OCR
Oxford Cambridge and RSA

Wednesday 23 May 2018 – Morning

A2 GCE MATHEMATICS (MEI)

4763/01 Mechanics 3

QUESTION PAPER

Candidates answer on the Printed Answer Book.

OCR supplied materials:
- Printed Answer Book 4763/01
- MEI Examination Formulae and Tables (MF2)

Other materials required:
- Scientific or graphical calculator

Duration: 1 hour 30 minutes

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INSTRUCTIONS TO CANDIDATES

These instructions are the same on the Printed Answer Book and the Question Paper.

- The Question Paper will be found inside the Printed Answer Book.
- Write your name, centre number and candidate number in the spaces provided on the Printed Answer Book. Please write clearly and in capital letters.
- **Write your answer to each question in the space provided in the Printed Answer Book.** Additional paper may be used if necessary but you must clearly show your candidate number, centre number and question number(s).
- Use black ink. HB pencil may be used for graphs and diagrams only.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Answer **all** the questions.
- Do **not** write in the barcodes.
- You are permitted to use a scientific or graphical calculator in this paper.
- Final answers should be given to a degree of accuracy appropriate to the context.
- The acceleration due to gravity is denoted by $g\,\mathrm{m\,s^{-2}}$. Unless otherwise instructed, when a numerical value is needed, use $g = 9.8$.

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- You are advised that an answer may receive **no marks** unless you show sufficient detail of the working to indicate that a correct method is being used.
- The total number of marks for this paper is **72**.
- The Printed Answer Book consists of **16** pages. The Question Paper consists of **4** pages. Any blank pages are indicated.

INSTRUCTION TO EXAMS OFFICER/INVIGILATOR

- Do not send this Question Paper for marking; it should be retained in the centre or recycled. Please contact OCR Copyright should you wish to re-use this document.

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.

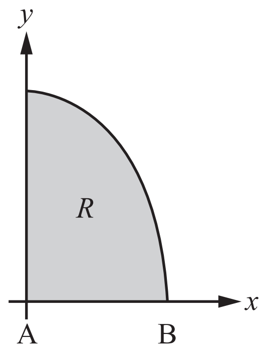

Fig. 1

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]**

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 lamina is suspended freely from the point B.

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

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.

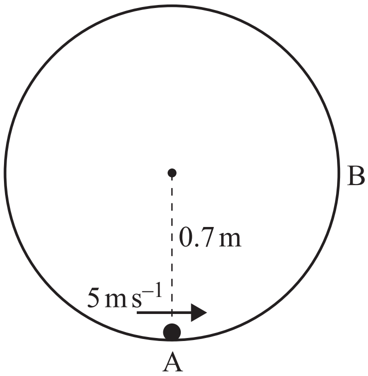

Fig. 2

(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]**

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]**

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

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]**

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]**

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

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

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]**

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

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

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

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

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]**

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]**

END OF QUESTION PAPER

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Candidate forename		Candidate surname	

Centre number						Candidate number				

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1 (i)	

1 (ii)	
	(answer space continued on next page)

1 (ii)	**(continued)**
1 (iii)	

2 (i)

2 (ii)	
	(answer space continued on next page)

2 (ii)	(continued)

2 (iii)	

3 (i)	

3 (ii)	

3 (iii)	

3 (iv)	

4 (a)(i)	

4 (a)(ii)	
4 (a)(iii)	

4 (b)(i)	
4 (b)(ii)	
4 (b)(iii)	

4 (b)(iv)	

GCE

Mathematics (MEI)

Unit **4763**: Mechanics 3 (M3)

