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GCE Mechanics M3 (6679) Paper 01

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Introduction

There was something for all abilities on this paper; questions 2 and 3 proved accessible to almost all while 4 and 6 were answered successfully only by the most able. There was no evidence that candidates had been short of time, although many had saved time by making no attempt at the hard questions. The general standard of presentation seems to be getting worse – too many scribbled solutions in hard to decipher handwriting and, very noticeable on this paper, far too many answers without adequate reasoning. Many candidates lost potential method marks by just writing numbers where they should have been showing their reasoning. This was common, not only in the difficult questions (moments in 4(b), integrals in 6(a) and distances in 6(b)), but also in straightforward calculations such as solving quadratic equations. They should be reminded that they risk losing marks if they solve these by calculator without showing any working. Similarly, candidates need reminding of the risks of substituting numbers into any formula without first quoting the formula. They should also be discouraged from doing working in pencil and rubbing it out – this can lead to unjustified statements.

Although the specification states that the use of integration and/or symmetry to determine the centre of mass of a uniform body will be required it would appear from the responses seen for question 6 that for many candidates this part of the syllabus had been ignored.

In calculations the numerical value of g which should be used is 9.8, as advised on the front of the question paper. Final answers should then be given to 2 (or 3) significant figures – more accurate answers will be penalised, including fractions. If there is a printed answer to show then candidates need to ensure that they show sufficient detail in their working to warrant being awarded all of the marks available.

In all cases, as stated on the front of the question paper, candidates should show sufficient working to make their methods clear to the Examiner.

If a candidate runs out of space in which to give his/her answer then he/she is advised to use a supplementary sheet – if a centre is reluctant to supply extra paper then it is crucial for the candidate to say whereabouts in the script the extra working is going to be done.

Question 1

This seemed a perfectly straightforward question which should have offered an easy start but it proved surprisingly difficult for many. Of the correct attempts at (a), those using $v\frac{\mathrm{d}v}{\mathrm{d}x}$ were generally more successful than those differentiating $\frac{1}{2}v^2$ as these often forgot to square the initial 2. However, alongside these correct solutions were a great many wrong claims that $a = \frac{\mathrm{d}v}{\mathrm{d}x}$. Those who knew the correct method for (b) almost always completed the solution without error, even though some made it very difficult for themselves by, for instance, integrating $\frac{1}{2}\mathrm{e}^{-x}$ by parts. Only a very few forgot the "+c" in their integral, so losing 3 marks. The many failed attempts at (b) often revealed a very weak grasp of the underlying calculus; solutions saying $\frac{\mathrm{d}x}{\mathrm{d}t} = 2\mathrm{e}^{-x},\ x = 2\mathrm{e}^{-x}t + c$ were not unusual, and there were similar ones starting with $\frac{\mathrm{d}v}{\mathrm{d}t} =$ (answer to part a). Others juggled meaninglessly with integral signs, differentials and formulae without ever reaching the starting point for a solution. A small but significant number used the given formula for v to find the velocity at t = 0 and 1 and then used a constant acceleration equation. Several candidates failed to read the requirements of the question, namely to find x in terms of t, leaving their answer either as $\mathrm{e}^x = 2t + 1$ or t as a function of x.

Question 2

This proved very straightforward for almost all and the majority gained full marks. The most common error among the rest was to give a negative answer in (b). Only a few tried to solve (c) using degrees or using cosine instead of sine. In questions like this, where a constant found in (a) is used repeatedly, they should always remember to double check that first calculation; a few unfortunates lost 4 marks in an easy question through a careless slip in finding ω. As ever, a very few seemed to have no knowledge of SHM and either tried to use constant acceleration equations or left a blank page.

Question 3

This too proved very straightforward for the majority and by far the most common mark was 9/10, with one mark lost for giving a 4 significant figure answer for the upper tension. Numerical slips accounted for most of the other lost marks, most frequently cos θ = 0.4/0.6 or errors in calculating the radius. This was one of the questions where they could note the earlier comment about writing a general, formulaic equation before a numerical one; quite a few wrote their horizontal equation using immediately a calculator generated value for $m\omega^2r$. An error here, if the formula hadn't been shown, would lose 6 marks. Method errors, such as using a tension in only the top string or quoting a wrong acceleration formula, were seen only rarely. Not all candidates substituted numerical values into their equations before solving simultaneously – substitution produced equations which were much easier to handle.

Question 4

Part (a) was generally well done but (b) proved too hard for all but the most able. The most common errors in (a) were caused by using a wrong formula for the volumes or by not reading the question and working with areas of triangles. Candidates should be reminded that these formulae are not in the formula book and need to be learned. A few added the two moments instead of subtracting, a solution which, unfortunately for them, led to the "correct" answer of 5a/4 if distances had been measured from the base.

