OCR
RECOGNISING ACHIEVEMENT

Wednesday 25 January 2012 – Afternoon

A2 GCE MATHEMATICS (MEI)

4763 Mechanics 3

QUESTION PAPER

Candidates answer on the Printed Answer Book.

OCR supplied materials:
- Printed Answer Book 4763
- 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 in the centre of 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 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 $g\,\text{m}\,\text{s}^{-2}$. Unless otherwise instructed, when a numerical value is needed, use $g = 9.8$.

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- The number of marks is given in brackets **[ ]** at the end of each question or part question on the Question Paper.
- 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 **12** 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 surface tension of a liquid enables a metal needle to be at rest on the surface of the liquid. The greatest mass m of a needle of length a which can be supported in this way by a liquid of surface tension S is given by

$$m = \frac{2Sa}{g}$$

where g is the acceleration due to gravity.

(i) Show that the dimensions of surface tension are MT^{-2}. **[3]**

The surface tension of water is 0.073 when expressed in SI units (based on kilograms, metres and seconds).

(ii) Find the surface tension of water when expressed in a system of units based on grams, centimetres and minutes. **[3]**

Liquid will rise up a capillary tube to a height h given by $h = \frac{2S}{\rho g r}$, where ρ is the density of the liquid and r is the radius of the capillary tube.

(iii) Show that the equation $h = \frac{2S}{\rho g r}$ is dimensionally consistent. **[3]**

(iv) Find the radius of a capillary tube in which water will rise to a height of 25 cm. (The density of water is 1000 in SI units.) **[2]**

When liquid is poured onto a horizontal surface, it forms puddles of depth d. You are given that $d = kS^{\alpha}\rho^{\beta}g^{\gamma}$ where k is a dimensionless constant.

(v) Use dimensional analysis to find α, β and γ. **[4]**

Water forms puddles of depth 0.44 cm. Mercury has surface tension 0.487 and density 13 500 in SI units.

(vi) Find the depth of puddles formed by mercury on a horizontal surface. **[3]**

2 A light inextensible string of length 5 m has one end attached to a fixed point A and the other end attached to a particle P of mass 0.72 kg.

At first, P is moving in a vertical circle with centre A and radius 5 m. When P is at the highest point of the circle it has speed $10\,\text{m s}^{-1}$.

(i) Find the tension in the string when the speed of P is $15\,\text{m s}^{-1}$. **[5]**

The particle P now moves at constant speed in a horizontal circle with radius 1.4 m and centre at the point C which is 4.8 m vertically below A.

(ii) Find the tension in the string. **[3]**

(iii) Find the time taken for P to make one complete revolution. **[4]**

Another light inextensible string, also of length 5 m, now has one end attached to P and the other end attached to the fixed point B which is 9.6 m vertically below A. The particle P then moves with constant speed $7\,\text{m s}^{-1}$ in the circle with centre C and radius 1.4 m, as shown in Fig. 2.

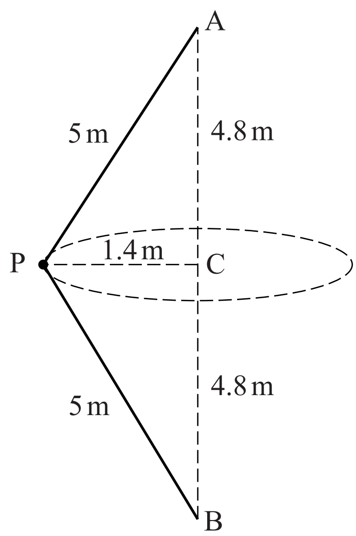

Fig. 2

(iv) Find the tension in the string PA and the tension in the string PB. **[6]**

3 A bungee jumper of mass 75 kg is connected to a fixed point A by a light elastic rope with stiffness $300\,\mathrm{N\,m^{-1}}$. The jumper starts at rest at A and falls vertically. The lowest point reached by the jumper is 40 m vertically below A. Air resistance may be neglected.

(i) Find the natural length of the rope. **[4]**

(ii) Show that, when the rope is stretched and its extension is x metres, $\ddot{x} + 4x = 9.8$. **[3]**

The substitution $y = x - c$, where c is a constant, transforms this equation to $\ddot{y} = -4y$.