Advanced GCE

Mark Scheme for June 2018

This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

Annotations and abbreviations

Annotation in scoris	Meaning
✓and ✗	
BOD	Benefit of doubt
FT	Follow through
ISW	Ignore subsequent working
M0, M1	Method mark awarded 0, 1
A0, A1	Accuracy mark awarded 0, 1
B0, B1	Independent mark awarded 0, 1
SC	Special case
^	Omission sign
MR	Misread
Highlighting	
Other abbreviations in mark scheme	**Meaning**
E1	Mark for explaining
U1	Mark for correct units
G1	Mark for a correct feature on a graph
M1 dep*	Method mark dependent on a previous mark, indicated by *
cao	Correct answer only
oe	Or equivalent
rot	Rounded or truncated
soi	Seen or implied
www	Without wrong working

Subject-specific Marking Instructions for GCE Mathematics (MEI) Mechanics strand

a Annotations should be used whenever appropriate during your marking.

The A, M and B annotations must be used on your standardisation scripts for responses that are not awarded either 0 or full marks. It is vital that you annotate standardisation scripts fully to show how the marks have been awarded.

For subsequent marking you must make it clear how you have arrived at the mark you have awarded.

b An element of professional judgement is required in the marking of any written paper. Remember that the mark scheme is designed to assist in marking incorrect solutions. Correct *solutions* leading to correct answers are awarded full marks but work must not be judged on the answer alone, and answers that are given in the question, especially, must be validly obtained; key steps in the working must always be looked at and anything unfamiliar must be investigated thoroughly.

Correct but unfamiliar or unexpected methods are often signalled by a correct result following an *apparently* incorrect method. Such work must be carefully assessed. When a candidate adopts a method which does not correspond to the mark scheme, award marks according to the spirit of the basic scheme; if you are in any doubt whatsoever (especially if several marks or candidates are involved) you should contact your Team Leader.

c The following types of marks are available.

M
A suitable method has been selected and *applied* in a manner which shows that the method is essentially understood. Method marks are not usually lost for numerical errors, algebraic slips or errors in units. However, it is not usually sufficient for a candidate just to indicate an intention of using some method or just to quote a formula; the formula or idea must be applied to the specific problem in hand, eg by substituting the relevant quantities into the formula. In some cases the nature of the errors allowed for the award of an M mark may be specified.

A
Accuracy mark, awarded for a correct answer or intermediate step correctly obtained. Accuracy marks cannot be given unless the associated Method mark is earned (or implied). Therefore M0 A1 cannot ever be awarded.

B
Mark for a correct result or statement independent of Method marks.

E
A given result is to be established or a result has to be explained. This usually requires more working or explanation than the establishment of an unknown result.

Unless otherwise indicated, marks once gained cannot subsequently be lost, eg wrong working following a correct form of answer is ignored. Sometimes this is reinforced in the mark scheme by the abbreviation isw. However, this would not apply to a case where a candidate passes through the correct answer as part of a wrong argument.

d When a part of a question has two or more 'method' steps, the M marks are in principle independent unless the scheme specifically says otherwise; and similarly where there are several B marks allocated. (The notation 'dep *' is used to indicate that a particular mark is dependent on an earlier, asterisked, mark in the scheme.) Of course, in practice it may happen that when a candidate has once gone wrong in a part of a question, the work from there on is worthless so that no more marks can sensibly be given. On the other hand, when two or more steps are successfully run together by the candidate, the earlier marks are implied and full credit must be given.

e The abbreviation ft implies that the A or B mark indicated is allowed for work correctly following on from previously incorrect results. Otherwise, A and B marks are given for correct work only — differences in notation are of course permitted. A (accuracy) marks are not given for answers obtained from incorrect working. When A or B marks are awarded for work at an intermediate stage of a solution, there may be various alternatives that are equally acceptable. In such cases, exactly what is acceptable will be detailed in the mark scheme rationale. If this is not the case please consult your Team Leader.

Sometimes the answer to one part of a question is used in a later part of the same question. In this case, A marks will often be 'follow through'. In such cases you must ensure that you refer back to the answer of the previous part question even if this is not shown within the image zone. You may find it easier to mark follow through questions candidate-by-candidate rather than question-by-question.

f Unless units are specifically requested, there is no penalty for wrong or missing units as long as the answer is numerically correct and expressed either in SI or in the units of the question. (e.g. lengths will be assumed to be in metres unless in a particular question all the lengths are in km, when this would be assumed to be the unspecified unit.)

