

**ADVANCED GCE  
MATHEMATICS (MEI)**  
Mechanics 3

**4763**

Candidates answer on the answer booklet.

**OCR supplied materials:**

- 8 page answer booklet (sent with general stationery)
- MEI Examination Formulae and Tables (MF2)

**Other materials required:**

- Scientific or graphical calculator

**Wednesday 26 January 2011  
Afternoon**

**Duration:** 1 hour 30 minutes



**INSTRUCTIONS TO CANDIDATES**

- Write your name, centre number and candidate number in the spaces provided on the answer booklet. Please write clearly and in capital letters.
- Use black ink. 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 bar codes.
- 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  $g \text{ m s}^{-2}$ . Unless otherwise instructed, when a numerical value is needed, use  $g = 9.8$ .

**INFORMATION FOR CANDIDATES**

- The number of marks is given in brackets [ ] at the end of each question or part question.
- 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**.
- This document consists of **8** pages. Any blank pages are indicated.

- 1 (i) Write down the dimensions of force, density and angular speed. [3]

The breaking stress,  $S$ , of a material is defined by

$$S = \frac{F}{A}$$

where  $F$  is the force required to break a specimen with cross-sectional area  $A$ .

- (ii) Show that the dimensions of breaking stress are  $\text{ML}^{-1}\text{T}^{-2}$ . [2]

In SI units (based on kilograms, metres and seconds), the unit of breaking stress is the pascal (Pa). The breaking stress of steel is  $1.2 \times 10^9$  Pa.

- (iii) Find the breaking stress of steel when expressed in a new system of units based on pounds, inches and milliseconds, where 1 pound = 0.454 kg, 1 inch = 0.0254 m and 1 millisecond = 0.001 s. [3]

A material has breaking stress  $S$  and density  $\rho$ . When a disc of radius  $r$ , made from this material, is rotated very quickly, there is a critical angular speed at which the disc will break apart. This critical angular speed,  $\omega$ , is given by

$$\omega = kS^\alpha \rho^\beta r^\gamma$$

where  $k$  is a dimensionless constant.

- (iv) Use dimensional analysis to find  $\alpha$ ,  $\beta$  and  $\gamma$ . [4]

Steel has breaking stress  $1.2 \times 10^9$  Pa and density  $7800 \text{ kg m}^{-3}$ . For a steel disc of radius 0.5 m the critical angular speed is  $3140 \text{ rad s}^{-1}$ . Aluminium has density  $2700 \text{ kg m}^{-3}$  and for an aluminium disc of radius 0.2 m the critical angular speed is  $8120 \text{ rad s}^{-1}$ .

- (v) Find the breaking stress of aluminium. [4]

Using a different system of units, a disc of radius 15 is made from material with breaking stress 630 and density 70.

- (vi) Find, in these units, the critical angular speed for this disc. [2]

- 2 (a) A particle P, of mass 48 kg, is moving in a horizontal circle of radius 8.4 m at a constant speed of  $V \text{ m s}^{-1}$ , in contact with a smooth horizontal surface. A light inextensible rope of length 30 m connects P to a fixed point A which is vertically above the centre C of the circle, as shown in Fig. 2.1.

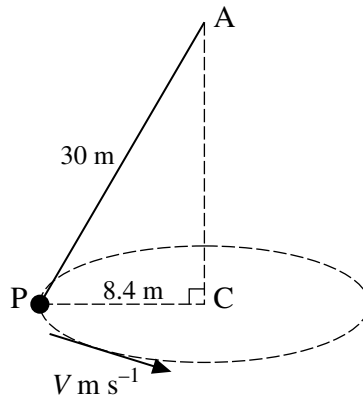


Fig. 2.1

- (i) Given that  $V = 3.5$ , find the tension in the rope and the normal reaction of the surface on P. [5]
- (ii) Calculate the value of  $V$  for which the normal reaction is zero. [4]
- (b) The particle P, of mass 48 kg, is now placed on the highest point of a fixed solid sphere with centre O and radius 2.5 m. The surface of the sphere is smooth. The particle P is given an initial horizontal velocity of  $u \text{ m s}^{-1}$ , and it then moves in part of a vertical circle with centre O and radius 2.5 m. When OP makes an angle  $\theta$  with the upward vertical and P is still in contact with the surface of the sphere, P has speed  $v \text{ m s}^{-1}$  and the normal reaction of the sphere on P is  $R \text{ N}$ , as shown in Fig. 2.2.

