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Examiners' report

MATHEMATICS (MEI)

3895-3898, 7895-7898

4763/01 Summer 2018 series

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Contents

Introduction

Our examiners' reports are produced to offer constructive feedback on candidates' performance in the examinations. They provide useful guidance for future candidates. The reports will include a general commentary on candidates' performance, identify technical aspects examined in the questions and highlight good performance and where performance could be improved. The reports will also explain aspects, which caused difficulty and why the difficulties arose, whether through a lack of knowledge, poor examination technique, or any other identifiable and explainable reason.

Where overall performance on a question/question part was considered good, with no particular areas to highlight, these questions have not been included in the report. A full copy of the question paper can be downloaded from OCR.

Paper 4763/01 series overview

This was the final regular examination of Mechanics 3 (4763/01) unit from the 3890-7892 suite of GCE Mathematics qualifications. The majority of candidates were certificating A Level Further Maths, the rest certificating AS Further Maths. The work on this paper was generally of a high standard. Most candidates were able to demonstrate good knowledge and understanding of the topics being examined, and completed the paper in the time allowed.

The quality of the answers on centres of mass (question 1) and dimensional analysis (question 4(b)) was extremely good. The candidates found circular motion (question 2) and elasticity (question 3) to be more challenging, and had the most difficulty with simple harmonic motion (question 4(a)).

There were several places where the answers were given on the question paper. In such cases, candidates are advised to show full details of all their working, to avoid losing marks unnecessarily.

Question 1 (i)

1 The shaded region R in the xy plane is bounded by the axes and the part of the curve $y = 8 - x^3$ that lies in the first quadrant as shown in Fig. 1. The points A and B on the boundary of R are at the origin and the point where the curve meets the positive x-axis, respectively.

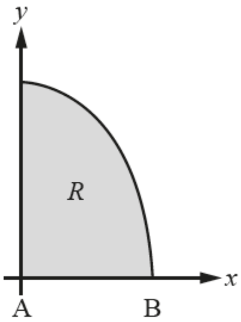

Fig. 1

A uniform solid is formed by rotating R through one complete revolution about the x-axis.

(i) Find the coordinates of the centre of mass of the solid. **[7]**

Most candidates understood how to find the x-coordinate of the centre of mass, and carried out the work accurately. Most also stated that the y-coordinate was zero, with just a few omitting to mention this.

Question 1 (ii)

A uniform lamina is made in the shape of R.

(ii) Show that the coordinates of the centre of mass of the lamina are $\left(\frac{4}{5}, \frac{24}{7}\right)$. **[6]**

The techniques for finding the centre of mass of a lamina were well known, and most candidates applied them accurately. With the answers given, any mistakes made were usually corrected.

Question 1 (iii)

The lamina is suspended freely from the point B.

(iii) Calculate the angle that AB makes with the vertical. **[3]**

Most candidates identified a suitable right-angled triangle and used $\tan\theta = \frac{\bar{y}}{2-\bar{x}}$.

Some used $\tan\theta = \frac{\bar{y}}{1-\bar{x}}$, presumably taking the length of AB to be 1 instead of 2. The most common error was to use $\tan\theta = \frac{\bar{y}}{\bar{x}}$, which gives the angle when the lamina is suspended from the point A.

Question 2 (i)

2 A smooth cylindrical pipe of internal radius 0.7 m is fixed in a position with its axis horizontal. A small ball of mass 0.1 kg is inside the pipe and is projected horizontally from the lowest point, A, of the pipe. The ball moves in a vertical plane perpendicular to the axis of the cylinder. The initial speed of the ball is $5\,\text{m s}^{-1}$. The point B is where the ball first reaches the same vertical level as the axis of the pipe. The ball is still in contact with the pipe at B. The cross-section of the pipe in which the ball moves and the positions of A and B are shown in Fig. 2.

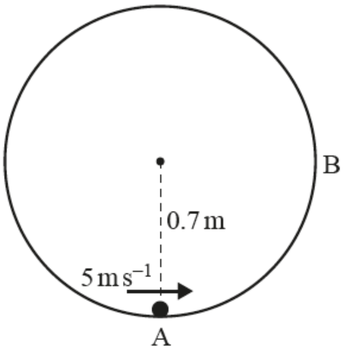

Fig. 2

(i) Calculate the speed of the ball when it is at B. Calculate also the normal reaction of the pipe on the ball at B. **[5]**

Most candidates applied the conservation of energy correctly to find the speed at B, and then used the acceleration towards the centre to find the normal reaction.

Question 2 (ii)

The ball leaves the inner surface of the pipe at the point C. It subsequently passes through a point D which is vertically above A.

(ii) Calculate the horizontal and vertical components of the velocity of the ball at C. **[10]**

This part involved several steps.

Most candidates started by writing down the radial equation of motion correctly. Conservation of energy was usually also applied correctly, with some making sign errors or missing out part of the gravitational potential energy.

These two equations then had to be solved simultaneously to find the speed at C and the direction of OC (where O is the centre of the circle), and this was generally done well.

Finally, the velocity had to be resolved into horizontal and vertical components, and this did cause some difficulty. The velocity is perpendicular to OC, and many candidates were not sufficiently careful with the angles.

It was very common for the horizontal and vertical components to be interchanged. Nevertheless, the overall standard of the work was good, and about 60% of the candidates scored full marks on this part.