We are usually quite flexible about the accuracy to which the final answer is expressed and we do not penalise over-specification.

When a value is given in the paper
Only accept an answer correct to at least as many significant figures as the given value. This rule should be applied to each case.

When a value is not given in the paper
Accept any answer that agrees with the correct value to 2 s.f.

ft should be used so that only one mark is lost for each distinct error made in the accuracy to which working is done or an answer given. Refer cases to your Team Leader where the same type of error (e.g. errors due to premature approximation leading to error) has been made in different questions or parts of questions.

There are some mistakes that might be repeated throughout a paper. If a candidate makes such a mistake, (eg uses a calculator in wrong angle mode) then you will need to check the candidate's script for repetitions of the mistake and consult your Team Leader about what penalty should be given.

There is no penalty for using a wrong value for *g*. E marks will be lost except when results agree to the accuracy required in the question.

g Rules for replaced work

If a candidate attempts a question more than once, and indicates which attempt he/she wishes to be marked, then examiners should do as the candidate requests.

If there are two or more attempts at a question which have not been crossed out, examiners should mark what appears to be the last (complete) attempt and ignore the others.

NB Follow these maths-specific instructions rather than those in the assessor handbook.

h For a *genuine* misreading (of numbers or symbols) which is such that the object and the difficulty of the question remain unaltered, mark according to the scheme but following through from the candidate's data. A penalty is then applied; 1 mark is generally appropriate, though this may differ for some units. This is achieved by withholding one A mark in the question.

Marks designated as cao may be awarded as long as there are no other errors. E marks are lost unless, by chance, the given results are established by equivalent working.

'Fresh starts' will not affect an earlier decision about a misread.

Note that a miscopy of the candidate's own working is not a misread but an accuracy error.

i If a graphical calculator is used, some answers may be obtained with little or no working visible. Allow full marks for correct answers (provided, of course, that there is nothing in the wording of the question specifying that analytical methods are required). Where an answer is wrong but there is some evidence of method, allow appropriate method marks. Wrong answers with no supporting method score zero. If in doubt, consult your Team Leader.

j If in any case the scheme operates with considerable unfairness consult your Team Leader.

Question			Answer	Marks	Guidance	
1.	(i)		(By symmetry,) $\bar{y} = 0$	B1		
			$V = \int_0^2 \pi(8 - x^3)^2 \, dx$	M1	For $\int (8 - x^3)^2 \, dx$	
			$= \pi\left[64x - 4x^4 + \frac{1}{7}x^7\right]_0^2$	M1	Expand and integrate (3 terms; allow one error; limits not required)	
			$= \frac{576}{7}\pi$	A1	For 576/7	
			$V\bar{x} = \int_0^2 \pi x(8 - x^3)^2 \, dx$	M1	For $\int x(8 - x^3)^2 \, dx$	
			$= \pi\left[32x^2 - \frac{16}{5}x^5 + \frac{1}{8}x^8\right]_0^2$	M1	Expand and integrate (3 terms; allow one error; limits not required)	
			$\Rightarrow \bar{x} = \frac{\left(\frac{288\pi}{5}\right)}{\left(\frac{576\pi}{7}\right)} = \frac{7}{10}$	A1		
				[7]		
	(ii)		$A = \int_0^2 (8 - x^3) \, dx = \left[8x - \frac{1}{4}x^4\right]_0^2 = 12$	B1	For 12 *(can be implied)*	
			$A\bar{x} = \int_0^2 x(8 - x^3) \, dx$	M1	For $\int x(8 - x^3) \, dx$	
			$= \left[4x^2 - \frac{1}{5}x^5\right]_0^2$	M1	Allow one error. Limits not required	
			$\Rightarrow \bar{x} = \frac{\left(\frac{48}{5}\right)}{12} = \frac{4}{5}$	E1	Answer given. Be convinced.	
			$A\bar{y} = \int_0^2 \frac{1}{2}(8 - x^3)^2 \, dx = \frac{288}{7}$	M1	For $\int \frac{1}{2}(8 - x^3)^2 \, dx$	
			$\Rightarrow \bar{y} = \frac{\left(\frac{288}{7}\right)}{12} = \frac{24}{7}$	E1	Answer given. Be convinced. Exact work required	
				[6]		
	(iii)		$\tan\theta = \frac{\frac{24}{7}}{2 - \frac{4}{5}}$	M1	Find suitable right angled triangle	
				A1	Correct expression for $\tan\theta$	
			$\theta = 71°$	A1	(70.7099...)	
				[3]		

