Mark Scheme (Results)

Summer 2015

Pearson Edexcel International A Level in Mechanics 3 (WME03/01)

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Summer 2015
Publications Code IA042169

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 IAL 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
- ∗ 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.

June 2015
WME03 M3
Mark Scheme

Question Number	Scheme	Marks
1	(30° or θ for the first 3 lines)	
	$R\sin 30° = mg$	M1A1
	$R\cos 30° = m\left(r\cos 30°\right)\omega^2$	M1A1A1
	$\omega^2 = \dfrac{R}{mr} = \dfrac{g}{r\sin 30}$	DM1
	$\omega = \sqrt{\dfrac{2g}{r}}$	A1
	Time = $\dfrac{2\pi}{\omega} = 2\pi\sqrt{\dfrac{r}{2g}} = \pi\sqrt{\dfrac{2r}{g}}$ *	A1cso [8]

M1 Resolving vertically 30° or θ
A1 Correct equation 30° or θ
M1 Attempting an equation of motion along the radius, acceleration in either form 30° or θ
Allow with r for radius
A1 LHS correct 30° or θ
A1 RHS correct, 30° or θ but not r for radius
DM1 Obtaining an expression for ω^2 or for v^2 **and** the length of the path 30° or θ Dependent on both previous M marks
A1 Correct expression for ω Must have the numerical value for the trig function now
A1cso Deducing the GIVEN answer

ALT: Resolve perpendicular to the reaction:

$mg\cos 30 = m \times rad \times \omega^2 \cos 60$	M2A1(LHS) A1(RHS)
$= mr\cos 30\omega^2 \cos 60$	A1
Obtain ω	M1A1
Correct time	A1

Question Number	Scheme	Marks
2 (a)	$F=\frac{K}{x^2}$	
	$x=R\Rightarrow F=mg \qquad \therefore mg=\frac{K}{R^2}$	M1
	$K=mgR^2$ *	A1 (2)
(b)	$\frac{mgR^2}{x^2}=-mv\frac{\mathrm{d}v}{\mathrm{d}x}$	M1
	$g\int\frac{R^2}{x^2}\,\mathrm{d}x=-\int v\,\mathrm{d}v$	
	$-g\frac{R^2}{x}=-\frac{1}{2}v^2 \quad (+c)$	DM1A1ft
	$x=3R,\ v=V\Rightarrow -g\frac{R^2}{3R}=-\frac{1}{2}V^2+c$	M1
	$c=-\frac{Rg}{3}+\frac{1}{2}V^2$	A1
	$x=R\Rightarrow \frac{1}{2}v^2=-\frac{Rg}{3}+\frac{1}{2}V^2+g\frac{R^2}{R}$	M1
	$v^2=V^2+\frac{4Rg}{3}$	
	$v=\sqrt{V^2+\frac{4Rg}{3}}$	A1 cso (7)
		[9]

(a) M1 Setting $F=mg$ **and** $x=R$
A1 Deducing the GIVEN answer

(b) M1 Attempting an equation of motion with acceleration in the form $v\frac{\mathrm{d}v}{\mathrm{d}x}$. The minus sign may be missing.
DM1 Attempting the integration
A1ft Correct integration, follow through on a missing minus sign from line 1, constant of integration may be missing
M1 Substituting $x=3R, v=V$ to obtain an equation for c
A1 Correct expression for c
M1 Substituting $x=R$ and their expression for c
A1 Correct expression for v, any equivalent form

Question Number	Scheme	Marks
3 (a)	$\frac{\mathrm{d}v}{\mathrm{d}t} = -2(t+4)^{-\frac{1}{2}}$	M1
	$v = -\int 2(t+4)^{-\frac{1}{2}}\,\mathrm{d}t$	
	$v = -4(t+4)^{\frac{1}{2}} \quad (+c)$	DM1A1
	$t = 0, v = 8 \Rightarrow c = 16$	M1
	$v = 16 - 4(t+4)^{\frac{1}{2}} \quad (\text{m s}^{-1})$ *	A1cso (5)
(b)	$v = 0 \quad 16 = 4(t+4)^{\frac{1}{2}}$	M1
	$16 = t + 4 \quad t = 12$	A1
	$x = 4\int\left(4 - (t+4)^{\frac{1}{2}}\right)\mathrm{d}t$	
	$x = 4\left(4t - \frac{2}{3}(t+4)^{\frac{3}{2}}\right) \quad (+d)$	M1A1
	$t = 0,\ x = 0 \quad d = 4 \times \frac{2}{3} \times 4^{\frac{3}{2}} = \frac{64}{3}$ oe	A1
	$t = 12 \quad x = 4\left(4 \times 12 - \frac{2}{3} \times 16^{\frac{3}{2}}\right) + \frac{64}{3} = 42\frac{2}{3}$ (m) oe eg 43 or better	DM1A1 (7)
		[12]

