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Examiners' Report
Principal Examiner Feedback

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In Mechanics M2 (6678/01)

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This paper offered all students an opportunity to demonstrate their knowledge and understanding. Many students did well in the early questions, but later questions offered more discrimination and challenge.

Much of the work seen was completed to a very good standard, but the standard of presentation varied considerably. The best solutions were accompanied by clear, accurately labelled, diagrams. Some students would earn more marks for correct methods if they wrote down the formulae they intended to use before substituting in their values - there is a difference between making a slip in applying a correct formula and using an incorrect formula. In checking their work, students should make sure that their response actually answers the question set.

Students should be reminded of the need to make their work clear to the examiners - some handwriting is so small that it is difficult to read. It would be helpful if students took more care in writing figures - there needs to be a distinction between 4 and 9, and it is common to see students miscopying their own 3, 5 and 8.

Students need to be reminded to read the rubric and the questions very carefully. In all cases, where a value for g is substituted, the value should be 9.8 m s^{-2}. The use of 9.81 will be penalised as an accuracy error. The rubric on the paper gives students a very clear reminder about the accuracy expected after the use of 9.8, but many students lose marks for giving too many significant figures in their final answers.

Question 1
This question allowed all students to make a confident start to the paper.
(a) The relationship between impulse and momentum was well understood and nearly all students obtained a correct expression for the impulse. However, a significant number of students overlooked the request that they should find the magnitude of the impulse. Most responses worked on the whole vector, although a few worked on the **i** and **j** components separately with many not explaining this well.
(b) Most students identified and calculated an appropriate angle correctly, but many failed to move on to the next step and find the angle with **j**. A quick diagram might have helped students identify the angle they needed to find.

Question 2
(a) Most students found the driving force correctly, and hence the required rate of working. The few errors seen were through missing out a required term or trig. or sign errors. Students who considered the truck and trailer separately tended to make more errors in setting up their equations.
(b) Some students did not understand that the only forces they needed to consider here were the forces acting on the truck. Most errors were due to including the trailer in the equation. Some students formed a dimensionally incorrect equation by using power rather than driving force in their equation of motion. A few students, especially where there had not been a clear diagram, could not identify the remaining forces acting on the truck after separation.
(c) Students who used *suvat* equations rather than the work-energy principle (required by the question) scored no marks here. Many students did attempt to use work and energy, and almost half of all students reached the correct solution. Here again there was some confusion about what forces were involved, with several students including the truck in their working. Other common errors were to leave out the work done against the resistance, or to double count the change in GPE (which many students regard as being distinct from the work done against the weight).

Question 3
(a) The most common approach to this question was the first one given on the mark scheme. The majority of students were able to calculate the correct position of the centre of mass of each part.

However, a significant number of students worked with incorrect mass ratios because they counted the triangle only once, giving a total area of $10a^2$. Some fudging of working was evident when the given answer was not obtained, but many students were able to go back and trace and correct their error. Having been asked to demonstrate a given answer, students needed to give enough detail in their working to confirm that their moments equation did give the required distance.
The most common alternative was to treat the figure as a pair of trapezia. This proved to be more complicated, with several errors in locating the position of the centre of mass of each trapezium.
The question asked students to find the distance of the centre of mass from *EF*. Most students did this, but a minority used distances from other axes - the cleverest of these centring at *G* so the moment of the squares cancelled each other out in both directions.
(b) Relatively few students used symmetry to find the second coordinate of the centre of mass, most preferring to start from scratch and calculate a *y* value. A significant number of students calculated *y* correctly but then used 2*a* instead in an incorrect tangent expression. Some of the solutions here would have benefitted from a good diagram; many students found a relevant angle but did not identify the angle they had been asked to find.