Question			Answer	Marks	Guidance
2.	(i)		$\frac{1}{2}\times 0.1\times 5^2=\frac{1}{2}\times 0.1v^2+0.1g\times 0.7$	M1 A1	Use energy (PE and KE) Correct equation
			$\Rightarrow v^2=11.28\Rightarrow v=3.36\text{ m s}^{-1}$ (3sf) $R=0.1v^2/0.7$ $=1.61$ N (3sf)	A1 M1 A1 ft [5]	(3.35857…) N2L with v^2/r (1.61142…) FT is $v^2/7$
	(ii)		if θ = angle with upward vertical $mg\cos\theta=mv^2/0.7$	M1* A1	N2L in radial direction Correct equation
			$\frac{1}{2}mv^2+mg\cdot 0.7\cos\theta=\frac{1}{2}m\cdot 5^2-mg\cdot 0.7$	M1* A1	Energy equation (KE and PE) Correct equation
			$\frac{1}{2}(0.7g\cos\theta)+0.7g\cos\theta=\frac{1}{2}\cdot 5^2-0.7g$	M1dep*	Solve for one of $\cos\theta$, θ, v or v^2. Dependent on previous M marks
			$\cos\theta\approx 0.548$ (or $\theta\approx 56.8°$)	A1	$\cos\theta$ or θ correct ($\cos\theta=\frac{188}{343}=0.548104\ldots$, $\theta=56.7628\ldots$)
			$v^2=3.76$ (or $v\approx 1.94$)	A1	v or v^2 correct ($v=1.93907\ldots$)
			Components are $v\cos\theta$, $v\sin\theta$ Horiz $v\cos\theta$ **and** vert $v\sin\theta$ Horiz 1.06 m s^{-1} vert 1.62 m s^{-1}	M1 M1 A1 [10]	Either evaluated Both identified and evaluated (1.06281…) and (1.62185…)
	(iii)		Horizontal disp. from C = $0.7\sin\theta$ $t=(0.7\sin\theta)/1.06$ AD $=1.62t-4.9t^2+0.7(1+\cos\theta)$	M1* M1dep* M1	Find horizontal displacement for their θ Find time to pass above A Use $s=ut+\frac{1}{2}at^2$
			 $=0.49$ m	F1 A1 [5]	All correct working (using answers to (ii)) including initial height cao (also accept 0.48 m with correct working) (0.490114…)