(a) M1 Attempting an expression for the acceleration in the form $\frac{\mathrm{d}v}{\mathrm{d}t}$; minus may be omitted.
DM1 Attempting the integration
A1 Correct integration, constant of integration may be omitted (no ft)
M1 Using the initial conditions to obtain a value for the constant of integration
A1cso Substitute the value of c and obtain the final GIVEN answer

(b) M1 Setting the **given** expression for v equal to 0
A1 Solving to get $t = 12$
M1 Setting $v = \frac{\mathrm{d}x}{\mathrm{d}t}$ and attempting the integration wrt t At least one term must clearly be Integrated.
A1 Correct integration, constant may be omitted
A1 Substituting $t = 0,\ x = 0$ and obtaining the correct value of d. Any equivalent number, inc decimals.
DM1 Substituting their value for t and obtaining a value for the required distance. Dependent on The second M mark.
A1 Correct final answer, any equivalent form.

Question Number	Scheme	Marks
4(a)	Energy to top: $\frac{1}{2}\times 3m\times u^2-\frac{1}{2}\times 3mv^2=3mga$	M1A1
	NL2 at top: $T+3mg=3m\frac{v^2}{a}$	M1A1
	$T=3m\frac{u^2}{a}-6mg-3mg$	DM1
	$T\geqslant 0\ \Rightarrow\frac{u^2}{a}\geqslant 3g$	M1
	$u^2\geqslant 3ag$ *	A1 cso (7)
(b)	Tension at bottom:	
	$\frac{1}{2}\times 3m\times V^2-\frac{1}{2}\times 3mu^2=3mga$	M1
	$T_{max}-3mg=3m\frac{V^2}{a}$	M1
	$T_{max}=3mg+6mg+3m\frac{u^2}{a}$	A1
	$T_{min}=3m\frac{u^2}{a}-9mg$	
	$9mg+3m\frac{u^2}{a}=3\left(3m\frac{u^2}{a}-9mg\right)$	DM1
	$u^2=6ag$ *	A1 cso (5)
		[12]

(a) M1 Attempting an energy equation, can be to a general point for this mark. Mass can be missing but use of $v^2=u^2+2as$ scores M0

A1 Correct equation from *A* to the top

M1 Attempting an equation of motion along the radius at the top, acceleration in either form

A1 Correct equation, acceleration in form $\frac{v^2}{r}$

DM1 Eliminate v^2 to obtain an expression for T Dependent on both previous M marks

M1 Use $T\geqslant 0$ at top to obtain an inequality connecting a, g and u

A1cso Re-arrange to obtain the GIVEN answer

(b) M1 Attempting an energy equation to the bottom, maybe from *A* or from the top

M1 Attempting an equation of motion along the radius at the bottom

A1 Correct expression for the max tension

DM1 Forming an equation connecting *their* tension at the top with *their* tension at the bottom. If the 3 is multiplying the wrong tension this mark can still be gained. Dependent on both previous M marks

A1cso Obtaining the GIVEN answer.

Question Number	Scheme	Marks
5 (a)	$T=\frac{20e}{2}=\frac{15(1.8-e)}{1.2}$	M1A1
	$10e\times1.2=15(1.8-e)$	
	$e=1$	A1
	$AO=3\text{ m}$ *	A1cso (4)
(b)	$0.5\ddot{x}=\frac{20(1-x)}{2}-\frac{15(0.8+x)}{1.2}$	M1A1A1
	$\ddot{x}=-45x$ $\therefore$ SHM	A1cso (4)
(c)	String becomes slack when $x=(-)0.8$ (allow wo sign due to symmetry)	B1
	$v^2=\omega^2(a^2-x^2)$	
	$v^2=45(1-0.8^2)$ $(=16.2)$	M1A1ft
	$v=4.024...$ m s^{-1} (4.0 or better)	A1ft (4)
(d)	$\frac{1}{2}\times\frac{20y^2}{2}-\frac{1}{2}\times\frac{20\times1.8^2}{2}=\frac{1}{2}\times0.5\times16.2$ ft on v	M1A1A1ft
	$20y^2-64.8=16.2$	
	$y^2=4.05$ $y=2.012....$	A1
	Distance $DB=\lvert 5-4.012...\rvert=0.988...\text{m}$ (accept 0.99 or better)	A1ft (5) [17]
Alt for d:	Prove SHM with only one string M1A1 (equation) Value ω A1 Use $v=a\omega$ to find a A1ft (ft on v) Dist A1ft	

