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Mark Scheme (Results)

Summer 2016

Pearson Edexcel GCE in Mechanics 3 (6679/01)

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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.

PEARSON 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
These are marks given for a correct method or an attempt at a correct method. In Mechanics they are usually awarded for the application of some mechanical principle to produce an equation.
e.g. resolving in a particular direction, taking moments about a point, applying a suvat equation, applying the conservation of momentum principle etc.
The following criteria are usually applied to the equation.

To earn the M mark, the equation
(i) should have the correct number of terms
(ii) be dimensionally correct i.e. all the terms need to be dimensionally correct
e.g. in a moments equation, every term must be a 'force x distance' term or 'mass x distance', if we allow them to cancel 'g' s.
For a resolution, all terms that need to be resolved (multiplied by sin or cos) must be resolved to earn the M mark.

M marks are sometimes dependent (DM) on previous M marks having been earned.
e.g. when two simultaneous equations have been set up by, for example, resolving in two directions and there is then an M mark for solving the equations to find a particular quantity – this M mark is often dependent on the two previous M marks having been earned.

'A' marks
These are dependent accuracy (or sometimes answer) marks and can only be awarded if the previous M mark has been earned. E.g. M0 A1 is impossible.

'B' marks
These are independent accuracy marks where there is no method (e.g. often given for a comment or for a graph)

A few of the A and B marks may be f.t. – follow through – marks.

3. General 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 $\sqrt{}$ 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
- $\ast$ 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.

General Principles for Mechanics Marking

(But note that specific mark schemes may sometimes override these general principles)

- Rules for M marks: correct no. of terms; dimensionally correct; all terms that need resolving (i.e. multiplied by cos or sin) are resolved.
- Omission or extra g in a resolution is an accuracy error not method error.
- Omission of mass from a resolution is a 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. However, premature approximation should be penalised every time it occurs.

  Marks must be entered in the same order as they appear on the mark scheme.

- 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
- Mechanics Abbreviations

  M(A) Taking moments about A.

  N2L Newton's Second Law (Equation of Motion)

  NEL Newton's Experimental Law (Newton's Law of Impact)

  HL Hooke's Law

  SHM Simple harmonic motion

  PCLM Principle of conservation of linear momentum

  RHS, LHS Right hand side, left hand side.

M3 6679 June 2016
Mark Scheme

Question Number	Scheme	Marks
1(a)	$v = \dfrac{12}{x+3}$	
	$\dfrac{\mathrm{d}v}{\mathrm{d}x} = -\dfrac{12}{(x+3)^2}$	M1
	$F = 0.5v\dfrac{\mathrm{d}v}{\mathrm{d}x} = 0.5\times\dfrac{12}{x+3}\times -\dfrac{12}{(x+3)^2}$	DM1A1
	$x = 3 \quad \lvert F\rvert = 0.5\times\dfrac{12}{6}\times\dfrac{12}{6^2} = \dfrac{1}{3}\,\mathrm{N}$	A1 (4)
(b)	$\int (x+3)\,\mathrm{d}x = \int 12\,\mathrm{d}t$	
	$\dfrac{1}{2}x^2 + 3x = 12t\ (+c)$	M1A1
	$x = 4,\ t = 2 \quad 8 + 12 = 24 + c \quad c = -4$	DM1
	$x = 10 \quad 50 + 30 = 12t - 4$	DM1
	$t = 7$	A1cao (5)
ALT (b)	Definite integration:	[9]
	$\int_2^T 12\,\mathrm{d}t = \int_4^{10} (x+3)\,\mathrm{d}x$	
	$12(T-2) = \left[\dfrac{x^2}{2} + 3x\right]_4^{10}$ — M1A1 as main scheme - limits not needed	
	DM1 Correct limits shown	
	$12(T-2) = 80 - 20,\ T = 7$ — DM1 Substitute limits, A1 $T = 7$	

(a)M1 Attempt differentiation of $v = \dfrac{12}{x+3}$ or $\dfrac{1}{2}v^2 = \dfrac{72}{(x+3)^2}$ wrt x $\quad (x+3)^{-2}$ or $(x+3)^{-3}$ (oe) must be seen. Both sides of the equation must be differentiated wrt x

DM1 Use NL2 with accel $v\dfrac{\mathrm{d}v}{\mathrm{d}x}$ as obtained above. Must include mass. Dependent on the first M mark.