Question		Answer	Marks	Guidance
3.	(i)	Equilibrium so $T = mg$	B1	*Can be implied*
		$\frac{70x}{0.8} = 1.2g$	M1	Use of Hooke's law
		$\Rightarrow x = 0.1344$	A1	Must see previous line *(can be implied)*
		$\Rightarrow l = 0.9344$	E1	Must have earned all previous marks
			[4]	
	(ii)	$\frac{70 \times 0.5^2}{2 \times 0.8} = \frac{70(0.5-h)^2}{2 \times 0.8} + 1.2gh + \frac{1}{2} \cdot 1.2v^2$	M1*	Use extension $0.5 - h$ in EPE term
			A1	Correct EPE at general position
			M1*	Energy equation with KE, PE, EPE
			A1	Correct equation
			M1dep*	Rearrange
		$v^2 = \frac{1}{3}(159.95h - 218.75h^2)$	E1	Be convinced
		Alternative: SHM centred at equilibrium	*M1**	
		$A = 0.3656, \quad x = (\pm)(h - 0.3656)$	*A1*	both
		Finding ω^2	*M1**	Can quote $\omega^2 = \lambda/(ml)$ or consider acceleration
		$\omega^2 = 875/12$	*A1*	
		$v^2 = (\frac{875}{12})(0.3656^2 - (h - 0.3656)^2)$	*M1dep**	
		$v^2 = \frac{1}{3}(159.95h - 218.75h^2)$	*E1*	
			[6]	
	(iii)	$\frac{70 \times 0.5^2}{2 \times 0.8} = 1.2gh + \frac{1}{2} \times 1.2v^2$	M1	Or calculate v^2 when $h = 0.5$ and use in $v^2 = u^2 + 2as$ (oe)
			A1	Or $u^2 = 8.4291 \ldots$ and $s = h - 0.5$ used in $v^2 = u^2 + 2as$ (oe)
		$v^2 = \frac{1}{3}(54.6875 - 58.8h)$	A1	Accept, e.g. $v^2 = 18.2 - 2gh$
			[3]	
	(iv)	Max speed when acceleration zero	M1*	Or differentiate or complete the square on expression in (ii)
		so $T = mg \Rightarrow l = 0.9344 \Rightarrow h = 0.3656$	A1	Correctly deduced by any valid method
		$v^2 = \frac{1}{3}(159.95h - 218.75h^2)$	M1dep*	Use expression in (ii)
		$\Rightarrow v = 3.12 \text{ m s}^{-1}$ (3 s.f.)	A1	(3.121904…)
		Aliter: $v = A\omega = 0.3656\sqrt{\frac{875}{12}} = 3.12$	*M2A1A1*	
			[4]	

Question			Answer	Marks	Guidance
4.	(a)	(i)	$0.8 \times 1.25\ddot{\theta} = -0.8g\sin\theta$	M1	N2L in tangential direction
				A1	For $mg\sin\theta$
				A1	For $a = l\ddot{\theta}$ or $a = \ddot{x}$ with $\theta = x/l$ used (but NOT $\sin\theta = x/l$)
			$\sin\theta \approx \theta$	M1	Must be used
			$\ddot{\theta} \approx -7.84\theta$ i.e. SHM	E1	Must have earned all previous marks
			$T = 2\pi/\sqrt{7.84} = 5\pi/7$	E1	Must have earned all previous marks
				[6]	
		(ii)	$\dot{\theta}^2 = 7.84(0.1^2 - 0.05^2)$	M1	Or other complete method for angular speed (e.g. energy, via time)
			$\dot{\theta} = 0.242$ rad s^{-1}	A1	cao (0.242487…) (0.24236… by energy)
				[2]	
		(iii)	$\theta = 0.1\cos 2.8t$	M1	Or $\theta = 0.1\sin 2.8t$
			$\theta = 0.05 \Rightarrow t = \pi/8.4 \approx 0.374$	A1	cao (0.373999…)
				[2]	
	(b)	(i)	[moment]$= [Fd] = MLT^{-2}L = ML^2T^{-2}$	B1	
			$[KE] = \left[\frac{1}{2}mv^2\right] = M(LT^{-1})^2 = ML^2T^{-2}$	B1	B0 for $\left[\frac{1}{2}mv^2\right] = ML^2T^{-2}$
			Alternative: KE=WD=F.d	*M1*	
			and moment=F.d so same dimensions	*A1*	
				[2]	
		(ii)	$[\dot{\theta}] = T^{-1}$	B1	
			$[\ddot{\theta}] = T^{-2}$	B1	SC1 for S^{-1} and S^{-2}
				[2]	
		(iii)	$ML^2T^{-2} = [I]T^{-2}$	M1	
			$\Rightarrow [I] = ML^2$	E1	Must use given equation, not definition of I
				[2]	
		(iv)	$ML^2T^{-2} = M^{\alpha}.(ML^2)^{\beta}.(T^{-1})^{\gamma}$	M1	
			L: $2\beta = 2 \Rightarrow \beta = 1$,		
			T: $-2 = -\gamma \Rightarrow \gamma = 2$	A1	Both
			M: $1 = \alpha + \beta \Rightarrow \alpha = 1 - \beta = 0$	A1	cao
				[3]	