(iii) Find c, and state the maximum value of y. **[3]**

(iv) Using standard simple harmonic motion formulae, or otherwise, find

(A) the maximum speed of the jumper,

(B) the maximum deceleration of the jumper. **[3]**

(v) Find the time taken for the jumper to fall from A to the lowest point. **[5]**

4 **(a)** The region T is bounded by the x-axis, the line $y = kx$ for $a \leqslant x \leqslant 3a$, the line $x = a$ and the line $x = 3a$, where k and a are positive constants. A uniform frustum of a cone is formed by rotating T about the x-axis. Find the x-coordinate of the centre of mass of this frustum. **[6]**

(b) A uniform lamina occupies the region (shown in Fig. 4) bounded by the x-axis, the curve $y = 16(1 - x^{-\frac{1}{3}})$ for $1 \leqslant x \leqslant 8$ and the line $x = 8$.

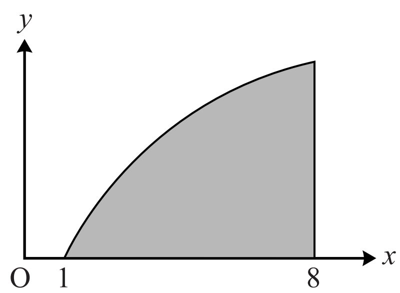

Fig. 4

(i) Find the coordinates of the centre of mass of this lamina. **[8]**

A hole is made in the lamina by cutting out a circular disc of area 5 square units. This causes the centre of mass of the lamina to move to the point (5, 3).

(ii) Find the coordinates of the centre of the hole. **[4]**

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Duration: 1 hour 30 minutes

Candidate forename		Candidate surname	

Centre number						Candidate number				

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1 (i)	
1 (ii)	

1 (iii)

1 (iv)

1 (v)

1 (vi)	
2 (i)	

2 (ii)	
2 (iii)	

2 (iv)	

3 (i)	
3 (ii)	

3 (iii)	
3 (iv) (*A*)	
3 (iv) (*B*)	

3 (v)

4 (a)	

4 (b) (i)

4 (b) (ii)	

GCE

Mathematics (MEI)

Advanced GCE

Unit **4763:** Mechanics 3

Mark Scheme for January 2012

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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. (eg 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 accuracy error, except for errors due to premature approximation which should be penalised only once in the examination.

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)		$[g] = \mathrm{L\,T^{-2}}$ $[S] = \left[\dfrac{mg}{2a}\right] = \dfrac{\mathrm{M(L\,T^{-2})}}{\mathrm{L}} = \mathrm{M\,T^{-2}}$	B1 M1 E1 **[3]**	Obtaining dimensions of S	
1	(ii)		$0.073 \times 1000 \times 60^2$ $= 262800$	M1M1 A1 **[3]**	For $\times 1000$ and $\times 60^2$ Give M1 for $\dfrac{1}{1000} \times \dfrac{1}{60^2}$	3 600 000 implies M2 2.8×10^{-7} or 2.0×10^{-8} implies M1
1	(iii)		$[\rho] = \mathrm{M\,L^{-3}}$ $[\mathrm{RHS}] = \dfrac{\mathrm{M\,T^{-2}}}{(\mathrm{M\,L^{-3}})(\mathrm{L\,T^{-2}})(\mathrm{L})} = \mathrm{L}$ [LHS] = L, so it is dimensionally consistent	B1 M1 E1 **[3]**	Obtaining dimensions of RHS Correctly shown	
1	(iv)		$r = \dfrac{2S}{\rho g h} = \dfrac{2 \times 0.073}{1000 \times 9.8 \times 0.25}$ $= 5.96 \times 10^{-5}$ m (3 sf)	M1 A1 **[2]**	Correct explicit numerical expression for r. May have 25 for h.	
1	(v)		$\mathrm{L} = (\mathrm{M\,T^{-2}})^{\alpha} (\mathrm{M\,L^{-3}})^{\beta} (\mathrm{L\,T^{-2}})^{\gamma}$ $\alpha + \beta = 0,\ -3\beta + \gamma = 1,\ -2\alpha - 2\gamma = 0$ $\alpha = \frac{1}{2},\ \beta = -\frac{1}{2},\ \gamma = -\frac{1}{2}$	M2 A2 **[4]**	For 3 equations (give M1 for 2 equations) CAO Give A1 (*dep M2*) for two correct	If [ρ] and/or [g] wrong, give A1 for at least two correct values FT