A1 Correct expression for F with correct mass and correct acceleration seen here or before use in NL2

A1 Use $x = 3$ to obtain the correct magnitude, $\dfrac{1}{3}$, 0.33 or better **Must** be positive

(b)M1 Use $v = \dfrac{\mathrm{d}x}{\mathrm{d}t}$ and attempt the integration

A1 Correct integration constant of integration not needed

DM1 Use given values to obtain a value for c. Dependent on first M mark

DM1 Use $x = 10$ to obtain a linear equation for t. Dependent on the first but **not** the second M mark

A1 cao $\quad t = 7$

Question Number	Scheme	Marks
2	$\int xy\,\mathrm{d}x = \int\left(-\frac{2x^2}{3}+6x\right)\mathrm{d}x$	M1
	$=\left[-\frac{2}{9}x^3+3x^2\right]_0^9$	DM1A1
	$=-162+243-0=81$	A1
	$\bar{x}=\frac{81}{27}=3$	M1A1cso (6)
		[6]

M1 Attempting to obtain the correct form for $\int xy\,\mathrm{d}x$, using an equation of a line. Limits not needed.

DM1 Attempting the integration. Limits not needed. Dependent on the first M mark.

A1 Correct integration and correct limits shown. This is **not** ft; equation of the line must be correct.

A1 Substitute the correct limits to obtain 81

M1 Divide their value from the integration by their area of the triangle

A1cso $\bar{x}=3$

ALTs:

1 Using C as the origin and AB parallel to y-axis:

Equation of line must be $y=\frac{2}{3}x$

$\int xy\,\mathrm{d}x = \int\left(\frac{2x^2}{3}\right)\mathrm{d}x == \left[\frac{2}{9}x^3\right]_0^9$ M1DM1A1

$=162$ A1

$\bar{x}=\frac{162}{27},(=6)$ Dist from $AB=9-6=3$ M1, A1

2 Using AB along the x-axis:

Must be using $\int \frac{1}{2}y^2\mathrm{d}x$

(i) Origin at B equation of line is $y=-\frac{3}{2}x+9$

(ii) Origin at A equation of line is $y=\frac{3}{2}x$

NB Ignore any work for the distance from BC, whether before or after distance from AB

Question Number	Scheme	Marks
3(a)	EPE gained $=\dfrac{14.7x^2}{2\times1.5}$	B1
	$\dfrac{14.7x^2}{3}=0.6g\times(x+1.5)$	M1A1ft
	$5x^2-6x-9=0$	
	$x=\dfrac{6\pm\sqrt{36+180}}{10}=2.069...$ (or -0.869)	DM1A1
	$OA=3.569...=3.6$ or 3.57	A1 (6)
(b)	$\dfrac{14.7\times2.069}{1.5}-0.6\times9.8=0.6a$ or $0.6\times9.8-\dfrac{14.7\times2.069}{1.5}=0.6a$	M1A1ft
	$a=23.993...=$ 24 or 24.0	A1 cao (3) [9]

(a) B1 Correct EPE when extension is x

M1 Equating EPE to GPE lost EPE to be of the form $k\dfrac{\lambda x^2}{l}$, where k is a rational no.

A1ft Correct equation ft their EPE. Use of unknown must be consistent.

DM1 Solve their equation (3TQ) (quadratic formula must be correct)

A1 $x=2.069...$neg value not needed

A1 Add 1.5 to 2.069... and give final answer to 2 or 3 sf. (No "exact" answers allowed here due to use of g.)

ALT 1: Using extension $(x-1.5)$:

B1 Correct EPE when extension is $(x-1.5)$ where x is total length

M1 Equating EPE to GPE lost EPE of form shown above

A1ft Correct equation ft their EPE. Use of unknown must be consistent. No simplification needed. Equation is $\dfrac{14.7(x-1.5)^2}{3}=0.6gx$

A1 Simplify to $x^2-4.2x+2.25=0$ or equivalent 3TQ

DM1 Solve their equation (3TQ) (quadratic formula must be correct)

A1 $x=3.57$ or 3.6 Must be 2 or 3 sf

ALT 2: Use $v^2=u^2+2as$ or energy to obtain speed at natural length, then energy to A.