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Qualification Accredited

Oxford Cambridge and RSA

AS/A LEVEL GCE

Examiners' report

MATHEMATICS (MEI)

3895-3898, 7895-7898

4763/01 Summer 2018 series

Version 1

www.ocr.org.uk/maths

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.

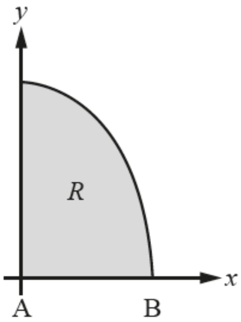

Fig. 1

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 $5\,\mathrm{m\,s^{-1}}$. 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.

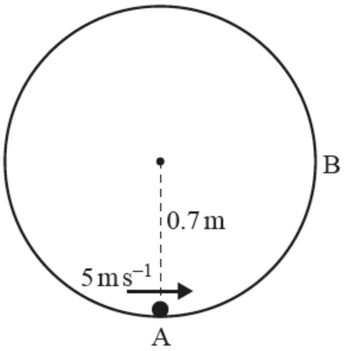

Fig. 2

(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 $v^2 = \omega^2 (A^2 - x^2)$ 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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AS GCE / Advanced GCE / AS GCE Double Award / Advanced GCE Double Award

AS & Advanced GCE Mathematics											
				Max Mark	a	b	c	d	e	u
4721	01	C1 Core mathematics 1 (AS)	Raw	72	61	55	50	45	40	0
			UMS	100	80	70	60	50	40	0
4722	01	C2 Core mathematics 2 (AS)	Raw	72	55	49	43	37	31	0
			UMS	100	80	70	60	50	40	0
4723	01	C3 Core mathematics 3 (A2)	Raw	72	55	48	41	34	28	0
			UMS	100	80	70	60	50	40	0
4724	01	C4 Core mathematics 4 (A2)	Raw	72	54	47	40	34	28	0
			UMS	100	80	70	60	50	40	0
4725	01	FP1 Further pure mathematics 1 (AS)	Raw	72	56	50	45	40	35	0
			UMS	100	80	70	60	50	40	0
4726	01	FP2 Further pure mathematics 2 (A2)	Raw	72	59	53	47	41	35	0
			UMS	100	80	70	60	50	40	0
4727	01	FP3 Further pure mathematics 3 (A2)	Raw	72	47	41	36	31	26	0
			UMS	100	80	70	60	50	40	0
4728	01	M1 Mechanics 1 (AS)	Raw	72	60	51	42	34	26	0
			UMS	100	80	70	60	50	40	0
4729	01	M2 Mechanics 2 (A2)	Raw	72	53	46	39	32	26	0
			UMS	100	80	70	60	50	40	0
4730	01	M3 Mechanics 3 (A2)	Raw	72	50	42	34	27	20	0
			UMS	100	80	70	60	50	40	0
4731	01	M4 Mechanics 4 (A2)	Raw	72	59	53	47	42	37	0
			UMS	100	80	70	60	50	40	0
4732	01	S1 – Probability and statistics 1 (AS)	Raw	72	57	50	43	36	29	0
			UMS	100	80	70	60	50	40	0
4733	01	S2 – Probability and statistics 2 (A2)	Raw	72	56	49	42	35	28	0
			UMS	100	80	70	60	50	40	0
4734	01	S3 – Probability and statistics 3 (A2)	Raw	72	59	50	41	32	24	0
			UMS	100	80	70	60	50	40	0
4735	01	S4 – Probability and statistics 4 (A2)	Raw	72	56	49	42	35	28	0
			UMS	100	80	70	60	50	40	0
4736	01	D1 – Decision mathematics 1 (AS)	Raw	72	55	48	42	36	30	0
			UMS	100	80	70	60	50	40	0
4737	01	D2 – Decision mathematics 2 (A2)	Raw	72	58	53	48	44	40	0
			UMS	100	80	70	60	50	40	0