Question			Answer	Marks	Guidance	
1	(vi)		$d = kS^{\frac{1}{2}}\rho^{-\frac{1}{2}}g^{-\frac{1}{2}}$			
			$d = 0.0044,\ S = 0.073,\ \rho = 1000,\ g = 9.8 \Rightarrow k = 1.612$	M1	Obtaining a value for k	Or $\left(\frac{0.487}{0.073}\right)^{\frac{1}{2}}$ or $\left(\frac{13500}{1000}\right)^{-\frac{1}{2}}$
			$d_M = 1.612 \times 0.487^{\frac{1}{2}} \times 13500^{-\frac{1}{2}} \times 9.8^{-\frac{1}{2}}$	M1	Obtaining expression for d_M	Or $0.0044 \times \left(\frac{0.487}{0.073}\right)^{\frac{1}{2}} \times \left(\frac{13500}{1000}\right)^{-\frac{1}{2}}$
			Depth for mercury is 0.00309 m (3 sf)	A1 **[3]**	CAO Or 0.31 (cm)	*But A0 for 0.31 m*
2	(i)		$\frac{1}{2}m(15^2 - 10^2) = m \times 9.8 \times (5 - 5\cos\theta)$	M1	Equation involving KE and PE	θ is angle with upward vertical
			$\cos\theta = -\frac{27}{98}$ [$\theta = 106°$]	A1		
			$T + (0.72)(9.8)\cos\theta = 0.72 \times \frac{15^2}{5}$	M1 A1	Using acceleration v^2 / r If evaluated, FT their $\cos\theta$	
			Tension is 34.3 N (3 sf)	A1 **[5]**		
2	(ii)		$\cos\alpha = 0.96$ [$\alpha = 16.26°$]	B1	α is angle between AP and vertical	
			$T\cos\alpha = 0.72 \times 9.8$	M1	Resolve vertically	
			Tension is 7.35 N	A1 **[3]**		
2	(iii)			M1	Horizontal equation of motion	
			$T\sin\alpha = (0.72)(1.4\omega^2)$ $\omega = 1.429$	A1	Or $T\sin\alpha = (0.72)(v^2 / 1.4)$ ($v = 2.00$)	
				M1	Period $\frac{2\pi}{\omega}$ with numerical ω	Or $\frac{2\pi \times 1.4}{v}$ with numerical v
			Time for one revolution is $\frac{2\pi}{\omega} = 4.40$ s (3 sf)	A1 **[4]**	FT is $\frac{11.92}{\sqrt{T}}$ (only)	Accept 1.4π

Question			Answer	Marks	Guidance	
2	(iv)		$T_{PA}\cos\alpha = T_{PB}\cos\alpha + 0.72\times 9.8$ $T_{PA} - T_{PB} = 7.35$	M1 A1	Resolving vertically 3 terms required	
			$T_{PA}\sin\alpha + T_{PB}\sin\alpha = 0.72\times\frac{7^2}{1.4}$ $T_{PA} + T_{PB} = 90$	M1 A1	Horizontal equation of motion	3 terms required
			Tension in PA is 48.7 N (3 sf) Tension in PB is 41.3 N (3 sf)	M1 A1 **[6]**	Obtaining tension in at least one string CAO	*Dependent on previous M1M1*
3	(i)		EE is $\frac{1}{2}(300)x^2$	B1	Or $\frac{1}{2}(300)(40-l_0)^2$	x is the maximum extension
			Change in PE is $75\times 9.8\times 40$	B1		
			$\frac{1}{2}(300)x^2 = 75\times 9.8\times 40$ $x = 14$	M1	Equation involving EE and PE	
			Natural length is 26 m	A1 **[4]**		
3	(ii)		$75\times 9.8 - 300x = 75\ddot{x}$ $\ddot{x} + 4x = 9.8$	M1 A1 E1 **[3]**	Equation of motion (three terms)	
3	(iii)		$\ddot{x} = -4(x-2.45)$	M1	Or $\ddot{y} + 4(y+c) = 9.8$	Condone sign errors for M1
			$c = 2.45$	A1	$c = 2.45$ implies M1A1 $c = -2.45$ implies M1A0	
			Maximum value of y is $14 - 2.45 = 11.55$	B1 **[3]**	FT is $37.55 - l_0$ *(must be positive)*	