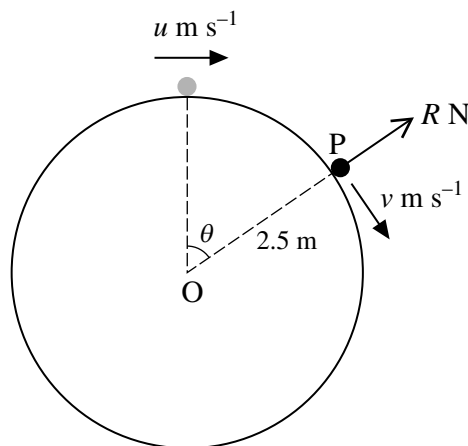
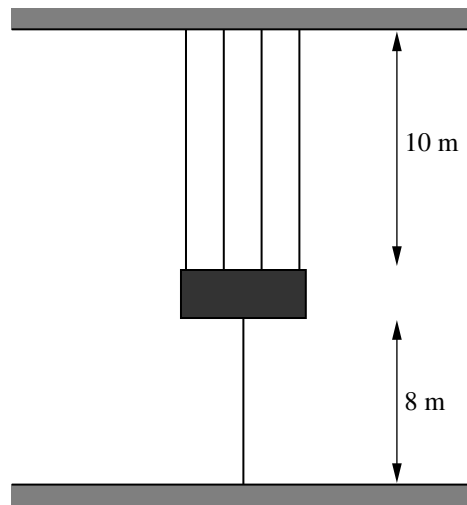


Fig. 2.2

- (i) Show that  $v^2 = u^2 + 49 - 49 \cos \theta$ . [3]
- (ii) Find an expression for  $R$  in terms of  $u$  and  $v$ . [4]
- (iii) Given that P loses contact with the surface of the sphere at the instant when its speed is  $4.15 \text{ m s}^{-1}$ , find the value of  $u$ . [2]

- 3 A block of mass 200 kg is connected to a horizontal ceiling by four identical light elastic ropes, each having natural length 7 m and stiffness  $180 \text{ N m}^{-1}$ . It is also connected to the floor by a single light elastic rope having stiffness  $80 \text{ N m}^{-1}$ . Throughout this question you may assume that all five ropes are stretched and vertical, and you may neglect air resistance.



**Fig. 3**

Fig. 3 shows the block resting in equilibrium, with each of the top ropes having length 10 m and the bottom rope having length 8 m.

- (i) Find the tension in one of the top ropes. [2]
- (ii) Find the natural length of the bottom rope. [4]

The block now moves vertically up and down. At time  $t$  seconds, the block is  $x$  metres below its equilibrium position.

- (iii) Show that  $\frac{d^2x}{dt^2} = -4x$ . [4]

The motion is started by pulling the block down 2.2 m below its equilibrium position and releasing it from rest. The block then executes simple harmonic motion with amplitude 2.2 m.

- (iv) Find the maximum magnitude of the acceleration of the block. [2]
- (v) Find the speed of the block when it has travelled 3.8 m from its starting point. [2]
- (vi) Find the distance travelled by the block in the first 5 s. [4]

4 (a)

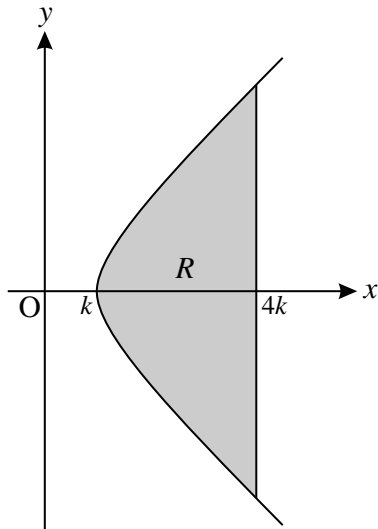


Fig. 4.1

The region  $R$ , shown in Fig. 4.1, is bounded by the curve  $x^2 - y^2 = k^2$  for  $k \leq x \leq 4k$  and the line  $x = 4k$ , where  $k$  is a positive constant. Find the  $x$ -coordinate of the centre of mass of the uniform solid of revolution formed when  $R$  is rotated about the  $x$ -axis. [7]

- (b) A uniform lamina occupies the region bounded by the curve  $y = \frac{x^3}{a^2}$  for  $0 \leq x \leq 2a$ , the  $x$ -axis and the line  $x = 2a$ , where  $a$  is a positive constant. The vertices of the lamina are  $O(0, 0)$ ,  $A(2a, 8a)$  and  $B(2a, 0)$ , as shown in Fig. 4.2.