Question 2 (iii)

(iii) Hence determine the distance AD. **[5]**

This was an exercise in projectile motion, with the starting position and initial velocity given by the answers to part (ii). Most candidates recognised this, using horizontal motion to find the time, then vertical motion to find the height of D. Some made sign errors in the calculation, a few assumed that the vertical velocity was constant, and many did not add on the height of C correctly. The average mark for this part was 3 out of 5.

Question 3 (i)

3 A light elastic string AB has natural length 0.8 m and modulus of elasticity 70 N. The end A is attached to a fixed point and the end B is attached to a particle of mass 1.2 kg.

The string and particle hang in equilibrium with B vertically below A.

(i) Show that the stretched length of the string is 0.9344 m. **[4]**

Almost all candidates applied Hooke's law correctly to obtain the given result.

Question 3 (ii)

The particle is now held at a point 1.3 m vertically below A and released from rest. In the subsequent motion the speed of the particle is $v\,\text{m s}^{-1}$ when it is at a height of h m above the release point.

(ii) Show that, during the motion before the string becomes slack, $v^2 = \frac{1}{3}(159.95h - 218.75h^2)$. **[6]**

Most candidates approached this by forming an equation involving kinetic energy, gravitational potential energy and elastic potential energy. This was generally well done, with some candidates making errors with signs or the extensions used in the elastic energy terms.

The answer is given, so to earn full marks all the working must be correct. Some candidates lost a mark by working with rounded decimals and then claiming that the given (exact) answer followed from their working. The result can also be obtained by using the standard formula $v^2 = \omega^2\left(A^2 - x^2\right)$ for simple harmonic motion, after identifying the quantities ω, A and x. Some candidates did this, and they tended to be less successful than those who used energy.

Question 3 (iii)

(iii) Find an expression for v^2 in terms of h during the motion while the string is slack. **[3]**

This was answered quite well, with about 60% of the candidates obtaining the correct expression. Many candidates considered conservation of energy from the point of release, as in part (ii). Others found the speed when the string becomes slack and then used the constant acceleration formula.

Question 3 (iv)

(iv) Calculate the maximum speed of the particle during its motion. **[4]**

Most candidates realised that the maximum speed occurs at the equilibrium position $(h = 0.3656)$. A common error was to say that the maximum speed occurs at the point where the string becomes slack.

Question 4 (a) (i)

4 **(a)** A simple pendulum consists of a light rigid rod AB of length 1.25 m with a mass 0.8 kg attached to the end B and the rod hinged at the end A so that the rod can rotate freely in a vertical plane. The rod is held at rest with AB making an angle 0.1 radians with the downward vertical, and released from rest.

(i) Show that the motion of the pendulum approximates to simple harmonic motion with period $\frac{5}{7}\pi$ seconds. **[6]**

This proved to be the most challenging item on the paper, with an average mark of 2 out of 6, and a significant number of candidates not gaining any credit.

Candidates were expected to write out the standard proof that the motion of a simple pendulum is approximately simple harmonic. Giving the equation of motion perpendicular to the rod in the form $-mg\sin\theta = m\left(l\ddot{\theta}\right)$ would earn 3 marks, and then $\sin\theta \approx \theta$ leads to the simple harmonic motion equation.

Many candidates considered vertical and horizontal motion, often assuming that the vertical acceleration was zero. When a linear displacement *x* was introduced it was often not clear whether this was intended to be arc length or horizontal distance. The correct equation $\ddot{\theta} = -7.84\theta$ (or $\ddot{x} = -7.84x$) very often appeared, but without justification, this was given no credit since a full justification of the given answer was needed.

Question 4 (a) (ii)

(ii) Calculate the angular speed of the pendulum when it has turned through 0.05 radians from its initial position. **[2]**

Most candidates understood how to apply the standard simple harmonic motion formulae, although some used $\omega = \frac{5\pi}{7}$ (the period) instead of $\omega = 2.8$. Those who were working with linear displacement *x* needed to convert the speed they found to angular speed, and many omitted to do this.

Question 4 (a) (iii)

(iii) Calculate the time the pendulum takes to turn through 0.05 radians from its initial position. **[2]**

Most candidates used a displacement-time equation of the correct form. Some chose to use a speed-time equation with the angular speed found in part (ii).

Question 4 (b) (i)

(b) **(i)** Show that the dimensions of moment of force and the dimensions of kinetic energy are the same. **[2]**

Most candidates gave the dimensions correctly and usually showed the derivations as force x distance and ½(mass) x (speed)^2. Without the derivations, only 1 mark was given, as the candidates were asked to show that the dimensions are the same.

Question 4 (b) (ii)

(ii) Given that angles are dimensionless, state the dimensions of angular speed and angular acceleration. **[2]**

This was very well answered. The most common error was to give the dimensions of linear speed and linear acceleration.

Question 4 (b) (iii)

A compound pendulum is formed when a rigid body is free to rotate about a fixed horizontal axis. The equation of motion of the compound pendulum is

$$\text{moment of weight} = -I\ddot{\theta},$$

where I is the moment of inertia of the compound pendulum and $\ddot{\theta}$ is its angular acceleration.

(iii) Use the equation of motion to deduce that I has dimensions ML^2. **[2]**

This was very well done.

Question 4 (b) (iv)

The kinetic energy, T, of the compound pendulum is believed to be given by the formula

$$T = km^{\alpha} I^{\beta} \dot{\theta}^{\gamma},$$

where k is a dimensionless constant, m is the mass of the compound pendulum and $\dot{\theta}$ is its angular speed.

(iv) Use dimensional analysis to determine α, β and γ. **[3]**

The method for finding the values of the indices was very well understood, and it was usually completed accurately. Some candidates made careless errors, particularly with signs.

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