Question			Answer	Marks	Guidance	
3	(iv)	(A)	Maximum speed is $A\omega$	M1		
			$= 11.55 \times 2 = 23.1\ \text{m s}^{-1}$	A1	FT max value of y in (iii).	
		(B)	Maximum acceleration is $A\omega^2$		Give M1 if M0 for maximum speed	
			$= 11.55 \times 2^2 = 46.2\ \text{m s}^{-2}$	A1	Allow -46.2	
				[3]		
3	(v)		Before rope is stretched, $26 = \frac{1}{2} \times 9.8 \times t_1^2$	B1	FT from wrong l_0	
			$t_1 = 2.304$			
			When rope is stretched	M1	For $A\sin\omega t$ or $A\cos\omega t$	
			$y = 11.55\cos 2t$	A1	For $11.55\sin 2t$ or $11.55\cos 2t$	($t = 0$ at lowest point) FT A, ω used in (iv)
			When $y = -2.45$, $t_2 = (\pm)\, 0.892$	M1	Fully correct strategy for finding t_2	
			Time to fall ($t_1 + t_2$) is 3.20 s (3 sf)	A1	CAO	
				[5]		
4	(a)		$V = \int_a^{3a} \pi (kx)^2 \, dx$	M1	For $\int ... x^2 \, dx$	
			$= \pi \left[\frac{k^2 x^3}{3} \right]_a^{3a} \quad \left(= \frac{26\pi k^2 a^3}{3} \right)$	A1	For $\frac{k^2 x^3}{3}$	
			$V\bar{x} = \int \pi x y^2 \, dx = \int_a^{3a} \pi x (kx)^2 \, dx$	M1	For $\int xy^2 \, dx$	
			$= \pi \left[\frac{k^2 x^4}{4} \right]_a^{3a} \quad (= 20\pi k^2 a^4)$	A1	For $\frac{k^2 x^4}{4}$	
			$\bar{x} = \frac{20\pi k^2 a^4}{\frac{26}{3}\pi k^2 a^3}$	M1	*Dependent on previous M1M1*	
			$= \frac{30a}{13}$	A1	Allow $2.3a$	
				[6]		

Question			Answer	Marks	Guidance	
		OR	$mx + (M - m)z = MX$ $x = \frac{3}{4}a$ and $X = \frac{3}{4}(3a)$ $M = 27m$ $z = 30a/13$		M3 Complete method based on Large cone minus Small cone A1 A1 A1	
4	(b)	(i)	$A = \int_1^8 16(1 - x^{-\frac{1}{3}})\,dx$ $= \left[16(x - \frac{3}{2}x^{\frac{2}{3}}) \right]_1^8 \quad (= 40)$ $A\bar{x} = \int xy\,dx = \int_1^8 16x(1 - x^{-\frac{1}{3}})\,dx$ $= \left[8x^2 - \frac{48}{5}x^{\frac{5}{3}} \right]_1^8 \quad (= 206.4)$ $\bar{x} = \frac{206.4}{40} = 5.16$ $A\bar{y} = \int \frac{1}{2}y^2\,dx = \int_1^8 \frac{1}{2}\{16(1 - x^{-\frac{1}{3}})\}^2\,dx$ $= \left[128(x - 3x^{\frac{2}{3}} + 3x^{\frac{1}{3}}) \right]_1^8 \quad (= 128)$ $\bar{y} = \frac{128}{40} = 3.2$	M1 A1 M1 A1 A1 M1 A1 A1 **[8]**	For $\int 16(1 - x^{-\frac{1}{3}})\,dx$ For $16(x - \frac{3}{2}x^{\frac{2}{3}})$ For $\int xy\,dx$ For $8x^2 - \frac{48}{5}x^{\frac{5}{3}}$ For $\int \dots y^2\,dx$ For $128(x - 3x^{\frac{2}{3}} + 3x^{\frac{1}{3}})$	
4	(b)	(ii)	$5\begin{pmatrix} x \\ y \end{pmatrix} + 35\begin{pmatrix} 5 \\ 3 \end{pmatrix} = 40\begin{pmatrix} 5.16 \\ 3.2 \end{pmatrix}$ $\begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} 6.28 \\ 4.6 \end{pmatrix}$	M1 M1 A1 A1 **[4]**	CM of composite body Correct strategy (including signs) FT requires $1 < x < 8$ FT requires $0 < y < 8$	(One coordinate sufficient)

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CB1 2EU

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4763 Mechanics 3

General Comments

The work on this paper was generally of a very high standard, with candidates setting out their solutions clearly. Most candidates had a good working knowledge of the topics being examined, and it was pleasing to see very many confident answers. The question on circular motion was answered rather better than in the past, although some candidates would benefit from drawing a clear diagram. The topic which caused the most trouble was simple harmonic motion.