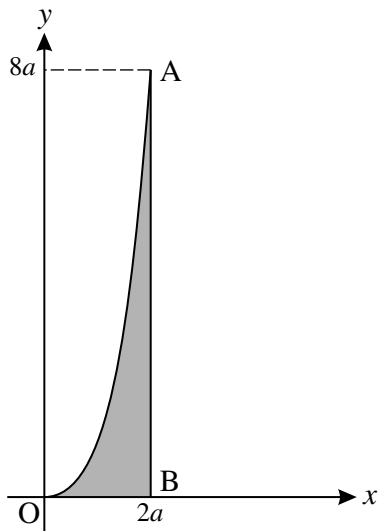


Fig. 4.2

- (i) Find the coordinates of the centre of mass of the lamina. [8]
- (ii) The lamina is freely suspended from the point  $A$  and hangs in equilibrium. Find the angle that  $AB$  makes with the vertical. [3]

**BLANK PAGE**

**BLANK PAGE**

**Copyright Information**

OCR is committed to seeking permission to reproduce all third-party content that it uses in its assessment materials. OCR has attempted to identify and contact all copyright holders whose work is used in this paper. To avoid the issue of disclosure of answer-related information to candidates, all copyright acknowledgements are reproduced in the OCR Copyright Acknowledgements Booklet. This is produced for each series of examinations and is freely available to download from our public website ([www.ocr.org.uk](http://www.ocr.org.uk)) after the live examination series.

If OCR has unwittingly failed to correctly acknowledge or clear any third-party content in this assessment material, OCR will be happy to correct its mistake at the earliest possible opportunity.

For queries or further information please contact the Copyright Team, First Floor, 9 Hills Road, Cambridge CB2 1GE.

OCR is part of the Cambridge Assessment Group; Cambridge Assessment is the brand name of University of Cambridge Local Examinations Syndicate (UCLES), which is itself a department of the University of Cambridge.



**Mathematics (MEI)**

Advanced GCE

Unit **4763**: Mechanics 3

**Mark Scheme for January 2011**

---

OCR (Oxford Cambridge and RSA) is a leading UK awarding body, providing a wide range of qualifications to meet the needs of pupils of all ages and abilities. OCR qualifications include AS/A Levels, Diplomas, GCSEs, OCR Nationals, Functional Skills, Key Skills, Entry Level qualifications, NVQs and vocational qualifications in areas such as IT, business, languages, teaching/training, administration and secretarial skills.

It is also responsible for developing new specifications to meet national requirements and the needs of students and teachers. OCR is a not-for-profit organisation; any surplus made is invested back into the establishment to help towards the development of qualifications and support which keep pace with the changing needs of today's society.

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.

OCR will not enter into any discussion or correspondence in connection with this mark scheme.

© OCR 2011

Any enquiries about publications should be addressed to:

OCR Publications  
PO Box 5050  
Annesley  
NOTTINGHAM  
NG15 0DL

Telephone: 0870 770 6622  
Facsimile: 01223 552610  
E-mail: [publications@ocr.org.uk](mailto:publications@ocr.org.uk)

**General marking instructions for MEI Mechanics****Types of marks**

- M** A suitable method has been selected and applied in a manner which shows the method is essentially understood. Method marks are not generally 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, e.g. 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** Follows **M** mark. Unless modified, it implies that errors already penalized in **earlier** parts of the question will be followed through for **no further loss**. It does **not** imply the following through of errors made in the **current** part of the question. A marks cannot be given unless the associated M mark is earned (including by implication).
- B** Freestanding. Unless modified, it is **cao**.
- 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.
- F** Specifies that working should be followed through within a part of a question or emphasizes that follow through is required from an earlier part of a question.