Question 4
(a) This was answered correctly by the vast majority of students. Many students used calculators or the quadratic formula rather than direct factorisation to obtain their solutions.
(b) Nearly all students understood the relationship between velocity, acceleration and displacement, and differentiated. Some students substituted $t = 3$ instead of $t = \frac{7}{3}$, which happened to give the same answer but scored no marks. A large number of students gave the answer as -2 and did not go on to state the magnitude.
(c) Most students knew that the question required them to integrate and almost all of them did this correctly. They then substituted the limits to obtain the correct answer. It was a common error for students to leave the answer as negative and not interpret distance as being positive. Some seemed unclear as to which distance was required and went on to calculate the total distance travelled up to $t = 3$. A handful used zero as one of their limits for *t* or added the displacements together instead of subtracting them. A small minority of students made inappropriate use of *suvat* equations.
(d) This part was more of a challenge for the majority of students and several did not attempt it. Those who followed the discriminant method, or completing the square, still needed to explain the significance of their results, which many did not. The statement "math error" is not sufficient justification to demonstrate that an equation has no roots. Students who went for more complicated methods and descriptive prose were generally less successful.

Question 5
(a) Many students started by writing down a lot of equations without any real direction. The simplest way to reach an equation in *R* only was to take moments about *C*, because this does not involve the other two unknowns, *T* and β. A good alternative, but double the amount of work, was to take moments about *A* and about *B* and then eliminate $T\sin\beta$. Whether taking moments or resolving, the most common error was to omit terms - usually the friction, but the weight was also often overlooked. Some students had *T* acting at angle α to the horizontal.
(b) Many students wrote down correct equations in part (a) that would have been useful if they had gone on to use them in part (b). A large number made their working so complicated in part (a) that they gave up and offered no solution to part (b). Students who resolved parallel and perpendicular to the rod were often successful because their equations lead them straight to a value for $\tan\beta$,
Those students who resolved vertically and horizontally could have moved directly to a value for $\tan(\beta-\alpha)$ but they often made their equations more complicated than necessary by expanding $\sin(\beta-\alpha)$ and $\cos(\beta-\alpha)$.

Question 6

(a) The working for this question was often muddled and untidy. Most students did eventually write down a correct equation for the vertical motion, equating either the vertical distances travelled by each particle or the initial vertical components of velocity. The equation for the horizontal motion proved to be more difficult, as many students equated the horizontal distances rather than stating that their sum was 40 m. Some students made errors through incorrect use of *suvat* equations (usually without quoting the equation they were trying to use). Students with a correct pair of simultaneous equations often made accuracy errors in solving them. There were also problems with rounding errors caused by 26.458 being rounded incorrectly to 26.4 or 27.

(b) The information given in the question was sufficient for students to be able to answer part (b) without completing part (a) and many correct solutions were seen. A few students found the vertical component of the velocity but did not go on to combine it with the horizontal component. Very few students used the energy approach.

Question 7

(a) The relationship between impulse and momentum was well understood, but a significant number of students failed to appreciate the effect of the change of direction on the impulse whilst other solutions lost at least one of the factors m and u.

(b) Many students did draw some form of diagram, but that did not prevent a large number of solutions from assuming that A and B would both be moving towards the wall after their collision - an assumption that suggests that students struggled with their intuitive understanding of the problem. Nearly all students were able to use the conservation of linear momentum and Newton's Experimental Law correctly as well as work through the algebra needed to find an expression for the velocity of B after the impact. The necessity to show that the particles were moving in the same direction after the impact, required explicit reference to $e \leq 1$, something that was often implied but not stated. Several students analysed the direction of motion of A after the motion, but this was not expected as the nature of the impact leads to only one possible outcome.

(c) Many students offered correct solutions to this problem. The working to find the value of e was often made more complicated than necessary by students multiplying out the brackets in their equation for kinetic energy rather than simply spotting that they were equating two perfect squares and using what they knew about the direction of motion. Some errors were caused by students placing the $\frac{1}{4}$ on the wrong side of their equation, and several students included the kinetic energy of A in their equation.

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