Comments on Individual Questions

1 *(Dimensional analysis)*
All parts of this question were generally answered well, with the exception of that involving conversion between systems of units.

(i) Almost all candidates derived the dimensions of surface tension correctly.

(ii) Only about one third of the candidates were able to carry out the conversion from one set of units to another. The most common error was to divide instead of multiply by 60^2. Some included the conversion factor for length (100) in their calculations, even though the dimensions of surface tension do not include L.

(iii) Most candidates could show that the given equation was dimensionally consistent. The dimensions of *ρ* and *g* were almost universally stated correctly, but some made errors in the manipulation of negative powers.

(iv) Most found the radius accurately, but a surprising number failed to rearrange the formula correctly to give *r*. Many gave the reciprocal of the correct answer. Some did not convert the height 25 cm into SI units.

(v) Almost all candidates obtained three equations by considering the powers of M, L and T, although the equation resulting from L, $-3\beta + \gamma = 1$, was quite often incorrect.

(vi) Most candidates approached this by finding the value of *k*, with just a few using a ratio method. Slips were often made in the substitutions, but about half obtained the correct answer.

2 *(Circular motion)*
This question was answered somewhat better than similar questions in previous papers; in particular the work on the two strings problem in the last part was most impressive. However, many candidates did not include a clear diagram, and wrote down equations involving $\sin\theta$ and $\cos\theta$ without any indication of which angle was intended to be *θ*. When the final answer was incorrect, this sometimes meant that intermediate marks could not be awarded.

(i) Most candidates considered the radial equation of motion, although there were several resolving and sign errors. Conservation of energy was also needed, to find the angle of the string, but not all candidates realised this. About 40% of the candidates obtained the correct answer.

(ii) Almost all candidates answered this correctly, by resolving vertically to find the tension.

(iii) Most candidates found the period of the conical pendulum correctly, although there was sometimes confusion between the speed and the angular speed.

(iv) Almost all candidates made good attempts to resolve vertically and form the horizontal equation of motion, and about three-quarters found the two tensions correctly.

3 *(Elasticity and simple harmonic motion)*
This was found to be the hardest question. The average mark was about 10 (out of 18), compared with about 14 for each of the other questions.

(i) Most candidates used conservation of energy to find the natural length correctly. However, about a quarter assumed that the jumper was in equilibrium at the lowest point.

(ii) Most candidates derived the result correctly. There were sometimes sign errors in the equation of motion, and the expression for the tension was occasionally wrong, for example $T = 300(x - 2.45)$ instead of $T = 300x$.

(iii) Many obtained the correct value, $c = 2.45$ but $c = -2.45$ was also quite frequently seen. Several candidates did not state the maximum value of *y*, and common incorrect values given here were 14 and 2.45. About a quarter of the candidates scored no marks in this part.

(iv) Although the formulae $A\omega$ and $A\omega^2$ for the maximum speed and acceleration were very often stated, many candidates did not realise that the amplitude was the maximum value of *y* found in part (iii).

(v) This was found to be the most difficult item on the paper. It was sometimes omitted altogether, and about one third of the candidates scored no marks. Only about 10% of the candidates answered it correctly. There were two stages to be considered: constant acceleration for a distance equal to the natural length of the rope, then simple harmonic motion while the rope was stretched. Some candidates considered only one of these stages, and several calculated the free-fall time for an incorrect distance. The second stage required some careful thought (the neatest method was to solve $11.55\cos 2t = -2.45$) and few candidates found this time correctly; by far the most common error was to assume that this was either one quarter or one half of the period.

4 *(Centres of mass)*
The methods for finding the centres of mass of a solid of revolution and a lamina were very well understood, and a great deal of confident and accurate work was seen in this question.

(a) About three-quarters of the candidates found the centre of mass of the solid of revolution correctly. Any errors made were usually just careless slips, sometimes involving powers of *a*.

(b) (i) Most candidates found the *x*-coordinate correctly. When finding the *y*-coordinate, mistakes were quite often seen in squaring the expression for *y* (such as forgetting to square the 16) and in the integration. Also, the factor ½, usually present at the start, was often dropped at some later stage in the calculation.

(b) (ii) This part was sometimes omitted, but most candidates understood how to work with the centres of mass of a composite body. The calculations were usually carried out accurately.