**General instructions**

1. Mark in red. Correct answers should be ticked, errors which determine marks (usually the first error in each part of a question) should be identified by ringing or by a cross or by underlining or, if an omission, by a caret  $\wedge$ . Do not cross out or obliterate any work. In cases of particular difficulty, brief annotations that explain the marks awarded (or not awarded) are correct or indicate that calculations correctly FT may be helpful should the script be reviewed at a later stage but, in general, comments on the candidate's work or corrections to it should not be written on the script. Each page of the script which includes any part of the candidate's answer must have some indication that it has been seen, e.g. a tick.
2. The marks indicated in the scheme may not be subdivided. If there is genuine doubt whether a candidate has earned a mark, allow the candidate the benefit of the doubt.
3. Unless otherwise indicated, marks once gained cannot subsequently be lost, (e.g. wrong working following a correct form of answer is ignored). However, this would not apply to a case where a candidate passed through the correct solution as part of a wrong argument, (e.g. when asked for an acceleration, finds the correct vector and then goes on to give just the modulus as the answer).
4. 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 M or B 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 run together by the candidate, the earlier marks are implied and full credit must be given.
5. The symbol  $\surd$  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 and B marks are not given for 'correct' answers or results 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 agreed at the standardisation meeting.

6. For a partially correct **part** of a question, exhibit the detailed marks, e.g. M1, A0, *in the margin* at the point where the marks have been first earned. Please give sufficient detail to allow your marking to be understood. For a completely correct **part** of a question, only the total mark for that part need be given, *in the margin*. Do not use subtotals (underlined or otherwise). The question total should be ringed and placed in the margin at the end of the question. *This total MUST equal the sum of all the marks in the margin for that question* and should be entered against the question number in the question grid on the front of the script.
7. If a candidate's answer to a question is in more than one instalment, indicate the carried forward total at the end of one instalment by, for example, ③ and the brought forward total at the start of the next instalment by, for example, ③.
8. The total mark for the paper should be obtained (a) by adding all the unringed marks through the script (checking at the same time that all pages have been marked) and (b) by adding the question marks in the grid in reverse order. The two totals must, of course, tally, and the resulting figure should be written, ringed, on the front of the script.
9. Remember that the mark scheme is designed to assist in marking incorrect solutions. Correct *solutions* get 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.
10. 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 single candidate adopts a method which does not correspond to the marking scheme, award marks according to the spirit of the basic scheme; this will usually involve preserving the ratio **M** : **A + B** : **F** marks and any emphasis on accuracy specific to that question. If you are in any doubt whatsoever (especially if several marks or candidates are involved) you should contact your Team Leader.
11. If a GDC 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.
12. If in any case the scheme operates with considerable unfairness, mark at discretion but please give a brief reason and initial the mark. *This discretion should be used very rarely, and only after consultation with your Team Leader.*
13. If there is any suspicion of cheating or copying, mark according to the scheme and enter the marks on the marksheet as usual. Send the script(s) to your Team Leader, as per OCR instructions. Notes concerning illness etc should be forwarded to OCR, but separately from the scripts or mark sheets. The scripts should be marked exactly as per the scheme, as any special circumstances that may have affected a candidate's performance are dealt with at a later stage.

14. Examiners are reminded of the *VITAL* importance of checking the accuracy of the addition of marks and of the transcriptions onto the marksheets; in particular that the marks are entered against the right candidates. Do not assume that the scripts are in the same order as the names on the marksheet. As detailed in §8 above, each Examiner must check the paper total, obtaining the same figure twice by different methods. The transcription to the marksheet should also be checked; ideally, the Checker should read out the candidate's name and mark from the marksheet, while the Examiner checks with the front of the script.

**The Examiner has final responsibility for the accuracy of the mark recorded on the marksheet.**

### **Tariffs and usage for common errors**

**Note that these general instructions may be varied in individual questions or papers**

#### **Wrong value of $g$ used**

No penalty. E marks will be lost except when results agree to the accuracy required in the question.

#### **Misread**

Lose 1 mark for each consistent misread. FT except when trivialized. E marks lost unless, by chance, the given results are established by equivalent working.