Many made no significant attempt at (b) at all. Among those who did, there were a lot of very poor attempts which gave the impression that they were expecting it to be much easier than it was and that all they should need to do was to find the right way of combining the information from (a) with 45°, 22.5° or maybe $\tan^{-1} 0.5$. It didn't seem to occur to them that they needed to do a significant amount of preliminary work on the geometry of the shape. A large clear diagram was vitally important for a successful solution but was rarely seen. The majority of the valid efforts attempted the moments method but struggled to find the correct distances. A number of these showed no reasoning to justify the numerical distances they were using. Those who set out to calculate the coordinates of the new centre of mass were generally more successful in earning marks, even though the majority of these couldn't then see how to use this information. A third approach, which unfortunately led nowhere, was to find the position of the new C of M by considering ratios on the line joining the original C of M to the extra particle. This located the C of M at a known distance from the corner, but none of those who tried this method were able to see that they needed extra information to be able to reach a solution. Fully correct solutions to (b) were relatively rare but usually very clearly argued, with the very best taking it for granted that an exact expansion of $\tan(45 - \tan^{-1} 0.5)$ would be expected.

Question 5

Part (a) was generally answered well, but as ever, there was often not as much working as is desirable for a "show that" question. Most chose to take the centre of the circle as the zero level for GPE, but some used the bottom while others simply worked with a change in height.

Part (b) was answered well on the whole. Most candidates did resolve, usually including the reaction and then setting it to zero. The direction of the reaction was not always correct but as it was then equated to zero this did not effect the solution. $\cos\theta = \frac{2}{5}$ was usually then obtained correctly by substituting the expression for v^2 given in (a) and a correct expression for v quickly followed. A few candidates seemed to think that the question required the value of θ at the point where the particle left the sphere rather than the speed. The most common mistake was to say that the particle leaves the surface when $\theta = 90$.

Question 6

Candidates who used the "first principles" method for (a) as given in the mark scheme were few and far between. Many opted to ignore the demand to use calculus and simply used the general result. They gained a maximum of B1 in part (a), often given when they used the area or mass in part (b). The majority opted to use either $\int xy\,\mathrm{d}x$ or $\int \frac{1}{2}y^2\mathrm{d}x$ depending on how they chose their axes relative to the sides of their triangle. The attempts at finding the equation of the line needed were poor, as were the attempts to obtain correct limits. Those who achieved a correct result for their integral rarely gave any meaningful reference to the fact that they had only considered half of the given triangle - they had arrived at the result they needed to prove, so felt they must have finished.

In part (b) most could obtain the area of the sectors which had been removed from the triangle. Few candidates could find the correct distance of the centre of mass of a sector along its radius. Incorrect formulae were used frequently; when the correct formulae was applied the angle often used was $\frac{\pi}{3}$ instead of $\frac{\pi}{6}$. Sometimes degrees were used instead of radians. Often this distance along the radius was then used in a moments equation without resolving to obtain a distance from the base of the triangle. In many cases it was impossible to unravel the candidate's attempt at the distance and marks could have been thrown away because of this. Overall, it was a small minority of candidates who achieved full marks on this question with many only scoring B1 in (a) and the first B1 in (b) or simply making no attempt at all.

Question 7

Part(a) proved to be very straightforward and most gained 3 marks.

Part (b) generally saw a correct approach, but there were a fair number of careless mistakes, either muddling up the distances or slipping up with the equation. Of those who split the motion into two parts not all included the necessary kinetic energy terms for their dividing point. Quite a few candidates did not show any working for solving their quadratic, which was costly if they had made a mistake earlier. Some candidates overlooked their substitution of a numerical value for g and failed to round their answer to 2 or 3 significant figures.

The specification requires a proof that a particle moves with SHM by obtaining an equation of the form $\ddot{x} = -\omega^2 x$. A common error was that the acceleration was left as "*a*" rather than $\ddot{x}$. Many attempts at the equation of motion measured *x* from the natural length rather than the equilibrium level and some candidates omitted the weight from their equation. Those who made both of these errors appeared to obtain a correct result but double errors are not rewarded with full marks; in this case no marks could be given as the equation had a missing force. At this level we expect to see a concluding statement to a question of this type, otherwise it is not clear whether the candidate is aware the work is complete. A fully numerical proof, a fully algebraic proof or a partly numerical and partly algebraic proof are all acceptable as there is no demand here to obtain the value of ω. However, this is needed for part (d).

When doing part (d) many candidates showed that they had little appreciation of the amplitude of this motion as they used an unacceptable value, often 0.15, for their *a* in $v = a\omega$. Often the amplitude used was 0.5, obtained by subtracting 0.9 (*AE*) from 1.4 (the rounded value of *AC*). This was premature approximation and gained M1 only.

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