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Mark Scheme (Results)

Summer 2013

GCE Mechanics 2 (6678/01)

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General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.

EDEXCEL GCE MATHEMATICS

General Instructions for Marking

1. The total number of marks for the paper is 75.

2. The Edexcel Mathematics mark schemes use the following types of marks:

- **M** marks: method marks are awarded for 'knowing a method and attempting to apply it', unless otherwise indicated.
- **A** marks: accuracy marks can only be awarded if the relevant method (M) marks have been earned.
- **B** marks are unconditional accuracy marks (independent of M marks)
- Marks should not be subdivided.

3. Abbreviations

These are some of the traditional marking abbreviations that will appear in the mark schemes:

- bod – benefit of doubt
- ft – follow through
- the symbol $\surd$ will be used for correct ft
- cao – correct answer only
- cso - correct solution only. There must be no errors in this part of the question to obtain this mark
- isw – ignore subsequent working
- awrt – answers which round to
- SC: special case
- oe – or equivalent (and appropriate)
- dep – dependent
- indep – independent
- dp decimal places
- sf significant figures
- * The answer is printed on the paper
- ⌐ The second mark is dependent on gaining the first mark

4. All A marks are 'correct answer only' (cao.), unless shown, for example, as A1 ft to indicate that previous wrong working is to be followed through. After a misread however, the subsequent A marks affected are treated as A ft, but manifestly absurd answers should never be awarded A marks.

5. For misreading which does not alter the character of a question or materially simplify it, deduct two from any A or B marks gained, in that part of the question affected.

6. If a candidate makes more than one attempt at any question:
   - If all but one attempt is crossed out, mark the attempt which is NOT crossed out.
   - If either all attempts are crossed out or none are crossed out, mark all the attempts and score the highest single attempt.

7. Ignore wrong working or incorrect statements following a correct answer.

8. In some instances, the mark distributions (e.g. M1, B1 and A1) printed on the candidate's response may differ from the final mark scheme

General Rules for Marking Mechanics

- Usual rules for M marks: correct no. of terms; dim correct; all terms that need resolving (i.e. multiplied by cos or sin) are resolved.

- Omission or extra g in a resolution is accuracy error not method error.

- Omission of mass from a resolution is method error.

- Omission of a length from a moments equation is a method error.

- Omission of units or incorrect units is not (usually) counted as an accuracy error.

- DM indicates a dependent method mark i.e. one that can only be awarded if a previous specified method mark has been awarded.

- Any numerical answer which comes from use of g = 9.8 should be given to 2 or 3 SF.

- Use of g = 9.81 should be penalised once per (complete) question.

- N.B. Over-accuracy or under-accuracy of correct answers should only be penalised *ONCE* per complete question.

- In all cases, if the candidate clearly labels their working under a particular part of a question i.e. (a) or (b) or (c),……then that working can only score marks for that part of the question.

- Accept column vectors in all cases.

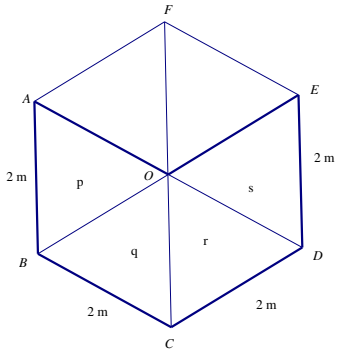
- Misreads – if a misread does not alter the character of a question or materially simplify it, deduct two from any A or B marks gained, bearing in mind that after a misread, the subsequent A marks affected are treated as A ft.

Question Number	Scheme	Marks	Notes
1.	Use of $\mathbf{I} = m\mathbf{v} - m\mathbf{u}$	M1	Must be subtracting. Condone subtraction in the wrong order
	$2\mathbf{v} = (3\mathbf{i} + 6\mathbf{j}) + 2(\mathbf{i} - 4\mathbf{j})$	A1	Correct unsimplified equation ($= 5\mathbf{i} - 2\mathbf{j}$)
	$\mathbf{v} = 2.5\mathbf{i} - \mathbf{j}$	A1	
	Speed $= \sqrt{2.5^2 + 1^2} = \sqrt{7.25} (= 2.69 (\text{m s}^{-1}))$	M1 A1 [5]	Use of correct Pythagoras with their $\mathbf{v}$ Exact form or 2s.f. or better. Watch out for fortuitous answers from $2.5\mathbf{i} + \mathbf{j}$.