#### **Units**

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 metre unless in a particular question all the lengths are km, when this would be assumed to be the unspecified unit.)

#### **Accuracy**

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, except when for errors due to premature approximation which should be penalised only once in the examination.

#### **Rules for crossed out and/or replaced work**

If work is crossed out and not replaced, examiners should mark the crossed out work if it is legible.

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 two or more attempts are made at a question, and just one is not crossed out, examiners should ignore the crossed out work and mark the work that is not crossed out.

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.

**Some commonly used abbreviations**

AEF	Any Equivalent Form (of answer or result) is equally acceptable
AG	Answer Given on the question paper (so extra care is needed in checking that the detailed working leading to the result is valid)
BOD	Benefit Of Doubt (allowed for work whose validity may not be absolutely plain)
CAO	Correct Answer Only (emphasising that no 'follow through' from a previous error is allowed)
FT	Follow through
ISW	Ignore Subsequent Working.
MR	Misread
NOS	Used to indicate an allocation of marks that is Not On Scheme
PA	Premature Approximation (resulting in basically correct work that is numerically insufficiently accurate)
SOS	See Other Solution (the candidate makes a better attempt at the same question)
SC	Special Case (detailing the mark to be given for a specific wrong solution, or a case where some standard marking practice is to be varied in the light of a particular circumstance)
WW	Without Working
WWW	Without Wrong Working

<b>1(a)(i)</b>	$[ \text{ Force } ] = \text{MLT}^{-2}$ $[ \text{ Density } ] = \text{ML}^{-3}$ $[ \text{ Angular speed } ] = \text{T}^{-1}$	B1 B1 B1	<i>Deduct one mark if given as kg ms<sup>-2</sup> etc</i>
<b>(ii)</b>	$[ \text{ Breaking stress } ] = \frac{\text{MLT}^{-2}}{\text{L}^2}$ $= \text{ML}^{-1} \text{T}^{-2}$	M1 E1	For $[ \text{ Force } ] \div \text{L}^2$
<b>(iii)</b>	$1.2 \times 10^9 \times \frac{1}{0.454} \times 0.0254 \times 0.001^2$ $= 67.1 \text{ lb in}^{-1} \text{ ms}^{-2} \quad (3 \text{ sf})$	M1 M1 A1	For $\times 0.001^2$ or $\times \frac{1}{0.001^2}$ For $\times \frac{0.0254}{0.454}$ $5.6 \times 10^{-8}$ implies M1M1A0 $2.15 \times 10^{16}$ implies M1M0A0
<b>(iv)</b>	$\text{T}^{-1} = (\text{ML}^{-1} \text{T}^{-2})^\alpha (\text{ML}^{-3})^\beta \text{L}^\gamma$ $\alpha = \frac{1}{2}$ $\beta = -\frac{1}{2}$ $0 = -\alpha - 3\beta + \gamma$ $\gamma = -1$	B1 B1 M1 A1	<i>All marks ft provided work is comparable</i>  Considering powers of L
<b>(v)</b>	$3140 = k(1.2 \times 10^9)^{\frac{1}{2}} (7800)^{-\frac{1}{2}} (0.5)^{-1}$ $k = 4.00 \quad (3 \text{ sf})$ $S = \frac{\omega^2 \rho r^2}{k^2} = \frac{8120^2 \times 2700 \times 0.2^2}{4^2}$ $= 4.44 \times 10^8 \text{ Pa} \quad (3 \text{ sf})$	M1 M1 M1 A1 cao	Obtaining equation for $k$ Obtaining numerical value for $k$  Obtaining equation for $S$
	OR $S = 1.2 \times 10^9 \times \left( \frac{8120}{3140} \right)^2 \times \frac{2700}{7800} \times \left( \frac{0.2}{0.5} \right)^2$ $= 4.44 \times 10^8$	M1M1M1 A1	
<b>(vi)</b>	$\omega = 4(630)^{\frac{1}{2}} (70)^{-\frac{1}{2}} (15)^{-1}$ $= 0.8$	M1 A1 cao	Obtaining equation for $\omega$