B1 for EPE at A

No more marks until an energy equation with EPE, GPE and KE terms seen.

M1A1ft Energy equation ft their EPE and initial speed EPE of form shown above

DM1A1
A1 As main scheme

NB: Solution of quadratic by calculator: Method mark only available if solution is correct (2.069 or 3.569)

(b)M1 Use NL2 at A inc use of Hooke's law. Formula for HL to be correct. Ext can be $(3.569-1.5)$

A1ft Correct numbers in the equation, ft their extension

A1 24 or 24.0 only. (No negatives allowed.)

Question Number	Scheme	Marks
4 (a)	Mass ratio $\frac{2}{3}\pi r^2 h$ $\quad \frac{1}{3}\pi r^2 kh$ $\quad \frac{2}{3}\pi r^2 h+\frac{1}{3}\pi r^2 kh$ (or 2 : k : (2 + k))	B1
	Dist from O $\quad -\frac{1}{2}h$ $\quad \frac{1}{4}kh$ $\quad \bar{x}$	B1
	$2\left(-\frac{1}{2}h\right)+k\times\frac{k}{4}h=(2+k)\bar{x}$	M1A1ft
	$\bar{x}=\frac{(k^2-4)h}{4(2+k)}=\frac{h(k-2)(k+2)}{4(2+k)}=\frac{h}{4}(k-2)$ *	A1cso (5)
(b)	$\tan\theta=\frac{\bar{x}}{r}$	M1
	$\tan\theta=\frac{32h}{4\times 8\times 3h}$	A1
	$\theta=18.43...$ or 0.321...rad Accept 18° or 0.32 rad or better	A1 (3) [8]

(a)B1 Correct **ratio** of volumes or masses - any form
B1 Correct distances from O or a vertex. One distance may be negative or all may be positive.
M1 Forming a moments equation. May be about O or either vertex.
A1ft Correct equation. All signs must be correct for their choice of point. Follow through the B marks.
A1cso Correct completion to the distance from O. (Factorisation **must** be shown.)

NB: First four marks available for $2\left(\frac{1}{2}h\right)-k\times\frac{k}{4}h=(2+k)\bar{x}$ **but** $k>2$ must be stated as a reason for changing $\frac{h}{4}(2-k)$ to the given answer.

(b)M1 Form an expression for $\tan\theta$ using the given $\bar{x}$ No need to substitute for r or k but $\bar{x}=h\Rightarrow$ correct $\bar{x}$ used. May be either way up
A1 Substitute for r and k to obtain a correct numerical (or equivalent to numerical) value for $\tan\theta$
A1 Correct angle, may be degrees or radians.

Question Number	Scheme	Marks
5(a)	$T_A \cos 30° = mg + T_B \cos 30°$	M1A1
	$T_A - T_B = \dfrac{2mg}{\sqrt{3}}$	
	Radius $= \dfrac{1}{2} l \tan 30° \quad \left(= \dfrac{\sqrt{3}}{6} l \ \text{ oe} \right)$	B1
	$T_A \cos 60° + T_B \cos 60° = mr\omega^2 = m\left(\dfrac{1}{2} l \tan 30°\right)\omega^2$	M1A1A1ft
	$T_A + T_B = \dfrac{ml\omega^2}{\sqrt{3}}$	
(i)	$T_A = \dfrac{1}{2}\left(\dfrac{2mg}{\sqrt{3}} + \dfrac{ml\omega^2}{\sqrt{3}}\right) = \dfrac{m\sqrt{3}}{6}\left(2g + l\omega^2\right)$ *	DM1A1cso
(ii)	$T_B = \dfrac{1}{2}\left(\dfrac{ml\omega^2}{\sqrt{3}} - \dfrac{2mg}{\sqrt{3}}\right)$ oe	A1cso (9)
(b)	$T_B > 0 \qquad 2mg < ml\omega^2$	M1
	$\omega^2 > \dfrac{2g}{l}$	A1
	$T = \dfrac{2\pi}{\omega} \quad T < 2\pi\sqrt{\dfrac{l}{2g}} = \pi\sqrt{\dfrac{2l}{g}}$ *	DM1A1cso (4) [13]