Question Number	Scheme	Marks	Notes
2a	Work done = $15\mu R = 15\times 0.4\times 3g\cos 20°$ $= 18g\cos 20 = 166\,(\text{J})$	M1 M1 A1 [3]	$F_{\max} = \mu\times 3g\cos 20\,(11.05)$. R must be resolved but condone trig confusion. $15\times$ their $F_{\max}$. Independent M $15\times\ F_{\max}+.....$ is M0 or 170 (J)
2b	Energy: WD against F + GPE + final KE = initial KE their WD $+ 3g\sin 20°\times 15 + \frac{1}{2}3v^2 = \frac{1}{2}3\times 20^2$ $v = 13.7\,(\text{m s}^{-1})$	 M1A2ft A1 [4]	Must include all four correct terms (including resolving). Condone sign errors and trig confusion. Any sign errors in the KE terms count as a single error. Follow their WD -1ee Follow their WD or 14
Or 2b	$3a = -\ 0.4\times 3g\cos 20 + 3g\sin 20$ and use of $v^2 = u^2 + 2as$ $v^2 = 20^2 + 2\times a\times 15 (= 188.93...)$ $v = 13.7\,(\text{m s}^{-1})$	M1 A1ft A1ft A1 [4]	Complete method. Their $F_{\max}$ +component of weight A correct equation with their $F_{\max}$. Allow for $a = +7.03...$ acting down the slope $a = -7.035....$ Correct equation for their a or 14 (m s^{-1})

Question Number	Scheme	Marks	Notes
3a	$v = 0 = 2t^2 - 14t + 20$ $= 2\ t-2\ \ t-5$ $t = 2$ or $t = 5$	M1 M1 A1 [3]	Set $v = 0$ Solve for t
	There are many different approaches to part (b). The allocation of the two M marks is M1: A method to find the time when the velocity is a minimum M1: Evaluate the speed at that time		
e.g. b	$t = 0$, $v = 20$ (m s^{-1}) $a = 4t - 14 = 0$ $t = \frac{7}{2}$, $v = 2 \times \frac{3}{2} \times \frac{-3}{2} = \frac{-9}{2}$ Max speed = 20 ms^{-1}	B1 M1 M1A1 A1 [5]	 Must see ± 4.5 Clearly stated & correct conclusion. Depends on the two M marks. From correct solution only.
balt1	$t = 0$, $v = 20$ (m s^{-1}) Sketch with symmetry about their $t = 3.5$ v(their 3.5) -4.5 Max speed = 20 ms^{-1}	B1 M1 M1 A1 A1 [5]	 Evaluate v at min. Correct work Clearly stated & correct conclusion. Depends on the two M marks. From correct solution only.
b alt 2	$t = 0$, $v = 20$ (m s^{-1}) Justification of minimum or tabulate sufficient values to confirm location Evaluate v at min. Correct work Correct conclusion. Depends on the two M marks	B1 M1 M1 A1 A1 [5]	 Clearly stated & from correct solution only.

Question Number	Scheme	Marks	Notes
b alt 3	$t = 0$, $v = 20$ (m s^{-1}) Complete the square as far as $\left(t - \frac{7}{2}\right)^2$ $2\left(t - \frac{7}{2}\right)^2 - \frac{9}{2}$ Max speed = 20 ms^{-1}	B1 M1 M1A1 A1 [5]	 Clearly stated & correct conclusion. Depends on the two M marks. From correct solution only.
c	$\int 2t^2 - 14t + 20 \, \mathrm{d}t = \frac{2}{3}t^3 - 7t^2 + 20t (+C)$ Distance = $\left[\frac{2}{3}t^3 - 7t^2 + 20t\right]_0^2 - \left[\frac{2}{3}t^3 - 7t^2 + 20t\right]_2^4$ $= 2\times\left[\frac{2}{3}t^3 - 7t^2 + 20t\right]^2 - \left[\frac{2}{3}t^3 - 7t^2 + 20t\right]_4$ $= 2\left[\frac{16}{3} - 7\times 4 + 40\right] - \left[\frac{2\times 64}{3} - 7\times 16 + 80\right] = 24$ (m)	M1 A1 M1 A1 A1 [5]	Integration. Need to see majority of powers going up All correct. Condone *C* missing Correct method to find the distance, for their 2 Correct unsimplified