<b>2(a)(i)</b>	$T \cos \alpha = m \frac{V^2}{r} \quad (\alpha \text{ is angle APC})$ $T \times \frac{8.4}{30} = 48 \times \frac{3.5^2}{8.4}$ <p>Tension is 250 N</p> $T \sin \alpha + R = mg$ $250 \times 0.96 + R = 48 \times 9.8$ <p>Normal reaction is 230.4 N</p>	M1 A1 A1 M1 A1	Equation of motion including $\frac{V^2}{r}$ Or $T \cos 73.7 = \dots$ or $T \sin 16.3 = \dots$ Resolving vertically (three terms)	<b>5</b>
<b>(ii)</b>	$T \sin \alpha = mg$ $T \times 0.96 = 48 \times 9.8$ $T = 490$ $T \cos \alpha = m \frac{V^2}{r}$ $490 \times 0.28 = 48 \times \frac{V^2}{8.4}$ $V = 4.9$	M1 A1  M1 A1	Vertical equation with $R = 0$ Or $T \sin 73.7 = \dots$ or $T \cos 16.3 = \dots$  Obtaining equation for $V$ Allow $T=490$ obtained in (i) and used correctly in (ii) for full marks	<b>4</b>
<b>(b)(i)</b>	$\frac{1}{2} m(v^2 - u^2) = m \times 9.8(2.5 - 2.5 \cos \theta)$ $v^2 - u^2 = 49(1 - \cos \theta)$ $v^2 = u^2 + 49 - 49 \cos \theta$	M1 A1  E1	Equation involving KE and PE	<b>3</b>
<b>(ii)</b>	$mg \cos \theta - R = m \frac{v^2}{r}$ $48 \times 9.8 \left( \frac{u^2 + 49 - v^2}{49} \right) - R = \frac{48v^2}{2.5}$ $9.6u^2 + 470.4 - 9.6v^2 - R = 19.2v^2$ $R = 470.4 + 9.6u^2 - 28.8v^2$	M1 A1  M1  A1	Radial equation (three terms)  Obtaining equation in $R, u, v$	<b>4</b>
<b>(iii)</b>	$470.4 + 9.6u^2 - 28.8 \times 4.15^2 = 0$ $u = 1.63 \quad (3 \text{ sf})$	M1  A1	Substituting $R = 0$ and $v = 4.15$ or other complete method leading to an equation for $u$ (ft requires $0 < u < 4.15$ )	<b>2</b>



3 (i)	Tension is $180(10-7)$ $= 540 \text{ N}$	M1 A1 <b>2</b>	Using $T = k \times \text{extension}$
(ii)	$4 \times 540 = T + 200 \times 9.8$ $T = 200$ Extension is $\frac{200}{80} (= 2.5)$ Natural length is $5.5 \text{ m}$	M1 A1  M1 A1 cao <b>4</b>	Resolving vertically
(iii)	$80(2.5-x) + 200 \times 9.8 - 4 \times 180(3+x) = 200 \frac{d^2x}{dt^2}$ $200 - 80x + 1960 - 2160 - 720x = 200 \frac{d^2x}{dt^2}$ $\frac{d^2x}{dt^2} = -4x$	B1 ft M1 A1  E1 <b>4</b>	For $180(3+x)$ or $80(2.5-x)$ Equation of motion (condone one missing force)
(iv)	Maximum acceleration is $\omega^2 A$ $= 4 \times 2.2 = 8.8 \text{ ms}^{-2}$	M1 A1 <b>2</b>	<i>Condone</i> $-8.8$
(v)	When $x = -1.6$ , $v^2 = \omega^2(A^2 - x^2)$ $= 4(2.2^2 - 1.6^2)$  Speed is $3.02 \text{ ms}^{-1}$ (3 sf)	M1  A1 <b>2</b>	Using $v^2 = \omega^2(A^2 - x^2)$ (or other complete method) (Allow M1 if $\omega^2 = 2$ or $16$ used but M0 if $x = 3.8$ is used) <i>Condone</i> $-3.02$
(vi)	$x = 2.2 \cos 2t$ When $t = 5$ , $x = -1.846$ Period is $\frac{2\pi}{\omega} = \pi$ , $5 \text{ s}$ is $\frac{5}{\pi} \approx 1.6$ periods Distance travelled is $6 \times 2.2 + (2.2 - 1.846)$ $= 13.6 \text{ m}$ (3 sf)	B1  M1  M1 A1 <b>4</b>	<i>Condone</i> $x = -2.2 \cos 2t$ <i>This B1 can be earned in (v)</i> Obtaining $x$ when $t = 5$ (from $x = A \cos \omega t$ or $x = A \sin \omega t$ )  Correct strategy for finding distance