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AS & Advanced GCE Mathematics (MEI)

				Max Mark	a	b	c	d	e	u
4751	01	C1 – Introduction to advanced mathematics (AS)	Raw	72	60	55	50	45	40	0
			UMS	100	80	70	60	50	40	0
4752	01	C2 – Concepts for advanced mathematics (AS)	Raw	72	53	47	41	36	31	0
			UMS	100	80	70	60	50	40	0
4753	01	(C3) Methods for Advanced Mathematics (A2): Written Paper	Raw	72	61	56	51	46	40	0
4753	02	(C3) Methods for Advanced Mathematics (A2): Coursework	Raw	18	15	13	11	9	8	0
4753	82	(C3) Methods for Advanced Mathematics (A2): Carried Forward Coursework Mark	Raw	18	15	13	11	9	8	0
			UMS	100	80	70	60	50	40	0
4754	01	C4 – Applications of advanced mathematics (A2)	Raw	90	63	56	49	43	37	0
			UMS	100	80	70	60	50	40	0
4755	01	FP1 – Further concepts for advanced mathematics (AS)	Raw	72	55	51	47	43	40	0
			UMS	100	80	70	60	50	40	0
4756	01	FP2 – Further methods for advanced mathematics (A2)	Raw	72	48	42	36	31	26	0
			UMS	100	80	70	60	50	40	0
4757	01	FP3 – Further applications of advanced mathematics (A2)	Raw	72	63	56	49	42	35	0
			UMS	100	80	70	60	50	40	0
4758	01	(DE) Differential Equations (A2): Written Paper	Raw	72	61	54	48	42	35	0
4758	02	(DE) Differential Equations (A2): Coursework	Raw	18	15	13	11	9	8	0
4758	82	(DE) Differential Equations (A2): Carried Forward Coursework Mark	Raw	18	15	13	11	9	8	0
			UMS	100	80	70	60	50	40	0
4761	01	M1 – Mechanics 1 (AS)	Raw	72	51	44	37	31	25	0
			UMS	100	80	70	60	50	40	0
4762	01	M2 – Mechanics 2 (A2)	Raw	72	59	53	47	41	35	0
			UMS	100	80	70	60	50	40	0
4763	01	M3 – Mechanics 3 (A2)	Raw	72	61	54	48	42	36	0
			UMS	100	80	70	60	50	40	0
4764	01	M4 – Mechanics 4 (A2)	Raw	72	59	51	44	37	30	0
			UMS	100	80	70	60	50	40	0
4766	01	S1 – Statistics 1 (AS)	Raw	72	59	53	47	42	37	0
			UMS	100	80	70	60	50	40	0
4767	01	S2 – Statistics 2 (A2)	Raw	72	54	47	41	35	29	0
			UMS	100	80	70	60	50	40	0
4768	01	S3 – Statistics 3 (A2)	Raw	72	61	54	47	41	35	0
			UMS	100	80	70	60	50	40	0
4769	01	S4 – Statistics 4 (A2)	Raw	72	56	49	42	35	28	0
			UMS	100	80	70	60	50	40	0
4771	01	D1 – Decision mathematics 1 (AS)	Raw	72	50	44	38	32	26	0
			UMS	100	80	70	60	50	40	0
4772	01	D2 – Decision mathematics 2 (A2)	Raw	72	55	51	47	43	39	0
			UMS	100	80	70	60	50	40	0
4773	01	DC – Decision mathematics computation (A2)	Raw	72	46	40	34	29	24	0
			UMS	100	80	70	60	50	40	0
4776	01	(NM) Numerical Methods (AS): Written Paper	Raw	72	57	52	48	44	39	0
4776	02	(NM) Numerical Methods (AS): Coursework	Raw	18	14	12	10	8	7	0
4776	82	(NM) Numerical Methods (AS): Carried Forward Coursework Mark	Raw	18	14	12	10	8	7	0
			UMS	100	80	70	60	50	40	0
4777	01	NC – Numerical computation (A2)	Raw	72	55	47	39	32	25	0
			UMS	100	80	70	60	50	40	0
4798	01	FPT - Further pure mathematics with technology (A2)	Raw	72	57	49	41	33	26	0
			UMS	100	80	70	60	50	40	0