Question Number	Scheme	Marks	Notes
4a	 For a valid division into basic elements: e.g. pair of rhombuses		
	AOCB | OCDE | whole 1 | 1 | 2 1/2 | 1/2 | $\overline{y}$	B1 B1	Correct mass ratios for parts and the arrow shape Correct vertical distances from a horizontal axis
	$2\overline{y} = 1\times\frac{1}{2} + 1\times\frac{1}{2}$	M1 A1	Moments equation about a horizontal axis Correct equation for their axis
	$\overline{y} = 0.5$ (m)	A1 [5]	
a alt 2	AOB | OBCD | DOE | whole 1 | 2 | 1 | 4 0 | 1 | 0 | $\overline{y}$	B1 B1	Rhombus + two triangles
	$4\overline{y} = 2\times 1$	M1A1	Moments equation
	$\overline{y} = 0.5$ (m)	A1 [5]	

<table>
<tr><th>Question Number</th><th>Scheme</th><th>Marks</th><th>Notes</th></tr>
<tr><td>a alt 3</td><td>
<table>
<tr><td>Hexagon</td><td>AOEF</td><td>whole</td></tr>
<tr><td>6</td><td>2</td><td>4</td></tr>
<tr><td>0</td><td>-1</td><td>$\bar{y}$</td></tr>
</table>
$4\bar{y} = 0 - \ -2\times 1$

$\bar{y} = 0.5$ (m)
</td><td>B1
B1

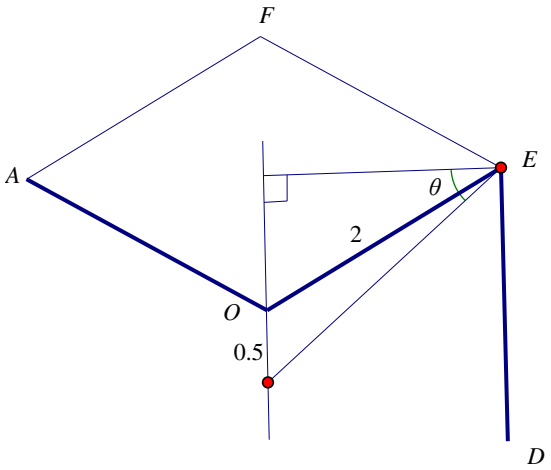
M1A1
A1
[5]</td><td>Hexagon – rhombus</td></tr>
<tr><td>a alt 4</td><td>
h = height of each triangle = $\sqrt{3}$

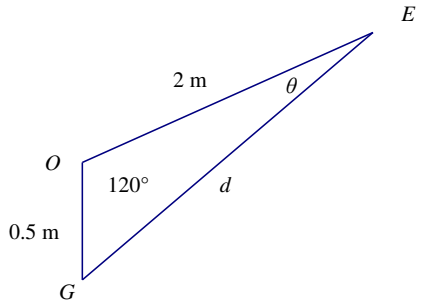
Distances of c of m from horizontal through O

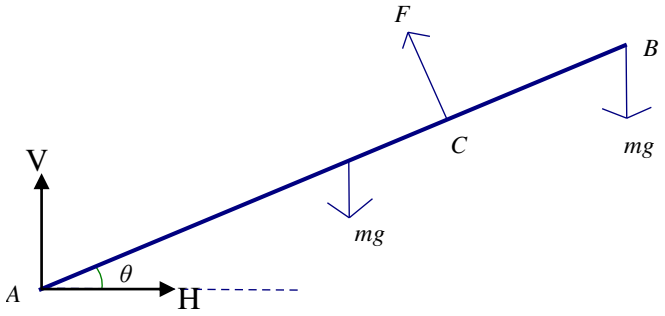
<table>
<tr><td>p</td><td>q</td><td>r</td><td>s</td><td>whole</td></tr>
<tr><td>1</td><td>1</td><td>1</td><td>1</td><td>4</td></tr>
<tr><td>0</td><td>$\frac{2}{3}h\cos 30$</td><td>$\frac{2}{3}h\cos 30$</td><td>0</td><td>$\bar{y}$</td></tr>
</table>
$4\bar{y} = 2\times 1\times \frac{2\sqrt{3}}{3}\cos 30 \left(= \frac{4\sqrt{3}}{3}\times \frac{\sqrt{3}}{2} = 2 \right)$