<p><b>4 (a)</b></p>	<p>Volume is <math>\int \pi y^2 dx = \int_k^{4k} \pi(x^2 - k^2) dx</math>  <math>= \pi \left[ \frac{1}{3}x^3 - k^2x \right]_k^{4k} \quad (= 18\pi k^3)</math></p> <p><math>\int \pi xy^2 dx = \int_k^{4k} \pi(x^3 - k^2x) dx</math>  <math>= \pi \left[ \frac{1}{4}x^4 - \frac{1}{2}k^2x^2 \right]_k^{4k} \quad (= \frac{225\pi k^4}{4})</math></p> <p><math>\bar{x} = \frac{\frac{225}{4}\pi k^4}{18\pi k^3}</math>  <math>= \frac{25k}{8} = 3.125k</math></p>	<p>M1 A1 M1 A1A1 M1 A1</p>	<p>For <math>\int (x^2 - k^2) dx</math> For <math>\frac{1}{3}x^3 - k^2x</math> For <math>\int xy^2 dx</math> For <math>\frac{1}{4}x^4</math> and <math>-\frac{1}{2}k^2x^2</math> <i>Dependent on previous M1M1</i></p> <p style="text-align: right;"><b>7</b></p>
<p><b>(b)(i)</b></p>	<p>Area is <math>\int_0^{2a} \frac{x^3}{a^2} dx</math>  <math>= \left[ \frac{x^4}{4a^2} \right]_0^{2a} \quad (= 4a^2)</math></p> <p><math>\int xy dx = \int_0^{2a} \frac{x^4}{a^2} dx</math>  <math>= \left[ \frac{x^5}{5a^2} \right]_0^{2a} \quad (= \frac{32a^3}{5})</math></p> <p><math>\bar{x} = \frac{\frac{32}{5}a^3}{4a^2} = \frac{8a}{5} = 1.6a</math></p> <p><math>\int \frac{1}{2}y^2 dx = \int_0^{2a} \frac{x^6}{2a^4} dx</math>  <math>= \left[ \frac{x^7}{14a^4} \right]_0^{2a} \quad (= \frac{64a^3}{7})</math></p> <p><math>\bar{y} = \frac{\frac{64}{7}a^3}{4a^2} = \frac{16a}{7}</math></p>	<p>M1 A1 M1 A1 A1 M1 A1 A1</p>	<p>For <math>\int \frac{x^3}{a^2} dx</math> For <math>\frac{x^4}{4a^2}</math> For <math>\int xy dx</math> For <math>\frac{x^5}{5a^2}</math> For <math>\int y^2 dx</math> or <math>\int (2a - x)y dy</math> For <math>\frac{x^7}{14a^4}</math> or <math>ay^2 - \frac{3}{7}a^{2/3}y^{7/3}</math></p> <p style="text-align: right;"><b>8</b></p>
<p><b>(ii)</b></p>	<p>Centre of mass is vertically below A  <math>\tan \theta = \frac{2a - \bar{x}}{8a - \bar{y}} = \frac{\frac{2}{5}a}{\frac{40}{7}a} \quad (= 0.07)</math>          Angle is <math>4.00^\circ</math> (3 sf)</p>	<p>M1 M1 A1</p>	<p><i>May be implied</i> Condone reciprocal</p> <p style="text-align: right;"><b>3</b></p>

## 4763 Mechanics 3

### General Comments

Most candidates were able to demonstrate their competence in many of the topics being examined. The work on this paper was generally of a high standard, with half the candidates scoring marks in the 60s and 70s (out of 72).