(a) M1 Attempting to obtain and equate the tensions in the two parts of the string.
A1 Correct equation, extension in *AP* or *BP* can be used or use *OA* as the unknown
A1 Obtaining the correct extension in either string (ext in *BP* =0.8 m) or another useful distance
A1cso Obtaining the correct GIVEN answer
(b) M1 Forming an equation of motion at a general point. There must be a difference of tensions, both with the variable. May have *m* instead of 0.5 Accel can be *a*
A1 A1 Deduct 1 for each error, *m* or 0.5 allowed, acceleration to be $\ddot{x}$ now
A1cso Correct equation in the required form, with a concluding statement; *m* or 0.5 allowed
(c) B1 For $x=\pm0.8$ Need not be shown explicitly
M1 Using $v^2=\omega^2(a^2-x^2)$ with *their* (numerical) ω and their x
A1ft Equation with correct numbers ft their ω
A1ft Correct value for v 2sf or better or exact
(d) M1 Attempting an energy equation with 2 EPE terms and a KE term
A1 2 correct terms may have $(1.8+x)$ instead of y
A1ft Completely correct equation, follow through their v from (c)
A1 Correct value for distance travelled after *PB* became slack. $x=0.21$
A1ft Complete to the distance *DB*. Follow through their distance travelled after *PB* became slack.
Alternatives at end of mark scheme

Question Number	Scheme	Marks
6(a)	Vol = $\pi\int_0^2 \left(x^2+3\right)^2 \mathrm{d}x$	M1
	$=\pi\int_0^2 \left(x^4+6x^2+9\right)\mathrm{d}x$	
	$=\pi\left[\frac{1}{5}x^5+2x^3+9x\right]_0^2$	DM1A1
	$=\frac{202}{5}\pi$ cm^3 *	A1 (4)
(b)	$\pi\int_0^2 x\left(x^2+3\right)^2 \mathrm{d}x=\pi\int_0^2\left(x^5+6x^3+9x\right)\mathrm{d}x$	M1
	$=\pi\left[\frac{1}{6}x^6+\frac{3}{2}x^4+\frac{9}{2}x^2\right]_0^2$	A1
	$=\frac{158}{3}\pi$ (Or by chain rule or substitution)	A1
	C of m $=\frac{158}{3}\times\frac{5}{202}$, $=1.3036...=1.30$ cm	M1A1 (5)
(c)	Mass ratio $2\times\frac{202}{5}\pi$ $\quad\frac{1}{3}\pi\times7^2\times6$ $\quad\left(\frac{404}{5}+98\right)\pi$	B1
	Dist from V 6.7 $\quad$ 4.5 $\quad$ $\bar{x}$	B1
	$\frac{404}{5}\times6.7+98\times4.5=\left(\frac{404}{5}+98\right)\bar{x}$	M1A1ft
	$\bar{x}=\dfrac{\frac{404}{5}\times6.7+98\times4.5}{\left(\frac{404}{5}+98\right)}=5.494....=5.5$ cm Accept 5.49 or better	A1 (5)
(d)	$\tan\theta=\frac{6-\bar{x}}{7}=\frac{0.5058...}{7}$	M1
	$\alpha=\tan^{-1}\left(\frac{6}{7}\right)-\tan^{-1}\left(\frac{0.5058...}{7}\right)=36.468...°=36°$ or better	M1A1 (3) [17]

Question Number	Scheme	Marks

(a) M1 Using $\pi\int y^2\mathrm{d}x$ with the equation of the curve, no limits needed

DM1 Integrating their expression for the volume

A1 Correct integration inc limits now

A1 Substituting the limits to obtain the GIVEN answer

(b) M1 Using $(\pi)\int xy^2\mathrm{d}x$ with the equation of the curve, no limits needed, π can be omitted

A1 Correct integration, including limits; no substitution needed for this mark

A1 Correct substitution of limits

M1 Use of $\dfrac{\pi\int xy^2\mathrm{d}x}{\pi\int y^2\mathrm{d}x}$ with their $\pi\int xy^2\mathrm{d}x$. π must be seen in both numerator and denominator or in neither.

A1cao Correct answer. Must be 1.30

(c) B1 Correct mass ratio

B1 Correct distances, from V or any other point, provided consistent

M1 Attempting a moments equation

A1ft Correct equation, follow through their distances and mass ratio

A1 Correct distance from V

(d) M1 Attempting the tan of an appropriate angle, numbers either way up

M1 Attempting to obtain the required angle

A1 Correct final answer 2sf or more

	Alternatives for 5(d)	
1	EPE in BP (at release) transferred to EPE in AP (same as MS, except 1 term for first A1)	
2	$0.5a = -10(1.8 + x)$	
	$v\dfrac{dv}{dx} = -36 - 10x$	
	$\int v\,dv = -\int(36 + 10x)dx$	
	$\dfrac{v^2}{2} = -36x + 5x^2 + c$	M1A1
	$x = 0, v = \dfrac{9\sqrt{5}}{5} \therefore c = 8.1$	A1
	Then $v = 0$ etc	M1A1

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