(a)M1	Attempt a vertical equation, can have θ for the angle
A1	Completely correct equation, must have numerical angle now
B1	Correct radius seen anywhere
M1	NL2 along the radius. Acceleration in either form and can have r for the radius
A1	Correct sum of tensions (may have a tension on each side)
A1ft	Correct mass x acceleration, follow through their radius
(i)DM1	Solve the equations to either T_A =... or T_B = ... Dependent on both previous M marks. Can be awarded for finding T_A or T_B
A1cso	Correct expression for T_A Given answer so no equivalents allowed.
(ii)A1 cso	Correct expression for T_B. Any equivalent 2 term expression allowed.
Special case	If only one of vertical and radial equations found and the given T_A used to find T_B, award the marks earned for the equation and radius, if used, and B1 for T_B (last A1 in (a) on e-PEN) Max score 5/9
(b)M1	Deducing an inequality from the expression for T_B Can have $2(m)g < (m)l\omega^2$ or $2(m)g \leqslant (m)l\omega^2$ or $2(m)g = (m)l\omega^2$
A1	$\omega^2 > \dfrac{2g}{l}$ or $\omega^2 \geqslant \dfrac{2g}{l}$ oe inc equivalent in words.
DM1	Use $T = \dfrac{2\pi}{\omega}$ with their ω to form an inequality for T, can have $T < ...$ or $T \leqslant ...$ Dependent on the first M mark of (b)
A1cso	For a correct final statement from a correct solution. Must be $T < \ldots$ or equivalent in words

Question Number	Scheme	Marks
6	Energy to horizontal: $\frac{1}{2}\times 2m\times\frac{7gl}{2}-\frac{1}{2}\times 2mv^2=2mgl$	M1A1A1
	$v=\sqrt{\frac{3gl}{2}}$	A1 (4)
(b)	Energy from horizontal to top: $\frac{1}{2}\times 2m\times\frac{3gl}{2}-\frac{1}{2}\times 2mV^2=2mgr$	M1A1
	$V^2=\frac{3gl}{2}-2gr$	
	NL2 at top: $\frac{2mV^2}{r}=2mg+T$	M1A1A1
	$T\geqslant 0\Rightarrow \frac{2mV^2}{r}\geqslant 2mg$	M1
	$\frac{3gl-4gr}{2r}\geqslant g$	DM1
	$\frac{3gl}{2}-2gr\geqslant gr$	
	$r\leqslant\frac{1}{2}l$	A1
	$AB\geqslant\frac{1}{2}l$ *	A1cso (9) [13]

(a)M1	Attempting an energy equation to the horizontal. Must be clear energy is being used and not $v^2=u^2+2as$. Mass can be m or $2m$. Mixed masses are accuracy errors.
A1	Correct difference of KE terms Mass can be m or $2m$
A1	Correct PE and all signs correct in equation. Mass can be m or $2m$ but mixed masses score A0.
A1	Correct speed at the horizontal (regardless of mass used).
(b)M1	Attempt energy equation from the horizontal to the top of the new (smaller) circle with unknown radius OR from lowest point of original circle to top of the new circle. Mass can be m or $2m$ or mixed.
A1	Correct equation. Mass can be m or $2m$ (but same in all terms).
M1	NL2 at top of the small circle. Mass can be m or $2m$ or mixed. Allow with $T=0$
A1	Correct mass x acceleration. Mass can be m or $2m$
A1	Both force terms correct. Mass can be m or $2m$ but must be the same as used in the acceleration term.
M1	Use $T\geqslant 0$ to obtain an inequality for V^2. Allow if T assumed to be zero in NL2.
DM1	Use the energy equation to eliminate V^2 Dependent on first and second M marks. These two method steps may occur in the reverse of the order shown here.
A1	Correct maximum value for r
A1cso	Correct inequality for AB. **This is cso. Candidates who have used *m* in NL2 or assumed *T* = 0 cannot be awarded this mark.**
ALT:	Combining lines 3 and 4 of (b): $\frac{2mV^2}{r}\geqslant 2mg$ scores M1A1A1M1 (All other marks as above.)
NB	Equations to/at general positions do not gain marks until correct size of angle used.