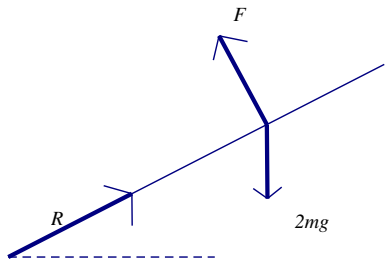
$\bar{y} = 0.5$ (m)
</td><td>B1
B1

M1A1
A1
[5]</td><td>4 triangles</td></tr>
</table>

Question Number	Scheme	Marks	Notes
4b	In 4(b) the first two marks are M1: Indentify a triangle, with one angle correct, and attempt to find the lengths of two sides A1ft: 2 sides correct, follow their answer to (a) DM1: Work sufficient to be able to go on to find the required angle. Dependent on the preceding M1 A1ft: follow their answer to (a) DM1: Find the required angle. Dependent on the preceding M1 A1 Correct answer …. for example ……  		
	$2\cos 30 = \sqrt{3}$, $"0.5" + 2\sin 30 = 1.5$	M1A1ft	Their 0.5 & their √3
	$\tan\theta = \dfrac{\text{their } 1.5}{\text{their } \sqrt{3}}$	DM1	Use of tan in a right angled triangle. Accept the reciprocal
		A1ft	Correct for their angle. Ft their 0.5
	Required angle = $\theta - 30 = \tan^{-1}\dfrac{1.5}{\sqrt{3}} - 30 = 40.89... - 30 = 10.9°$	DM1	Correct strategy to find required angle e.g. $"\theta" - 30°$ or $90° - 30° - "\theta"$
		A1 [6]	Accept $11°$, $10.9°$ or better

Question Number 4balt	Scheme	Marks	Notes
			
	SAS in a relevant triangle	M1A1ft	Their 0.5
	$d^2 = 2^2 + 0.5^2 - 2\times 2\times 0.5\cos 120 = 5.25$	DM1 A1ft	Correct cosine rule. Correct equation. Their 0.5
	$\frac{\sin\theta}{0.5} = \frac{\sin 120}{\sqrt{5.25}}$	DM1	
	$\theta = 10.9°$	A1 [6]	

Question Number	Scheme	Marks	Notes
5a	 Moments about A: $bF = a\cos\theta mg + 2a\cos\theta mg (= 3a\cos\theta mg)$ $F = \dfrac{3amg\cos\theta}{b}$ ***Answer given***	M1 A2 A1 [4]	Moments about A. Requires all three terms and terms of correct structure (force x distance). Condone consistent trig confusion -1 each error
5b	$\rightarrow$: $H = F\sin\theta = \dfrac{3amg\cos\theta\sin\theta}{b}$ $\uparrow$: $2mg = \pm V + F\cos\theta$ $\pm V = 2mg - \dfrac{3amg\cos\theta}{b} \times \cos\theta \left(= 2mg - \dfrac{3amg\cos^2\theta}{b} \right)$	M1 A1 M1 A1 A1 [5]	Resolve horizontally. Condone trig confusion RHS correct. Or equivalent. Resolve vertically. Condone sign error and trig confusion Correct equation RHS correct. Or equivalent

