossible | M1 | 1.1b |
| Convincing argument to support just one possible value for *k***\***. | A1\* | 2.2a |
|  | **(11)** |  |

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| **6(b)** | KE lost = difference of two KEs | | M1 | 3.1a |
|  | | A1ft | 1.1b |
| = or equivalent | | A1 | 1.1b |
|  | | **(3)** |  |
| **(14 marks)** | | | | |
| **Notes:** | | | | |
| 6a | B1 | Identify all possible options from given information | | |
| M1 | Complete strategy to find a pair of values for *k* and *e* | | |
| M1 | Correct use of CLM. All terms needed. Condone sign errors. Dimensionally correct | | |
| A1 | Correct unsimplified equation (for either option) | | |
| M1 | Correct use of impact law. | | |
| A1 | Correct unsimplified equation (for the same option) | | |
| A1 | Correct solution for one pair of *k* and *e* | | |
| M1 | Form second pair of simultaneous equations to fit the model. | | |
| A1 | Both equations correct unsimplified | | |
| M1 | Correct reasoning for elimination of one pair of values | | |
| A1\* | CSO. Deduce the **given result** having considered all the options. | | |
| 6b | M1 | Complete strategy to find an expression in *m*, (*k*) and *u* for the KE lost. | | |
| A1ft | Correct unsimplified expression in *k* or their *k* | | |
| A1 | or better | | |

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| **Question** | **Scheme** | **Marks** | **AOs** |
| **7(a)** |  |  |  |
| Complete strategy to find impulse | M1 | 3.1a |
| CLM parallel to line of centres | M1 | 3.1a |
|  | A1 | 1.1b |
| Use of impact law parallel to line of centres | M1 | 3.1a |
|  | A1 | 1.1b |
| Solve for *v* or *w*: | A1 | 1.1b |
| Correct trig ratio used | B1 | 1.1b |
| Magnitude of impulse | M1 | 3.1a |
|  | A1 | 1.1b |
| **\*** | A1\* | 2.2a |
|  | **(10)** |  |
| **7(b)** | Component of velocity perpendicular to line of centres | B1 | 3.4 |
| Speed  for their *w* | M1 | 2.1 |
|  | A1 | 1.1b |
|  | **(3)** |  |

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| **7(c)** | Impulse only acts along the line of centres | | B1 | 3.5b |
|  | | **(1)** |  |
| **(14 marks)** | | | | |
| **Notes:** | | | | |
| 7a | M1 | Over all strategy: form and solve simultaneous equations and use impulse/momentum. | | |
| M1 | Use of CLM parallel to l of c. All terms needed. Condone sign errors and sin/cos confusion. | | |
| A1 | Correct unsimplified equation | | |
| M1 | Must be used the right way round. Follow their components of *u* and 2*u*. | | |
| A1 | Correct unsimplified equation | | |
| A1 | *v* or *w* correct in terms of *u* and | | |
| B1 | Correct trig ratio seen or implied | | |
| M1 | Magnitude of impulse on either particle. Must be using change in component of velocity. | | |
| A1 | Correct unsimplified in terms of *m*, *u* and | | |
| A1\* | Substitute trig values and deduce the **given result** | | |
| 7b | B1 | Use conservation of component of velocity perpendicular to line of centres | | |
| M1 | Use of Pythagoras to combine the components parallel and perpendicular to the line of centres. Follow their *w*. | | |
| A1 | Any equivalent simplified form | | |
| 7c | B1 | Any valid modelling assumption – no spin, no friction, no change perpendicular to the line of centres | | |