Question Number	Scheme	Marks
7(a)	$T = -m\ddot{x}$	M1
	$\frac{15x}{1.2} = -0.5\ddot{x}$	M1A1
(i)	$\ddot{x} = -25x \quad \therefore$ SHM	A1cso
(ii)	Period = $\frac{2\pi}{5}$ (= 1.256 Accept 1.3 or better)	B1ft (5)
(b)	$v^2 = \omega^2\left(a^2 - x^2\right)$	
	$x = 0 \quad v = 5\times 0.8 \quad v = 4\ \text{m s}^{-1}$	M1A1 (2)
(c)	$x = a\cos\omega t$	
	$x = -0.6 \quad -0.6 = 0.8\cos 5t$	M1A1ft
	$t = \frac{1}{5}\cos^{-1}\left(-\frac{6}{8}\right) = 0.4837\ldots\text{s}$ accept 0.48 or better	A1cso (3)
(d)	$T = -m\ddot{y}$	
	$\frac{15y}{1.2} = -0.8\ddot{y}$	M1A1
	$\ddot{y} = -15.625y$ or $\ddot{y} = -\frac{125}{8}y \quad \therefore$ SHM	A1 (3)
(e)	Con of mom: $0.5\times 4 = (0.5 + 0.3)V$	M1
	$V = \frac{2}{0.8} = 2.5\ \text{m s}^{-1}$	A1
	$(2.5)^2 = 15.625a^2$	DM1
	$a^2 = \frac{2.5^2}{15.625}$	
	$a = 0.6324\ldots\text{m}$ accept 0.63 or better or $a = \frac{\sqrt{10}}{5}$ oe	A1 cso (4)
		[17]

Question Number	Scheme	Marks

(a)M1 Using NL2 with T for tension, acceleration a or $\ddot{x}$
M1 Using HL to obtain an equation connecting $\ddot{x}$ or a and x
A1 A correct equation - any equivalent to that shown - **must** have $\ddot{x}$ now.
(i)A1 $\ddot{x} = -25x$ **and** stating SHM
These 4 marks are available without substituting for any or all of m, λ or l
(ii)B1ft Period = $\dfrac{2\pi}{\text{their numerical } \omega}$ or decimal equivalent

(b)M1 Using $v^2 = \omega^2\left(a^2 - x^2\right)$ with $x = 0$ (or just $v = a\omega$) and $a = 0.8$, their ω
OR: using $v = -a\omega \sin \omega t$ with $t = \frac{1}{4} \times \text{their period}$, $a = 0.8$, their ω
A1 Correct value for v
ALT: Using energy: $\frac{1}{2} \times 0.5v^2 = \dfrac{15 \times 0.8^2}{2 \times 1.2}$ M1 $v = 4$ A1

(c)M1 Using $x = a\cos\omega t$ with their ω and $a = 0.8$, $x = \pm 0.6$ (or any other complete method)
Use of $x = a\sin\omega t$ requires further work to complete the method.
A1ft Correct equation follow through their ω
A1cso $t = 0.48$ or better.

(d)M1 Using NL2 with tension at the new extension **and increased** mass (any variable inc x for extension), acceleration in differential form or just a
A1 Correct equation, any equivalent form, acceleration in differential form or a
A1 $\ddot{y} = -15.625y$ **and** stating SHM (unless already penalised in (a)) **must** have differential form for acceleration

(e)M1 Using the conservation of momentum equation with their speed of P at B (see ans to (b)
A1 Correct speed for R at B (no ft)
Momentum equation often seen in (d). Marks can be awarded if the result is seen in (e)
DM1 Using $v^2 = \omega^2\left(a^2 - y^2\right)$ with $y = 0$ (or just $v = a\omega$) with their speed for R and their ω
Dependent on the first M mark of (e)
A1cso $a = 0.63$ or better or exact answer

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