AS GCE Statistics (MEI)

				Max Mark	a	b	c	d	e	u
G241	01	Statistics 1 MEI	Raw	72		No entry in June 2018				
			UMS	100	80	70	60	50	40	0
G242	01	Statistics 2 MEI	Raw	72		No entry in June 2018				
			UMS	100	80	70	60	50	40	0
G243	01	Statistics 3 MEI	Raw	72		No entry in June 2018				
			UMS	100	80	70	60	50	40	0

AS GCE Quantitative Methods (MEI)

				Max Mark	a	b	c	d	e	u
G244	01	Introduction to Quantitative Methods (Written Paper)	Raw	72	58	50	43	36	28	0
G244	02	Introduction to Quantitative Methods (Coursework)	Raw	18	14	12	10	8	7	0
			UMS	100	80	70	60	50	40	0
G245	01	Statistics 1	Raw	72	61	55	49	43	37	0
			UMS	100	80	70	60	50	40	0
G246	01	Decision Mathematics 1	Raw	72	50	44	38	32	26	0
			UMS	100	80	70	60	50	40	0

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Level 3 Certificate Mathematics - Quantitative Methods (MEI)

					Max Mark	a	b	c	d	e	u
G244	A	01	Introduction to Quantitative Methods with Coursework (Written Paper)	Raw	72	58	50	43	36	28	0
G244	A	02	Introduction to Quantitative Methods with Coursework (Coursework)	Raw	18	14	12	10	8	7	0
				UMS	100	80	70	60	50	40	0
				Overall	90	72	62	53	44	35	0

Level 3 Certificate Mathematics - Quantitative Reasoning (MEI)

				Max Mark	a	b	c	d	e	u
H866	01	Introduction to quantitative reasoning	Raw	72	56	49	42	35	28	0
H866	02	Critical maths	Raw	60	44	39	34	29	24	0
		*To create the overall boundaries, component 02 is weighted to give marks out of 72	Overall	144	109	96	83	70	57	0

Level 3 Certificate Mathematics - Quantitative Problem Solving (MEI)

				Max Mark	a	b	c	d	e	u
H867	01	Introduction to quantitative reasoning	Raw	72	56	49	42	35	28	0
H867	02	Statistical problem solving	Raw	60	40	36	32	28	24	0
		*To create the overall boundaries, component 02 is weighted to give marks out of 72	Overall	144	104	92	80	69	57	0

Advanced Free Standing Mathematics Qualification (FSMQ)

				Max Mark	a	b	c	d	e	u
6993	01	Additional Mathematics	Raw	100	56	50	44	38	33	0

Intermediate Free Standing Mathematics Qualification (FSMQ)

				Max Mark	a	b	c	d	e	u
6989	01	Foundations of Advanced Mathematics (MEI)	Raw	40	35	30	25	20	16	0