### Comments on Individual Questions

- 1) (i) The dimensions of force and density were almost always given correctly, but a large number of candidates gave the dimensions of angular speed as  $\text{LT}^{-1}$  instead of  $\text{T}^{-1}$ .
- (ii) Almost all candidates established the dimensions of breaking stress correctly. Just a few wrote  $\frac{\text{MLT}^{-2}}{\text{L}^{-2}}$  instead of  $\frac{\text{MLT}^{-2}}{\text{L}^2}$ .
- (iii) About half the candidates were unable to convert the units successfully. By far the most common error was to multiply by the reciprocal of the correct conversion factor.
- (iv) The method for finding the indices in the formula was very well understood, and most candidates completed the work accurately.
- (v) Most candidates knew how to find the breaking stress of aluminium, and many obtained the correct answer.
- (vi) This was also answered well. Some candidates did not realise that the value of the dimensionless constant  $k$  would be the same in the new system of units, usually assuming that  $k=1$ .
- 2) (a)(i) Most candidates gave equations for vertical equilibrium and horizontal acceleration. However, about a third of the candidates failed to obtain the correct answers; the normal reaction was often omitted completely, and very often put in horizontally or at right angles to the rope.
- (a)(ii) This situation (with no contact force) seemed to be much more familiar to the candidates, and most answered this part correctly.
- (b)(i) Almost all candidates applied conservation of energy to obtain the given result convincingly. Just a few wrote down  $v^2 = u^2 + 2as$  without any explanation, and this did not earn any credit.
- (b)(ii) The radial equation of motion was very often given correctly, although sign errors were fairly frequent. It was then necessary to substitute for  $\cos\theta$  from the result in part (i), but a surprisingly large proportion of candidates failed to do this.

- (b)(iii)** Almost all candidates knew that P leaves the surface when  $R=0$ , and the value of  $u$  can then be found immediately from the expression in part (ii). Many candidates who had not completed part (ii) were nevertheless able to answer this part independently and correctly.
- 3) (i)** Almost all candidates found the tension correctly, although a few confused stiffness with modulus of elasticity.
- (ii)** Most candidates also obtained the natural length of the bottom rope correctly.
- (iii)** Most candidates realised that they should apply Newton's second law to set up the equation of motion. However, the expressions for the tensions were very often incorrect and there were many sign errors. A significant proportion of candidates omitted this part altogether.
- (iv)** The maximum acceleration was usually found correctly; some candidates appeared to be finding the maximum speed instead.
- (v)** This was also answered well. Most candidates used  $v^2 = \omega^2(A^2 - x^2)$ , and a fairly common error was to take  $x=0.6$  or  $x=3.8$  instead of  $x=1.6$ . Some preferred to use displacement-time and velocity-time equations.
- (vi)** Most candidates found the position of the block after 5 seconds (although some worked in degrees instead of radians). However, only a minority could work out the distance travelled to get there.
- 4) (a)** Almost all candidates knew the method for finding the centre of mass of a solid of revolution. There were some careless slips when evaluating the definite integrals, and some candidates appeared to be working with  $y^2 = x^2 + k^2$  or  $y^2 = x - k$  or  $y^2 = (x^2 - k^2)^2$  instead of  $y^2 = x^2 - k^2$ .
- (b)(i)** The centre of mass of the lamina was found correctly by most candidates; the only common error being omission of a factor  $\frac{1}{2}$  from the y-coordinate.
- (b)(ii)** The method was well understood, and the angle was very often found correctly.

**OCR (Oxford Cambridge and RSA Examinations)**  
**1 Hills Road**  
**Cambridge**  
**CB1 2EU**

**OCR Customer Contact Centre**

**14 – 19 Qualifications (General)**

Telephone: 01223 553998

Facsimile: 01223 552627

Email: [general.qualifications@ocr.org.uk](mailto:general.qualifications@ocr.org.uk)

**[www.ocr.org.uk](http://www.ocr.org.uk)**

For staff training purposes and as part of our quality assurance programme your call may be recorded or monitored

**Oxford Cambridge and RSA Examinations**  
**is a Company Limited by Guarantee**  
**Registered in England**  
**Registered Office; 1 Hills Road, Cambridge, CB1 2EU**  
**Registered Company Number: 3484466**  
**OCR is an exempt Charity**



**OCR (Oxford Cambridge and RSA Examinations)**  
**Head office**  
**Telephone: 01223 552552**  
**Facsimile: 01223 552553**

© OCR 2011