Question Number	Scheme	Marks	Notes
5c	$\dfrac{2mg-\dfrac{3amg\cos^2\theta}{b}}{\dfrac{3amg\cos\theta\sin\theta}{b}}=\tan\theta$ $\dfrac{2b-3a\cos^2\theta}{3a\cos\theta\sin\theta}=\dfrac{\sin\theta}{\cos\theta}$ $\Rightarrow 2b-3a\cos^2\theta=3a\sin^2\theta\Rightarrow 2b=3a,\ \dfrac{a}{b}=\dfrac{2}{3}$	M1 A1 DM1 A1 [4]	Use of tan, either way up. *V*, *H*, *F* substituted. Correct for their components in θ only Simplify to obtain the ratio of a and b, or equivalent
5c alt 2	The centre of mass of the combined rod + particle is $\dfrac{3}{2}a$ from *A*  3 forces in equilibrium must be concurrent $\Rightarrow b=\dfrac{3}{2}a$ $\Rightarrow \dfrac{a}{b}=\dfrac{2}{3}$	M1A1 M1 A1 [4]	 Not on the spec, but you might see it.
alt c 3	*R* acts along the rod, so resolve forces perpendicular to the rod. $F=mg\cos\theta+mg\cos\theta$ $2mg\cos\theta=\dfrac{3amg\cos\theta}{b}$ $\Rightarrow \dfrac{a}{b}=\dfrac{2}{3}$	M1 A1 DM1 A1 [4]	Resolve and substitute for *F* Eliminate θ

Question Number	Scheme	Marks	Notes
alt c 4	R acts along the rod. Take moments about C $mg\cos\theta\ \ 2a-b\ \ =mg\cos\theta\ \ b-a$ $2a-b=b-a,\quad \Rightarrow \frac{a}{b}=\frac{2}{3}$	M1 A1 DM1A1 [4]	Moments about B gives $2a-b\ \ F=amg\cos\theta$ and substitute for F
c alt 5	Resultant parallel to the rod $\Rightarrow R=2mg\sin\theta$ And $V^2+H^2=R^2$ $2mg\sin\theta\ \ ^2=\left(\frac{3amg\cos\theta\sin\theta}{b}\right)^2+\left(2mg-\frac{3amg\cos^2\theta}{b}\right)^2$ Eliminate θ $\Rightarrow \frac{a}{b}=\frac{2}{3}$	M1 A1 DM1 A1 [4]	Substitute for V, H and R in terms of θ

Question Number	Scheme	Marks	Notes
6a	Conservation of energy: $\frac{1}{2}mu^2 + mg \times 8 = \frac{1}{2}m\ \ 2u\ ^2$ $mu^2 + 16mg = 4mu^2$ $16mg = 3mu^2, \quad u = \sqrt{\frac{16g}{3}}$ $u = 7.2$	M1 A2 -1ee DM1 A1 [5]	Energy equation must contain the correct terms, but condone sign error. Correct unsimplified Solve for u Accept 7.23. Accept $\sqrt{\frac{16g}{3}}$
6b	Vertical distance: $-8 = u\sin\theta \times 2 - \frac{g}{2} \times 4$ $\sin\theta = \frac{2g-8}{2u} = 0.802...$ $\theta = 53.3°$	M1 A2 -1ee A1 [4]	Condone sign errors or trig error. u must be resolved. Correct equation for their u. or 53°
6c	Min speed at max height, i.e. $u\cos\theta$ = 4.3 (m s^{-1})	M1 A1 [2]	Condone consistent trig confusion with part (b) or 4.32 (ms^{-1})

Question Number	Scheme	Marks	Notes
7a	CLM: $2mu = 2mv + 3mw$ Impact: $w - v = eu$ Subst $v = w - eu$: $2u = 2\ w - eu\ + 3w = 5w - 2eu$ $w = \frac{2}{5}\ 1 + e\ u$ ***Answer Given***	M1 A1 M1 A1 DM1 A1 (6)	All three terms required, but condone sign errors Condone sign error, but must be subtracting and e must be used correctly. Penalise inconsistent signs here. Solve for w. Requires the two preceding M marks
7b	$w = \frac{7u}{10}$ CLM: $3mw = 3mx + 4my$ and Impact: $y - x = \frac{3w}{4}$ Subst: $3w = 3x + 4\left(x + \frac{3}{4}w\right)$ $x = 0$, $y = \frac{3}{4}w = \frac{21}{40}u$	B1 M1A1 DM1 A1 A1 (6)	Seen, or implied by correct speeds. Both needed Solve for x or y. Dependent on the preceding M mark $0.525u$,
7c	$v = -\frac{u}{20}$ Speed of separation = $\frac{u}{20} + \frac{21u}{40} = \frac{23u}{40}$	B1 M1 A1 (3) [15]	Correct velocity of P Correct use of their values and substitute for e. Check directions carefully $0.575u$

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